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Maritimes Region

The Gully Marine Protected Area Data Assessment

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Foreword

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

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ABSTRACT

The Gully, located at the eastern edge of the Scotian Shelf, is the largest submarine canyon in Atlantic Canada and its seabed and waters support a unique and highly diverse ecosystem. The Gully has long been a focus of conservation interest and was designated a Marine Protected Area (MPA) under the *Oceans Act* in May 2004. In 2008, the *Gully Marine Protected Area Management Plan* outlined four priority conservation issues to be the focus of monitoring in the near term: protecting cetaceans from impacts caused by human activities; protecting seafloor habitat and associated benthic communities from alteration caused by human activities; maintaining or restoring the quality of the water and sediments of the Gully; and conserving other commercial and non-commercial living resources. To develop a monitoring plan for these conservation issues, as well as the current and potential pressures that may affect them, 47 indicators were proposed. This document presents an assessment for many of these indicators, written by scientific experts in government and academia, to evaluate whether the available data meet the indicator monitoring requirements. Overall, 44 of the indicators were evaluated. Data availability and analysis were inconsistent across the indicators, with more opportunistic than targeted studies taking place in the Gully MPA. Generally, indicators related to the conservation objectives themselves rely more on external funding to obtain data, while indicators related to current and potential pressures on conservation objectives have more stable sources of ongoing data collection through regional and national programs.

Évaluation des données sur la zone de protection marine du Gully

RÉSUMÉ

Le Gully, situé à l'extrémité est du plateau néo-écossais, est le plus grand canyon sous-marin dans les eaux du Canada atlantique, et son fond marin et ses eaux soutiennent un écosystème unique et très diversifié. Depuis longtemps, des efforts de conservation sont axés sur le Gully; celui-ci a été désigné zone de protection marine en vertu de la *Loi sur les océans* en mai 2004. Le Plan de gestion de la zone de protection marine du Gully, publié en 2008, décrit les quatre enjeux prioritaires en matière de conservation devant faire l'objet d'une surveillance à court terme : protéger les cétacés contre les impacts des activités humaines; protéger l'habitat benthique et ses communautés contre la détérioration causée par les activités humaines; maintenir ou restaurer la qualité de l'eau et des sédiments du Gully; et conserver les autres ressources biologiques, d'importance commerciale ou non. Afin d'élaborer un plan de surveillance pour les enjeux en matière de conservation, ainsi que les pressions actuelles et potentielles qui pourraient les toucher, 47 indicateurs ont été proposés. Ce document présente une évaluation d'un grand nombre de ces indicateurs, écrite par des experts scientifiques du gouvernement et du milieu universitaire, en vue de déterminer si les données disponibles répondent aux exigences en matière de surveillance des indicateurs. Au total, 44 indicateurs ont été évalués. La disponibilité des données et les analyses n'étaient pas uniformes entre les indicateurs; dans la zone de protection marine du Gully, des études ponctuelles sont plus souvent menées que des études ciblées. En général, les indicateurs liés aux objectifs de conservation en tant que tels dépendent plus du financement externe pour obtenir des données, tandis que les indicateurs liés aux pressions actuelles et potentielles sur les objectifs de conservation ont des sources plus stables de collecte de données continue au moyen de programmes régionaux et nationaux.

INTRODUCTION

The Gully is the largest submarine canyon in Atlantic Canada at roughly 40 km long, 16 km wide and with water depths exceeding 3000 m. It is located at the edge of the Scotian Shelf, 30 km east of Sable Island (Figure 1). A number of substantial feeder canyons run into the main canyon (mostly from the west) predominantly around the canyon head. The canyon head connects to a large, shallow basin in the Central Scotian Shelf called the Trough. The Gully seabed contains a wide variety of sediments, such as bedrock, boulders, gravel, sands and fine silts and its waters support a unique and highly diverse ecosystem including an endangered population of northern bottlenose whales and some of the most diverse coral communities in Canada. This area has been a focus of conservation interest since the 1970s and was ultimately designated as a Marine Protected Area (MPA) under the *Oceans Act* in May 2004. The Gully MPA was divided into three management zones (Figure 2) for which there are specific regulations. Zone 1 is the core canyon area and is afforded the highest level of protection with no fishing permitted. Zone 2 consists of the canyon walls, the head of the canyon and the deep waters of the abyssal plain. Few activities are permitted in Zone 2. Zone 3 encompasses the shallow banks on the sides of the canyon. More activities are allowed in Zone 3, provided any associated disturbance, damage or destruction is within the normal variability of the ecosystem.

The vision for the Gully MPA, as stated in the *Gully Marine Protected Area Management Plan* (DFO 2008), is “to protect the marine ecosystem of the Gully MPA for future generations by providing effective programs for management, conservation, research, monitoring, and stewardship.” The plan also outlines broad conservation objectives to protect the health and integrity of the Gully ecosystem: protecting the natural biodiversity of the Gully; protecting the physical structure of the Gully and its physical and chemical properties; and maintaining the productivity of the Gully ecosystem. The *Gully Marine Protected Area Management Plan* further describes four priority conservation issues to be the focus of monitoring in the near term:

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

In addition to monitoring these conservation issues specifically, current and potential pressures on the Gully MPA must also be monitored. Current and potential pressures on the Gully MPA include:

- Extraction/disturbance from fishing and research.
- Entanglement of cetaceans and other animals.
- Vessel traffic associated pressures (e.g., vessel strikes, contaminants, noise).
- Anthrogenic sound.

While research and monitoring activities have been conducted in the Gully since the mid-1900s, there has been little routine monitoring focused on evaluating the Gully MPA specifically. In 2010, a framework for environmental monitoring in the Gully MPA was developed (DFO 2010a), which proposed a suite of indicators aimed at addressing the conservation objectives in a cost-effective manner, while incorporating indicators, protocols and strategies from existing monitoring programs. A total of 47 indicators were proposed: 29 aimed at monitoring conservation objectives and 18 aimed at monitoring current and potential pressures on one or more of those conservation objectives (see Appendix 1, Table A1-1). This document presents an evaluation of many of these indicators. Scientific experts in government and academia were asked to identify, analyze and present results from past or existing monitoring programs and/or research studies that could be used to address each indicator. In addition, they provided comments on the practicality and usefulness of the indicator as a monitoring tool, suggesting necessary modifications to existing monitoring protocols and identifying potential issues where applicable. Last, a list of commonly used acronyms in the document is provided in Appendix 2.

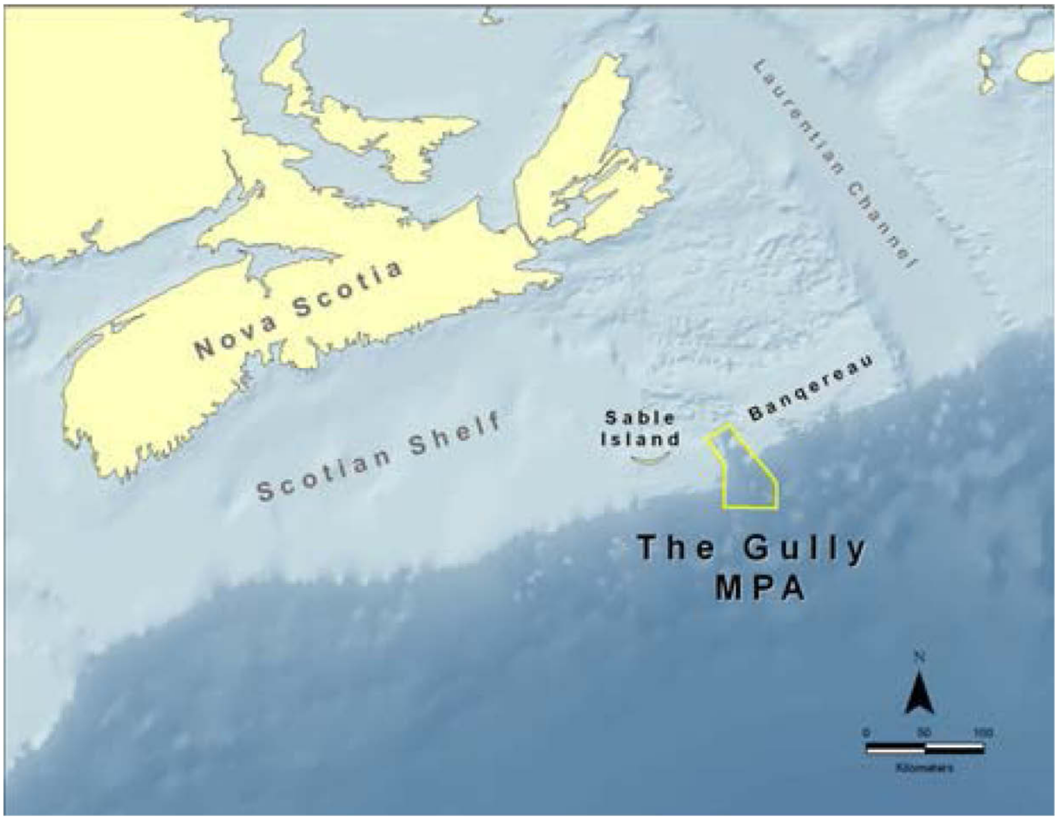


Figure 1. The location of the Gully Marine Protected Area (MPA) in relation to the Scotian Shelf.

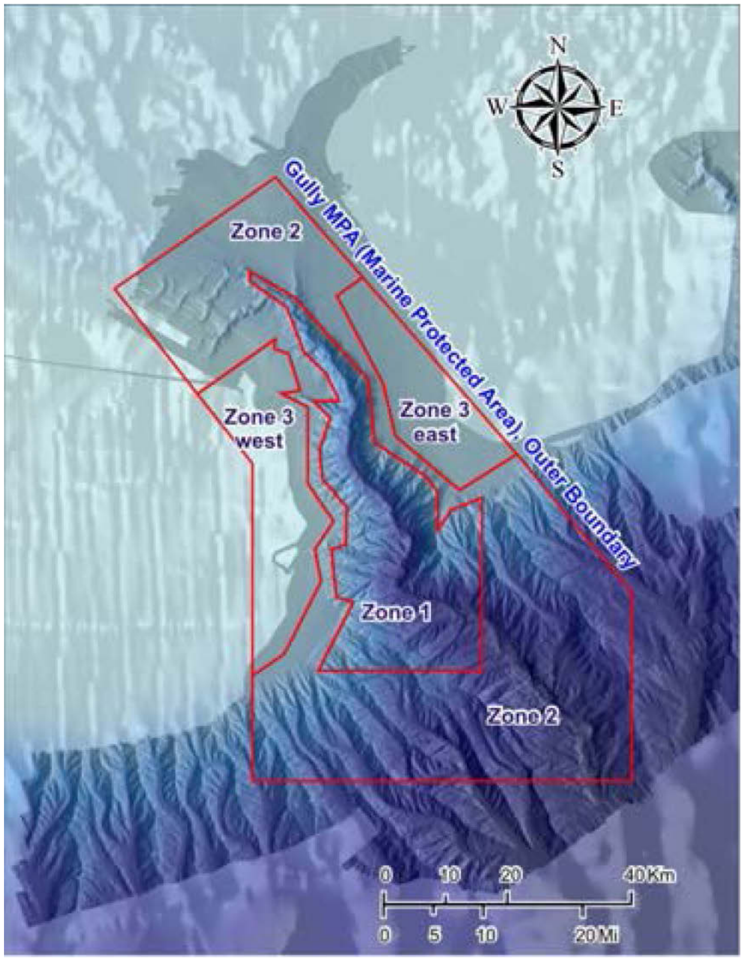


Figure 2. The outer boundary and the subdivision of Zones 1, 2 and 3 in the Gully MPA.

CURRENT STATE OF MONITORING

PROTECT CETACEANS FROM IMPACTS CAUSED BY HUMAN ACTIVITIES

H. Moors-Murphy and H. Whitehead

Indicators 1 through 12 were identified to meet the goal of protecting cetaceans from impacts caused by human activities. Cetacean studies have been carried out within the Gully and in the general region of the eastern Scotian Shelf since the 1980s, primarily by the Whitehead Lab of Dalhousie University. Much of the research effort has focused on conducting visual surveys and collecting information on sightings of cetaceans, photographing northern bottlenose whale dorsal fins for photographic-identification (photo-ID) studies and, more recently, recording video of northern bottlenose whale surface behaviour and collecting acoustic data. The following potentially useful sources of data are available through the Whitehead Lab:

- **Cetacean sightings:** Location, date, time, species and other information about all cetaceans sighted during transits to and from the Gully (and other nearby study areas) and during northern bottlenose whale-focused fieldwork on the Scotian Shelf. Available in a Whitehead Lab database and as part of the Fisheries and Oceans Canada (DFO) cetacean sightings database.

- **Northern bottlenose whale encounters:** Detailed information on northern bottlenose whale sightings including location, date, time, group composition and behaviour. Available in a Whitehead Lab database and as part of the DFO cetacean sightings database.
- **Environmental data:** Environmental variables such as sea state, wind speed, sea surface temperature and visibility collected at three-hour intervals. Available in a Whitehead Lab database.
- **Vessel track data:** Information about vessel position can be obtained from logbooks or Global Positioning System (GPS) tracks. Available in a Whitehead Lab database.
- **Photographic data:** Photographs and associated metadata (date, time, species), mainly of northern bottlenose whale dorsal fins and melons, taken for photo-ID studies. Available in a Whitehead Lab database and as part of the DFO northern bottlenose whale multimedia database.
- **Northern bottlenose whale photo-ID database:** Information about analyzed northern bottlenose whale photographs including identified individuals and mark types. Available in a Whitehead Lab database and as part of the DFO northern bottlenose whale multimedia database.
- **Genetic data:** Data used in past genetic studies (Dalebout et al. 2006) are available through the Whitehead Lab and by contacting Merel Dalebout.
- **Contaminant data:** Data used in past contaminant studies (Hooker et al. 2008) are available through the Whitehead Lab and by contacting Sasha Hooker.
- **Video data:** Video recordings and associated metadata (date, time, species) of (mainly) northern bottlenose whales from surface behaviour studies are available in a Whitehead lab database and as part of the DFO northern bottlenose whale multimedia database.
- **Acoustic data:** Acoustic recordings obtained from various systems (surface-deployed arrays, bottom-mounted hydrophones) and associated metadata (date, time) of (mainly) northern bottlenose whales and cetaceans from the Scotian Slope region are available in a Whitehead Lab database and as part of the DFO northern bottlenose whale multimedia database.

Over the past few years, DFO has become more involved in cetacean science in the Gully by supporting studies carried out by the Whitehead Lab and, most recently, by implementing a long-term passive acoustic monitoring study in the Gully and surrounding regions. Some acoustic data has been collected through DFO monitoring initiatives, but has yet to be analyzed. Potentially useful sources of data at DFO include:

- **DFO Maritimes cetacean sightings database:** Location, date, time, species and other information about all cetaceans species sighted in the DFO Maritimes Region from various sources including researchers, at-sea observers and marine mammal observers. Cetacean sightings collected on the Scotian Shelf by the Whitehead Lab are included in this database.
- **DFO northern bottlenose whale multimedia database:** Photographic, video and acoustic data and associated metadata collected primarily by the Whitehead Lab and DFO.
- **At-sea observer reports:** Reports of cetacean entanglements and bycatch.

Periodically, other research groups conduct cetacean studies in or near the Gully. The St. Andrews Marine Mammal Research Unit conducted northern bottlenose whale tagging and acoustic studies in the summers of 2011 and 2013. Their cetacean sightings and acoustic data have been submitted to the Whitehead Lab to be incorporated into the sightings database.

Other relevant data sources include the Marine Animal Response Society (MARS) database which includes information on entanglements, strandings and reported fatalities for a variety of species.

Indicator 1: Abundance of the Scotian Shelf population of Northern Bottlenose Whales

H. Moors-Murphy and H. Whitehead

Available data

The northern bottlenose whale photo-ID database maintained by the Whitehead Lab has data from 1988 onward. Data collection and analysis is ongoing, but dedicated effort occurs only every few years. Whitehead and Wimmer (2005) provide the most recent published estimate of population size; a more recent estimate, as yet unpublished in primary literature, is provided in O'Brien (2013).

Data collection

Photo-ID survey protocols have been established by the Whitehead Lab (Gowans et al. 2000; Whitehead and Wimmer 2005; O'Brien 2013). Generally, researchers actively search for northern bottlenose whales within the study area and approach individuals to obtain photographs of melons and dorsal fins. Information about the encounter is recorded.

Analysis

All available data up to 2011 has been analyzed (O'Brien 2013). Collected photographs are rated first for quality and then the marks on the dorsal fins or melons are matched to individuals in a catalogue. The number of 'recaptured' individuals is then used to produce abundance estimates using various mark and recapture models. Analysis methods and abundance estimate models have been established by the Whitehead Lab. Past analyses' methods are described in Gowans et al. (2000) and Whitehead and Wimmer (2005); O'Brien (2013) describes modified analysis methods for digital photographs.

Results

Whitehead and Wimmer (2005) and O'Brien (2013) estimate the number of individuals in the northern bottlenose whale population to be 163 (95% Confidence Interval (CI) = 119-214 individuals) and 143 (95% CI = 129-156 individuals), respectively. The number of individuals in the population has been stable since the 1980s (DFO 2010b; COSEWIC 2011; O'Brien 2013).

Evaluation of existing protocols for meeting indicator monitoring requirements

Over the past decade the Whitehead Lab has conducted photo-ID studies primarily in the Gully with some effort also in Shortland and Haldimand canyons. Generally, these studies are approximately three years apart and span two consecutive field seasons (e.g., 2001–2003, 2006–2007 and 2010–2011). Dedicated photo-ID studies have been shown to be more precise than shipboard and aerial surveys in generating population and trend estimates for Scotian Shelf northern bottlenose whales. Past abundance estimates have had a confidence interval of ±30% (Whitehead and Wimmer 2005). More recent data collection, using digital cameras, has allowed for a higher percentage of photographed individuals to be identified; thus, population estimates have become more precise with a confidence interval of ±12% for the most recent population estimate (O'Brien 2013). With the introduction of digital cameras, some modifications have been made to Whitehead and Wimmer's (2005) methods (which involved analysis of film negatives). These modifications to previous methods are described by O'Brien (2013). Whenever possible, digital cameras should be used to collect data in the future. It would also be worthwhile to investigate the ability of computer software programs such as FINSCAN and DIGITS to increase the efficiency of analysis of these photographs.

The current dataset allows for detection of major changes in the size of the population. If focused photo-ID studies continue every few years, the population size of northern bottlenose whales should be effectively monitored over time. Continued use of digital cameras will likely allow even more subtle trends in population size to be detected.

Threats to ongoing monitoring

Data collection and analysis is done by the Whitehead Lab and depends on external funding sources (e.g., National Sciences and Engineering Research Council of Canada—NSERC), vessel availability and research priorities.

Additional comments

This indicator is one of the more important indicators relevant to cetaceans and should be given higher priority.

Indicator 2: Use of the Gully MPA by Northern Bottlenose Whales, measured as the percentage of the Scotian Shelf population within the Gully MPA

H. Moors-Murphy and H. Whitehead

Suggested improvements to indicator wording

"Residency of the Scotian Shelf population of northern bottlenose whales within the Gully MPA."

Both the percentage of northern bottlenose whales occurring within the Gully MPA and the amount of time that individuals tend to remain within the Gully MPA are important for understanding how the population is using the Gully. The appropriate biological term for these types of measures is 'residency'.

Available data

The northern bottlenose whale photo-ID database maintained by the Whitehead Lab has data from 1988 onward. Data collection is ongoing, but dedicated effort only occurs every few years. Estimates of the percentage of the population that occurs in the Gully and the mean number of days that individuals remain within the Gully were first produced by Gowans et al. (2000). Wimmer and Whitehead (2004) produced an estimate of the mean number of days that individuals remain within the Gully and Shortland and Haldimand canyons.

Data collection

Photo-ID survey protocols have been established by the Whitehead Lab (Gowans et al. 2000; Whitehead and Wimmer 2005; O'Brien 2013). Generally, researchers actively search for northern bottlenose whales within the study area and approach individuals to obtain photographs of melons and dorsal fins. Information about the encounter is recorded.

Analysis

Collected photographs are rated first for quality and then the marks on the dorsal fins or melons are matched to individuals in a catalogue. Residency parameters such as the estimated number of individuals in the Gully at a given time and the mean number of days that individuals remain within the Gully can be calculated using lagged identification rates (Gowans et al. 2000; Wimmer and Whitehead 2004).

Results

An estimated 33% (44±6 individuals) of the Scotian Shelf northern bottlenose whale population reside within the Gully at any one time (Gowans et al. 2000), but there is insufficient data to determine any trends. The mean number of days whales remain within the Gully was estimated to be 20 days by Gowans et al. (2000) and 22 days by Wimmer and Whitehead (2004).

Evaluation of existing protocols for meeting indicator monitoring requirements

Methods have been developed to examine residency patterns (Gowans et al. 2000; Wimmer and Whitehead 2004). These methods should be used to update the residency parameter estimates for the Gully MPA using the most recent data. Increased photo-ID data collection in Shortland and Haldimand canyons would increase the power of such analyses.

Threats to ongoing monitoring

Data collection and analysis is done by the Whitehead Lab and depends on external funding sources (e.g., NSERC), vessel availability and research priorities.

Indicator 3: Size, age, and sex structure of the Scotian Shelf population of Northern Bottlenose Whales

H. Moors-Murphy and H. Whitehead

Suggested improvements to indicator wording

“Age and sex structure of the Scotian Shelf population of northern bottlenose whales.”

Information about the size of northern bottlenose whales is difficult to collect and a substantial amount of effort would be required to determine the size structure of the population. The age/sex class of the animals (calf, females/immatures, sub-adult male, mature male) are regularly collected in the field and generally easily determined.

Available data

The northern bottlenose whale photo-ID database maintained by the Whitehead Lab has data from 1988 onward. Data collection is ongoing, but dedicated effort only occurs every few years. Estimates of the age and sex structure of the population were produced by Gowans et al. (2000).

Data collection

Photo-ID survey protocols have been established by the Whitehead Lab (Gowans et al. 2000; Whitehead and Wimmer 2005; O’Brien 2013). Generally, researchers actively search for northern bottlenose whales within the study area and approach individuals to obtain photographs of melons and dorsal fins. Information about the encounter is recorded.

Analysis

Collected photographs are rated first for quality and then the marks on the dorsal fins or melons are matched to individuals in a catalogue. Gowans et al. (2000) provided abundance estimates for each age/sex class and O’Brien (2013) investigated changes in sex ratios over time.

Results

Gowans et al. (2000) estimated age and sex structure of the Scotian Shelf northern bottlenose whale population, based on a photographic catalogue from 1988-1999, as follows: 45% females/immatures (57 individuals with a range of 45 to 77); 17% sub-adult males (22 individuals with a range of 16 to 39); 21% mature males (27 individuals with a range of 19 to 39) and approximately 17% un-sexed individuals. O’Brien (2013) provided estimates of the age and sex ratio for 2010 and 2011, which ranged between 33-55% females/immatures; 0-18% sub-adult males; 10-17% mature males and 21-55% unknown, depending on location and side of the dorsal fin included in the analysis. O'Brien (2013) indicates that the sex ratio has not changed significantly between 1988 and 2011.

Evaluation of existing protocols for meeting indicator monitoring requirements

Existing protocols are adequate and no protocol upgrades are recommended.

Threats to ongoing monitoring

Data collection and analysis is done by the Whitehead Lab and depends on external funding sources (e.g., NSERC), vessel availability and research priorities.

Indicator 4: Percentage of individuals in the Scotian Shelf Northern Bottlenose Whales population showing fresh scars

H. Moors-Murphy and H. Whitehead

Suggested improvements to indicator wording

"Percentage of individuals of the Scotian Shelf population of northern bottlenose whales showing marks likely caused by interactions with humans."

Cetaceans may acquire scars and other markings from both human causes (fishing gear entanglements, vessel collisions and skin disease) and natural causes (interactions with conspecifics): However, the aim of this indicator is to determine the percentage of Scotian Shelf northern bottlenose whales that have marks caused by human activities.

Available data

The northern bottlenose whale photo-ID database maintained by the Whitehead Lab has data from 1988 onward. Data collection is ongoing, but dedicated effort only occurs every few years. Some of the existing northern bottlenose whale melon photographs have been examined to determine the number of individuals showing marks produced by interactions with humans (Mitchell 2008). No dorsal fin photographs have been analyzed to quantify marks likely to be produced by such interactions.

Data collection

Photo-ID survey protocols have been established by the Whitehead Lab (Gowans et al. 2000; Whitehead and Wimmer 2005; O'Brien 2013). Generally, researchers actively search for northern bottlenose whales within the study area and approach individuals to obtain photographs of melons and dorsal fins. Information about the encounter is recorded.

Analysis

Collected photographs are rated first for quality and then the marks on the dorsal fins or melons are matched to individuals in a catalogue. Mitchell (2008) analyzed photographs of northern bottlenose whale melons to determine the presence of scars caused by fishing gear entanglements, vessel collisions and skin disease. A similar analysis has yet to be conducted on dorsal fin photographs.

Results

While marks caused by fishing gear entanglements, vessel collisions and skin disease were identified by Mitchell (2008), not enough data exists to estimate the percentage of the population showing such scars.

Evaluation of existing protocols for meeting indicator monitoring requirements

The analysis conducted by Mitchell (2008) only examined 99 melon photographs. A more extensive analysis of the currently available melon photographs is needed to determine the feasibility of using melon photographs to address this indicator. In addition, there are more dorsal fin photographs than melon photographs available for the northern bottlenose whale population. The feasibility of using dorsal fin photographs to address this indicator should be investigated. If it is determined that analysis of dorsal fin photographs can be used to address this indicator then Mitchell's (2008) method should be adapted for analysis of dorsal fins, and the available dorsal fin photographs should be analyzed for the presence of marks caused by fishing gear entanglements, vessel collisions and skin disease.

Threats to ongoing monitoring

Data collection and analysis is done by the Whitehead Lab and depends on external funding sources (e.g., NSERC), vessel availability and research priorities.

Additional comments

The Whitehead Lab currently has no plans to analyze melon or dorsal fin photographs for the presence of marks likely caused by humans. Some funding, potentially for a graduate student, may be required to complete such an analysis.

Indicator 5: Genetic diversity within the Scotian Shelf population of Northern Bottlenose Whales

H. Moors-Murphy and H. Whitehead

Available data

Biopsy samples were collected from northern bottlenose whales off the coast of Nova Scotia in 1996, 1997, 2002 and 2003.

Data collection

Skin biopsy samples were collected from free-swimming northern bottlenose whales in the Gully using biopsy darts: stainless steel biopsy tips (2.5 cm long and 0.6 cm in diameter) attached to a crossbow bolt. Darts were fired at animals 5 to 15 metres away using a 67 kg draw crossbow. The biopsy sampling techniques are described in detail by Hooker et al. (2001). A subsample of skin from each biopsy was stored in salt-saturated dimethyl sulphoxide (DMSO) solution (Dalebout et al. 2001). In total, 36 biopsy samples representing 34 unique individuals were collected from the study area (Dalebout et al. 2006).

Analysis

Genetic analysis was conducted by M. Dalebout. Prior genetic analyses are described in Dalebout et al. (2001) and Dalebout et al. (2006).

Results

Studies indicate a relatively low level of genetic diversity in the population (Dalebout et al. 2001; Dalebout et al. 2006): overall heterozygosity in microsatellite DNA was 0.65 and overall allelic richness was 5.27 (Dalebout et al. 2006).

Evaluation of existing protocols for meeting indicator monitoring requirements

Sampling methods required to adequately address this indicator, including sampling time frame and number of samples, need to be determined. Several biopsy sampling techniques are now available; they should be investigated to identify the least invasive technique. Biopsy sample storage and genetic analysis methods should also be investigated to ensure the most up-to-date knowledge and techniques are incorporated into any future studies. The most appropriate metric to address this indicator should also be determined.

Threats to ongoing monitoring

No biopsy data has been collected from the population since 2003.

Additional comments

This indicator will not be adequate for detecting changes over the short term, only over very long time scales (50 to 100 years).

Indicator 6: Levels of contaminants in the blubber of individuals in the Scotian Shelf population of Northern Bottlenose Whales

H. Moors-Murphy and H. Whitehead

Available data

Biopsy samples were collected from northern bottlenose whales off the coast of Nova Scotia in 1996, 1997, 2002 and 2003.

Data collection

Skin biopsy samples were collected from free-swimming northern bottlenose whales in the Gully using biopsy darts: stainless steel biopsy tips (2.5 cm long and 0.6 cm in diameter) attached to a crossbow bolt. Darts were fired at animals 5 to 15 metres away using a 67 kg draw crossbow. The biopsy sampling techniques are described in detail by Hooker et al. (2001). Subsamples of each biopsy were stored in salt-saturated dimethyl sulphoxide (DMSO), neutral buffered formalin, and hexane-washed foil in liquid nitrogen, then transferred to hexane-washed glassware with Teflon-lined lids stored in a $-20\ ^{o}C$ freezer (Hooker et al. 2008). In total, 36 biopsy samples representing 34 unique individuals were collected from the area (Dalebout et al. 2006).

Analysis

Contaminant analyses were conducted by and are described in Hooker et al. (2008).

Evaluation of existing protocols for meeting indicator monitoring requirements

Sampling methods required to adequately address this indicator, including sampling time frame and number of samples, need to be determined. Several biopsy sampling techniques are now available; they should be investigated to identify the least invasive technique. Biopsy sample storage and contaminant analysis methods should also be investigated to ensure the most up-to-date knowledge and techniques are incorporated into any future studies.

Results

Baseline values obtained from the 1996 and 1997 biopsy samples are summarized in Table 6-1 and provided in more detail in Hooker et al. (2008). There was a significant increase in CYP1A1 in 2003 as compared to 1996, 1997 and 2002. There was also an overall significant increase in contaminants between the earlier samples years (1996–1997) and the later sample years (2002–2003) although changes in the concentration of specific contaminants over time varied. For example, DDTs and chlordane increased significantly, HCHs and endosulfans decreased significantly and PCPs stayed the same (Table 6-1). The magnitude of the detected changes detected can be obtained from Hooker et al. (2008).

Threats to ongoing monitoring

No biopsy data has been collected from the population since 2003.

Additional comments

This indicator will be most useful if sampling is conducted before and after large-scale development in the Scotian Shelf region.

Table 6-1: Summary of contaminant levels in biopsy samples obtained from Scotian Shelf northern bottlenose whales (from Hooker et al. 2008).

Contaminant	Concentration (ng/g lipid)				Trends over time (difference between 1996–1997 and 2002–2003)
	Males		Females		
	1996–1997	2002–2003	1996–1997	2002–2003	
PCBs	7273	6841	3791	4061	No significant difference
HCHs	209	24	57	40	Significant decrease
DDTs	14 658	21 571	4143	7601	Significant increase
Chlordane	909	1809	475	1189	Significant increase
Endosulfan	612	102	95	40	Significant decrease

Indicator 7: Relative abundances of cetaceans (other than Northern Bottlenose Whales) in the Gully MPA

H. Moors-Murphy and H. Whitehead

Suggested improvements to indicator wording

“Sighting rates of cetaceans (other than northern bottlenose whales) in the Gully MPA.”

Sighting rate is a more appropriate metric to use because abundance of other cetacean species cannot be estimated with the available dataset.

Available data

Cetacean sightings are available from 1988 onward; data are maintained by the Whitehead Lab. Data collection is ongoing, but dedicated effort only occurs every few years. Whitehead (2013) examines sighting rates of cetaceans other than northern bottlenose whales in the Gully and Shortland and Haldimand canyons.

Data collection

Generally, researchers actively search for northern bottlenose whales within the study area and approach individuals to obtain photographs of melons and dorsal fins (Gowans et al. 2000; Whitehead and Wimmer 2005; O’Brien 2013). During such studies all incidental sightings of other cetacean species are also recorded.

Analysis

A detailed description of methods used to estimate encounter rates of the various species sighted within the Gully are provided in Whitehead (2013).

Results

Baseline values of sighting rates of cetaceans other than northern bottlenose whales in the Gully are summarized in Table 7-1 and provided in more detail in Whitehead (2013). While sighting rates between 1988 and 2011 decreased for fin whales, humpback whales, Atlantic white-sided dolphins and striped dolphins, they increased for blue whales, Sowerby’s beaked whales and pilot whales. No change was observed for common dolphins. Whitehead (2013) provides a detailed description of trends in sighting rates for various species over time; these trends are summarized in Figure 7-1. The magnitudes of these changes over time, as well as possible explanations, are also provided in Whitehead (2013).

Evaluation of existing protocols for meeting indicator monitoring requirements

Sighting rates could be estimated for most cetacean species that regularly occur in the Gully MPA with the exception of sperm whales because earlier field studies had targeted them specifically. Since recent fieldwork has been focused on northern bottlenose whales, it may be possible to incorporate sperm whale encounter rates into future analyses.

The influence of number of individuals in each sighting on the results should also be investigated.

Threats to ongoing monitoring

Data collection and analysis is done by the Whitehead Lab and depends on external funding sources (e.g., NSERC), vessel availability and research priorities.

Additional comments

This indicator is one of the more important indicators relevant to cetaceans and should be given higher priority.

Table 7-1: Number of sightings, sighting rate and trend observed in sightings rate over time for Zone 1 of the Gully MPA by species (Whitehead 2013). A dash (-) indicates no value.

Species	Total number of sightings	Sighting rate (sightings/hour)	Trend (proportional change/year)	
			Estimate	Standard deviation
Blue whale	30	0.0126	0.11	0.08
Fin whale	46	0.0194	-0.07	0.02
Minke whale	6	0.0013	-	-
Humpback whale	3	0.0173	-0.15	0.07
Sowerby's beaked whale	41	0.0303	0.21	0.06
Pilot whale	175	0.0737	0.09	0.14
Atlantic white-sided dolphin	225	0.0947	-0.04	0.02
Common dolphin	181	0.0762	No trend	-
Striped dolphin	46	0.0194	-0.06	0.10
Bottlenose dolphin	16	0.0067	-	-

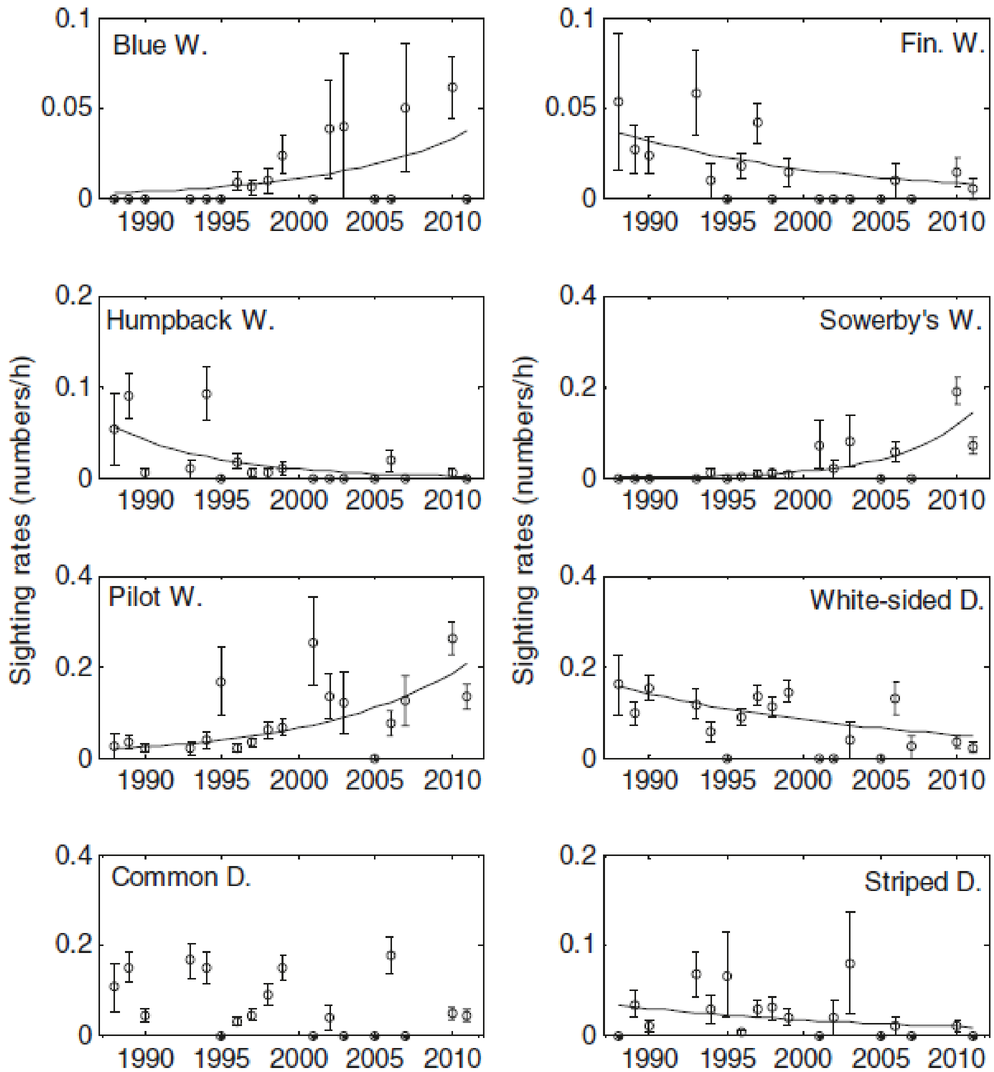


Figure 7-1: Sighting rate (number per hour) of the most commonly sighted species in Zone 1 of the Gully MPA (SE error bars from Poisson distribution approximation). A trend line is shown when a trend was included in the best supported model (Whitehead 2013).'W' stands for whale and 'D' for dolphin.

Indicator 8: Cetacean presence and activity in the MPA, year-round

H. Moors-Murphy and H. Whitehead

Available data

There are several acoustic datasets available for the Gully MPA; however, analysis of vocalizations produced by a variety of cetacean species requires recordings with a broad frequency range and examination of seasonal and yearly trends requires long-term (weeks to months) datasets. These requirements greatly reduce both the quantity and the scientific value of data currently available for analysis. Ocean-bottom seismometer (OBS) data is available from 2003, 2005 and 2006 and pop-up hydrophone (PU) data is available from 2006 to 2008 (Table 8-1; Figure 8-1). Autonomous Multi-channel Acoustic Recorders (AMARs), which record a broad frequency range, will be deployed adjacent to and within the Gully MPA for a cetacean passive acoustic monitoring study taking place from 2012 to 2014.

Data collection

Systems are deployed at desired recording locations within the Gully (determined according to monitoring priorities) and are returned to the lab for data extraction and analysis. Past recording locations have typically been along the axis at of the Gully (Figure 8-1) at depths between 1250 m and 1950 m (Table 8-1).

Data analysis

An automated detector for northern bottlenose whale and sperm whale clicks on PU recordings was developed by Moors (2012) to examine presence and behaviour of northern bottlenose whales and sperm whales over various temporal and spatial scales. Differences in click presence and click rate between the head (upper) and mouth (lower) of the Gully was examined as part of this study, as well as diurnal foraging patterns. Trends observed in the Gully were also compared to locations on the adjacent slope. Detailed methodology and results from this study can be obtained from Moors (2012). Analysis of existing data for other species present on the PU recordings such as delphinids and baleen whales has not yet occurred, but development of automated detectors for these other species is underway. The presence of sperm whale clicks and baleen whale vocalizations could potentially be analyzed on the OBS recordings.

Results

Some information on the presence of northern bottlenose whales and sperm whales in the Gully MPA is available from Moors (2012), but baseline values are unknown. Trends in northern bottlenose whale and sperm whale presence over time (including daily, monthly and seasonal time scales) on the PU recordings are described in detail in Moors (2012). This study is not able to address inter-annual variability or changes in presence and activity over longer time scales. Trends for other species have not yet been assessed.

Evaluation of existing protocols for meeting indicator monitoring requirements

Additional automated detectors are currently being developed for other cetacean species as part of the AMAR cetacean acoustic monitoring project. These can potentially be used to analyze the currently available data for the presence of other species. The vocalizations of Sowerby's beaked whales, however, have not yet been described, and so recordings of their vocalizations (from surface-deployed arrays) are required when Sowerby's are sighted at the surface. The detection and false positive rates of automated detectors needs to be determined separately for each acoustic dataset analyzed.

The effective recording range of the various systems is dependent on the target species, the sensitivity of the hydrophone and the level of environmental noise. Generally, beaked whales can be detected to a range of a few kilometres, sperm whales to a range of 7-10 kilometres and baleen whales to a range of tens of kilometres. Most of the existing OBS recordings have an effective upper frequency limit of 2 kHz, which does not encompass the full frequency band required for recording vocalizations of most cetacean species that use the Gully MPA. They may, however, be useful for determining the presence of low frequency baleen and sperm whale vocalizations. The PUs had a higher frequency range (up to 25 kHz) (Moors 2012), and can thus be used to detect sperm whale and delphinid species such as common and Atlantic white-sided dolphins and pilot whales, as well as the lower frequency calls of baleen whales. The PUs are not ideal for recording beaked whale clicks as only the lower-frequency portion of the clicks can be recorded (Moors 2012). The recording range of PUs was likely 1 to 5 kilometres for northern bottlenose whale clicks. The AMARs are able to record at a much broader frequency range (20 Hz to more than 60 kHz) and can thus effectively record baleen and toothed whale vocalizations, including the entire frequency range of beaked whale clicks. The AMARs, therefore, offer the most appropriate means of assessing the presence of multiple species in the Gully MPA for future studies. Initial examination of data collected during short-term AMAR test deployments in 2010 and 2011 (Table 8-1) suggests that these systems will be useful for characterizing biological signals, including the vocalizations produced by toothed and baleen whales and sounds produced by fish, as well as natural and anthropogenic noise levels. However, research also needs to be done on the effective recording range of AMARs for the cetacean species being assessed.

The available OBS data span periods of less than 25 days, but do include recordings from several different times of year (Table 8-1). The PUs were deployed for longer durations (2–3 months; Table 8-1). Longer-term, ideally multi-month, deployments and yearly coverage are needed to properly assess year-round presence of cetaceans within the Gully MPA, and to gain an understanding of variation in any results obtained over time. The AMARs owned by the DFO Species at Risk Management Division (SARMD) and the DFO Ocean and Ecosystem Sciences Division (OESD) will be deployed in slope regions adjacent to and within the Gully MPA for a 2012-2014 cetacean acoustic monitoring study. It is important to note that data collected in the future from AMAR recordings will not be directly comparable to past studies due to differences in recorder capabilities and acoustic sampling methods.

While the focus of future studies should be the Gully MPA, concurrent monitoring of adjacent shelf areas (such as that which will occur in the planned 2012–2014 passive acoustic monitoring study) as a means of comparison would enhance the dataset. Long-term acoustic monitoring of cetaceans will necessarily require commitment of monitoring resources well beyond the time frame of the planned cetacean monitoring study. It is important that DFO Science retain acoustic expertise within the department to support long-term acoustic monitoring studies, including studies of cetacean presence and characterization of natural and anthropogenic noise levels within the Gully MPA.

Threats to ongoing monitoring

There are currently no acoustic monitoring efforts planned within the Gully beyond the 2012-2014 passive acoustic monitoring study. Further monitoring will likely be required to support monitoring of cetacean presence and ambient and anthropogenic noise levels within the MPA (see Indicator 47). Data collection in support of these indicators will depend on continued acoustic monitoring efforts within the Gully MPA by DFO Science.

Additional comments

This indicator is one of the more important indicators relevant to cetaceans and should be given higher priority.

Table 8-1: Summary of acoustic recordings collected from the Gully and surrounding areas that may potentially be useful for analysis of cetacean presence. N/A indicates not applicable.

Type of system	Unit	Date range	Days of recordings (#)	Location	Deployment coordinates Latitude (N)	Longitude (W)	Depth (m)
OBS	A	June 23–July 3, 2003	9.8	GM5	43°39.60'	058°54.90'	1850
OBS	P	June 23–July 3, 2003	9.9	GM6	43°38.14'	059°02.74'	1190
OBS	S	June 28–July 3, 2003	5.1	G C	43°55.43'	058°58.59'	1360
OBS	T	June 23–26, 2003	3.2	G SW	43°48.52'	058°58.06'	1080
OBS	M	June 16–July 11, 2005	24.3	G S	43°51.00'	058°55.17'	1935
OBS	Z	June 16–July 11, 2005	24.3	G SC	43°55.95'	058°59.63'	1550
OBS	S	April 22–25, 2006	2.9	G C	43°53.53'	058°57.47'	1740
OBS	Z	April 22–25, 2006	3.0	G SC	43°55.95'	058°59.63'	1550
OBS	M	July 30–Aug 20, 2006	21.1	G C	43°58.96'	058°59.03'	1330
OBS	Z	July 30–Aug 8, 2006	9.0	G S	43°50.98'	058°54.72'	1900
OBS	M	Nov 21–Dec 9, 2006	18.2	G S	43°51.06'	058°55.14'	1920
OBS	S	Nov 21–23, 2006	1.7	G C	43°56.00'	058°59.66'	1540
OBS	Z	Nov 21–Dec 11, 2006	20.0	G N	43°59.00'	058°59.05'	1340
PU	96	July 25–Sep 16, 2006	52.8	GULM	43°52.06'	058°56.17'	1950
PU	83	July 25–Sep 16, 2006	52.8	GULH	43°57.29'	058°59.54'	1250
PU	83	Dec 9, 2006–Jan 30 2007	52.0	GULM	43°50.97'	058°55.15'	1950
PU	93	Aug 1–Oct 1, 2007	60.8	SWGUL	43°32.44'	059°19.40'	1500
PU	92	Aug 4–Oct 1, 2007	57.9	EGUL	43°53.49'	058°36.98'	1500
PU	7	Aug 4–Oct 1, 2007	57.5	HALD	44°11.92'	058°36.95'	1500
PU	93	Dec 7, 2007–Feb 25, 2008	79.6	SWGUL	43°32.32'	059°19.35'	1500
PU	96	Dec 7, 2007–Feb 25, 2008	79.5	GULH	43°56.95'	058°59.43'	1500
PU	92	Dec 7, 2007–Feb 25, 2008	79.5	EGUL	43°53.51'	058°36.95'	1500
PU	32	Dec 7, 2007–Feb 25, 2008	79.5	SHORT	44°05.98'	058°21.33'	1500
PU	79	Dec 7, 2007–Feb 25, 2008	79.5	HALD	44°11.93'	057°58.08'	1500
PU	32	June 23–Sep 11, 2008	79.6	SHORT	44°05.98'	058°21.31'	1650
PU	92	June 19–Sep 7, 2008	79.6	HALD	44°11.93'	057°57.89'	1550
PU	32	Dec13–Mar 3, 2008	79.5	SHORT	44°06.00'	058°21.33'	1500
PU	92	Dec 13–Mar 3, 2008	79.6	HALD	44°11.97'	057°58.04'	1600
AMAR	N/A	March 16–25, 2010	10	2010	43°57.22'	058°59.97'	1150
AMAR	N/A	Oct 11–12, 2011	2	2011	43°52.16'	058°55.94'	1725

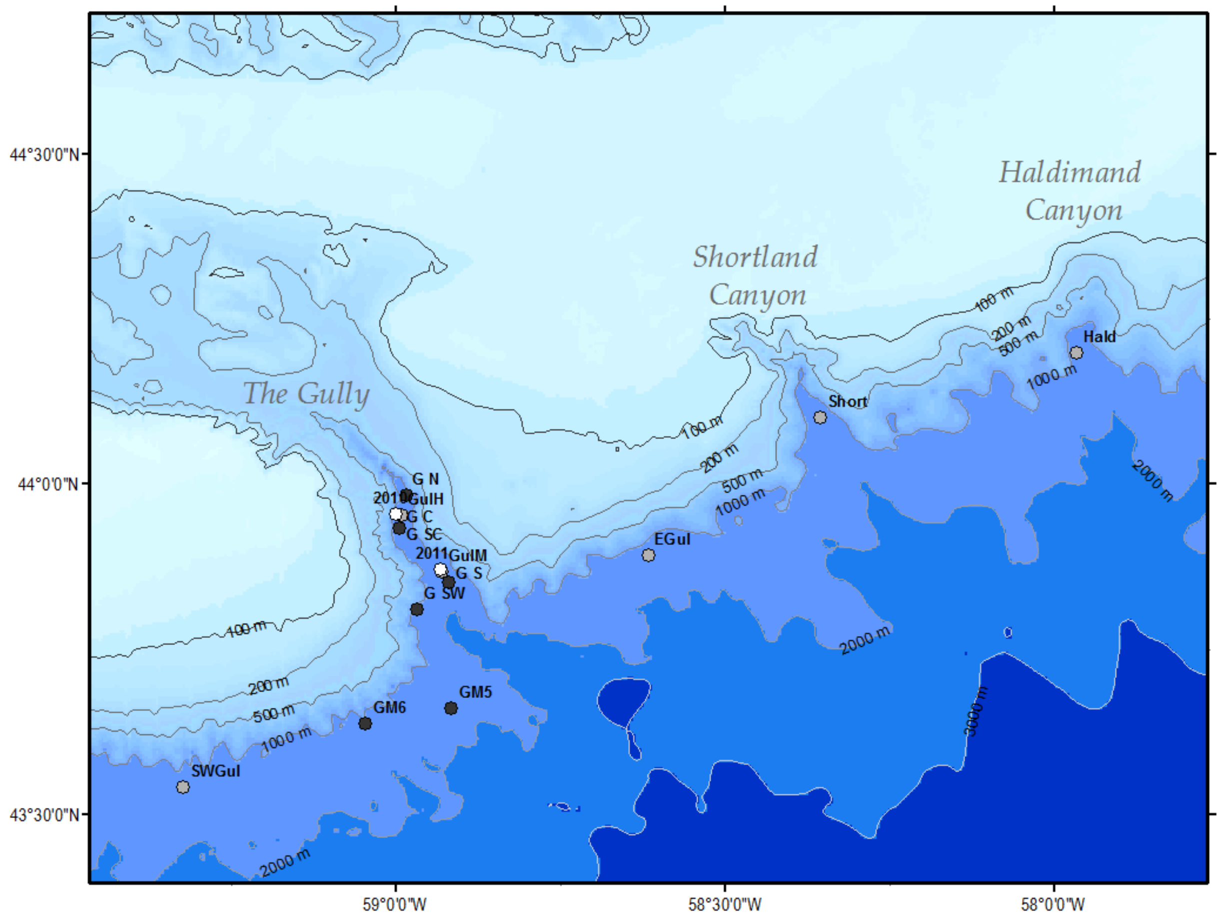


Figure 8-1: Location of OBS (black circles), PU (grey circles) and AMAR (white circles) acoustic recording stations.

Indicator 9: Number of reported strandings of Scotian Shelf Northern Bottlenose Whales

Indicator 10: Number of reported ship strikes on cetaceans in or near the Gully, and of strikes on Scotian Shelf Northern Bottlenose Whales elsewhere

Indicator 11: Number of reported gear entanglements of cetaceans in or near the Gully, and of entanglement of Scotian Shelf Northern Bottlenose Whales elsewhere

Indicator 12: Number of reports of other interactions between human activities and cetaceans in or near the Gully, and of interactions with Scotian Shelf Northern Bottlenose Whales elsewhere

H. Moors-Murphy and H. Whitehead

Suggested improvements to indicator wording

Merging Indicators 9 through 12 into two new indicators is suggested:

“Number of reported northern bottlenose whale incidents likely to be caused by human interactions (entanglements, ship strikes, strandings and other human-caused mortalities) in the northwest Atlantic.”

“Number of reported cetacean incidents likely to be caused by human interactions (entanglements, ship strikes, strandings and other human-caused mortalities) in or near the Gully.”

Indicators 9 through 12 are essentially examining two things: human-caused injuries or mortalities to individuals of the Scotian Shelf northern bottlenose whale population (requires a broader monitoring area than the Gully MPA) and human-caused injuries and mortalities to cetaceans in general (including northern bottlenose whales) within the vicinity of the Gully. Because northern bottlenose whales are year-round residents of the Gully and the Gully is the focal point of their distribution, monitoring incidents specifically involving northern bottlenose whales, as well as cetacean incidents in general, is warranted. In addition, very few cetacean strandings, ship strikes, entanglements and mortalities likely to be caused by humans in the Gully and nearby offshore areas or incidents involving northern bottlenose whales in the northwest Atlantic, have been reported. For some indicators, as previously listed, no data currently exists. For example, there are currently no known reports of northern bottlenose whale ship strikes (Table 9-1). It can also be difficult sometimes to determine exact cause of death. Grouping these indicators together and citing the overall number of incidents with information about their causes (when possible) would be sufficient.

Available data

Data regarding incidents with cetaceans is available from the MARS database, the DFO Maritimes Region Cetacean Sightings database and from at-sea observer reports from the 1960s to present.

Data collection

All reported strandings, entanglements, ship strikes and other human interactions within the region (including associated data such as location, date, time, species and information source) are recorded in the MARS database.

Results

Reported northern bottlenose whale incidents (entanglements, ship-strikes, strandings and other human-caused mortalities) likely to be caused by human interactions in the northwest Atlantic are summarized in Table 9-1.

Evaluation of existing protocols for meeting indicator monitoring requirements

Many cetacean species that occur within the Gully are migratory, so incidents reported in or near the Gully MPA may not necessarily have occurred there. For example, an entangled humpback whale was observed in the Gully during the summer of 2010 and some of the gear was removed from the animal and traced back to a vessel fishing 150 km east of the MPA (not all incidents can be traced back to where they actually occurred). In addition, the number of human-caused cetacean injuries or mortalities likely to be observed and reported in or near the Gully is likely quite low because of its remote, offshore location. Animals that are injured and killed may sink before ever being observed and carcasses may never reach shore. The number of reported human-caused injuries or mortalities, therefore, likely only represents some fraction of the actual number of incidents that occur. For most species, including northern bottlenose whales, the percentage of incidents resulting from interactions with humans that are actually reported is unknown. Increased at-sea observer coverage in or near the Gully and along the Scotian Slope (where northern bottlenose whales are most likely to occur) may provide better data on the number of entanglements, ship strikes, strandings and other human interactions that occur in the area. Although existing protocols are adequate for meeting existing monitoring requirements (monitoring the number of reported incidents), increased at-sea observer coverage would increase the reporting of incidents that occur within these regions. Seven of the nine northern bottlenose whale entanglements reported in Table 9-1 were reported by at-sea observers.

Threats to ongoing monitoring

MARS is a non-profit organization that depends on external funding sources to operate. In particular, development and maintenance of their database has been supported through financial support from DFO. Financial support may be required in the future to ensure that MARS data collection efforts continue.

Additional comments

While it is important to monitor the number of cetacean injuries and mortalities caused by human interactions that occur over time, and to carefully investigate their cause, conclusions that can be drawn about the state of the Gully ecosystem based on this sort of data are limited. Rather, such data are perhaps more appropriate for evaluating the effectiveness of the Gully MPA at protecting cetaceans, particularly the resident population of Scotian Shelf northern bottlenose whales that reside in the canyon throughout the year.

Table 9-1: Number of reported northern bottlenose whale incidents (entanglements, ship-strikes, strandings and other human-caused mortalities) likely to be caused by human interactions in the northwest Atlantic. Numbers in brackets indicate minimum number of fatal incidents.

Year	Entanglements	Ship strikes	Strandings	Other Mortalities
Before 2004	8 (2)	0	0	88*
After 2004	1 (1)	0	0	0
Total	9	0	0	88

* 87 of these mortalities were taken during the whaling period. This number does not include the estimated 1154 kills that occurred in more northern waters of the northeastern Atlantic. The remaining mortality was caused by acoustic disturbance from military activities.

PROTECT SEAFLOOR HABITAT AND ASSOCIATED BENTHIC COMMUNITIES

Indicator 13: Coral distribution, density and size structure by species at selected monitoring sites within the MPA

Indicator 14: Coral diversity at selected monitoring sites within the MPA

Indicator 15: Proportions of live and dead corals, by species, at selected monitoring sites within the MPA

Indicator 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

An evaluation of these indicators was conducted and presented at the workshop, but the results are not included here.

CONSERVE COMMERCIAL AND NON-COMMERCIAL LIVING RESOURCES

Indicators 17 through 20 relate to the conservation of commercial and non-commercial living resources. This includes groundfish, trawl-vulnerable invertebrates, longline-vulnerable species, trap-vulnerable species and mesopelagic nekton.

Indicator 17: Relative abundances, size distributions, and diversity of selected groundfish and trawl-vulnerable invertebrate species in Zone 3 of the MPA.

An evaluation of this indicator was not conducted.

Indicator 18: Relative abundances, size distributions, and diversity of selected longline-vulnerable species in Zones 2 and 3 of the MPA

M. Vaughan and M.K. Trzcinski

Background

Historically, the Gully has supported a number of important commercial fisheries, particularly for groundfish and large pelagic species (Breeze 2002). There are two major commercial fisheries currently operating in Zones 2 and 3 of the MPA (Figure 18-1): a bottom longline fishery for Atlantic halibut (*Hippoglossus hippoglossus*) and a surface longline fishery for swordfish (*Xiphias gladius*) (DFO 2008). Fishing is not permitted in Zone 1. Monitoring of these fisheries is important for understanding impacts on biodiversity and ensuring the protection of the Gully ecosystem. The requirements for fisheries monitoring in the Gully are described in detail in the *Gully Marine Protected Area Management Plan* (DFO 2008). The following provides an overview of the Industry/DFO longline halibut survey and commercial index and considers whether or not it can be used to monitor ecosystem health and diversity in the Gully MPA.

Available data

The Industry/DFO longline halibut survey (the 'halibut survey') was initiated in 1998 and data was analyzed up to 2010. The only fixed station within the boundaries of the Gully MPA is Station 85 (Figure 18-2). Only data from this station was analyzed, however Station 85 was not part of the halibut survey from 2006 to 2007 and there was no commercial index in the Gully MPA from 1999 to 2001 and from 2005 to 2006. Commercial index data was only included if the vessel was located inside the Gully MPA at the start of the set. Only the observed portion (not the non-observed port-sampled portion) from the commercial index was analyzed.

Data collection

Halibut survey

The halibut survey covers the Scotian Shelf and southern Grand Banks (Northwest Atlantic Fisheries Organization [NAFO] Division: 3NOPs4VWX5Zc). Industry boats meeting vessel requirements participate in the yearly halibut survey from May 22 to July 22. Vessel restrictions are based on licence category, vessel capability and certification. Bottom longline gear is used for fishing and catches are typically made at depths between 200 and 500 metres. The survey uses a fixed-station design. In 1998, 222 stations were selected based on the previous five years of commercial catch and the goal of wide spatial coverage. A total of 73 stations were added from 2005 to 2008. On average, 200 of the 295 stations are fished each year at the rate of one set per station (Trzcinski et al. 2009). In 2006, 77 stations were identified as having priority over all other stations. The selection of these core stations was based on achieving equal representation in each NAFO division of the management area, achieving equal representation of the three depth strata and maintaining those stations with the greatest number of years completed. Station 85 was not designated as a core station. The number of stations surveyed in addition to the core stations is variable and depends on the number of participants, station location, weather, proper gear functioning and proper vessel functioning. Some fixed stations are located in closed areas (e.g., the Haddock Box), but none are within Zone 1 of the Gully MPA.

Each vessel is permitted a maximum of 0.8 fishing days for every survey station covered on the Scotian Shelf and 1.0 days for stations covered on the southern Grand Banks. Fishing during the survey is standardized, however, it is reasonable to expect a certain amount of variation due to complications such as with weather and gear. The survey protocol provides specifications for hook size (#14 circle hook or larger), number of hooks (950–1050), soak time (6–12 hours) and maximum distance from a station (3 NM). Catch summaries are recorded and include: kept weight, discard weight and, for halibut, total number caught. The protocol also provides the following detailed sampling instructions:

- All halibut are measured for length and weight by sex.
- Observers sample one halibut per sex per 5 cm length grouping.
- Additional sampling may also include maturity staging and assessment of gut fullness, as well as the collection of stomach, gonad and otolith samples.
- Detailed sampling of halibut takes priority over sampling of other species.
- If time permits, other species are sampled in the following order: cod, cusk, white hake and wolffish.

As a result, length frequencies, sex and weight may or may not be recorded for non-target species.

Commercial index

The commercial index operates in the same area and during the same time as the halibut survey but has approximately three times more sets than the survey. Commercial index sets are done by survey participants after their fixed station sets have been completed. Participants fish at locations of their choosing (but adhering to all normal closures) as long as licence and quota requirements are met. Fishing during the commercial index is concentrated along the slope of the continental shelf, where catch rates are typically higher (Trzcinski et al. 2009). The fishing protocol for the commercial index specifies the same hook size and gear used in the halibut survey, but fishers can use more gear per set (to a daily maximum of 7000 hooks). Soak time is usually determined by fishing; typically, 2 to 4 sets are made per day with a distance of 5 to 10 nautical miles (nm) between sets. Soak times will vary depending on the number of sets and the order in which the sets are hauled back. Consequently, there is more variation in fishing practices in the commercial index than in the halibut survey. Fishers are not required to have an at-sea observer when fishing a commercial index set and often do not have an observer when fishing in the Gully; 21% to 48% of sets are observed per year. When an observer is on board, the commercial index uses the same sampling protocol as the halibut survey. The dockside observer protocol requires detailed sampling of halibut only, with catch summaries being recorded on Captain’s Sheets.

Analysis

All analyses were conducted using R statistical software. Species diversity was calculated using the Shannon-Weaver diversity index (R package: Vegan). The Shannon-Weaver index calculates diversity (H”) using the equation:

$$H'' = -\sum (N_i/N) \log_2 (N_i/N) \qquad [1,\infty]$$

where N is the number of individuals. According to Wilhm (1968), the Shannon equation can be adapted to calculate diversity using biomass units instead of numbers of individuals. Since observers sometimes do not record numbers caught, but always record catch weight, diversity was calculated for each year using the equation:

$$H'' = -\sum (W_i/W) \log_2 (W_i/W) \quad [1,\infty]$$

where W_i is the biomass of the ith species. Wilhm (1968) did not provide a method for calculating standard error when using biomass to estimate diversity. H” provides an estimation of actual species diversity (H’) when N is high (Wilhm 1968); H” is not as strongly affected by sampling bias as some other indices because it uses log ratios. A species accumulation curve was generated for the commercial index to show the number of species expected for a certain number of sets (R package: Vegan). Detailed analyses of catch distribution and catch rate were only conducted for halibut and major non-target species. These ‘top species’ were selected if they were caught in five years or more; assuming that after five years, sample size would be large enough to be informative. Catch rates were calculated by species and year, standardized to 1000 hooks and 10 hours soak time, but not standardized by a generalized linear model for vessel, stratum or area effects. This likely affected catch rates.

Results

Catch distribution

Fishing on the halibut survey was concentrated on the northwestern end of the MPA near the location of Station 85 (Figures 18-3 to 18-7). As a result, the halibut survey does not cover a large area of the Gully MPA. Catches for the survey were relatively small and only one set was done at Station 85 each year. The commercial index provides better spatial coverage than the survey, with fishing occurring both in the canyon and near the canyon mouth (Figures 18-8 to

18-14). The index also had multiple sets and catches were larger. The halibut survey does, however, provide better temporal coverage, surveying the Gully in all but two years, compared to the commercial index, which did not fish five out of thirteen years. The overall spatial extent of the data is also limited due to depth and area restrictions.

Catch rates

Halibut made up the largest portion of the catch for both the survey and the commercial index (Figures 18-15 to 18-16). Cusk (*Brosme brosme*) and white hake (*Urophycis tenuis*) were also prominent species in some years. In the halibut survey, catch rates increased over time for halibut (Figure 18-17), remained relatively low and constant for both redfish (*Sebastes* spp.) and thorny skate (*Amblyraja radiata*) and varied somewhat for cusk and white hake. However, due to very small sample sizes, error estimates are not available for catch rates, and variations in catch rate are unlikely to provide accurate estimates of changes in abundance.

The catch rate analysis for the commercial index may be slightly more reliable due to the larger sample size. Catch rates increased for halibut (approximately 30%) and northern wolffish (*Anarhichas denticulatus*) with the former being marginally significant (slope= 5.71, p= 0.06) and the latter significant (slope= 1.12, p= 0.02). There was a significant decline in catch rates for white hake (slope= −1.94, p= 0.02) to less than 10 kg per 1000 hooks per 10 hours (Figure 18-18). Mean annual catch rates were relatively low for Atlantic cod (*Gadus morhua*), but did not change significantly over time. There were no significant changes in catch rates for cusk, black dogfish (*Centroscyllium fabricii*), thorny skate or redfish (Figure 18-19).

Overall, catch rates for halibut suggest the population is increasing, which is consistent with the results of Trzcinski et al. (2011). In addition, catch rates for northern wolffish, which is listed as ‘threatened’ under the *Species At Risk Act* (SARA), show signs that the health of the Gully population is improving. The decrease in catch rates for white hake is concerning. The population has declined since 1987 (Bundy and Simon 2005) and recent assessments suggest the status of white hake in NAFO Division 4VsW is poor. Continued monitoring of the Gully could pose a threat to this already vulnerable species. For some species, such as the black dogfish, catch rates were highly variable with no clear trend over time. Whether these variations in catch rate indicate changes in abundance is uncertain. Large fluctuations in catch rate are likely a result of shifts in population distribution and not abundance.

Species richness and diversity

Analysis of catch data collected across the entire Eastern Scotian Shelf during the halibut survey and commercial index found an annual species richness value of 21 species. However, as the Gully is a canyon ecosystem, it likely has a different community structure than the shelf ecosystem. Regional processes may influence species richness in local communities so a comparison between adjacent canyons may yield a more informative result than from across the entire shelf. Length-based gear selectively may also limit the ability of the halibut survey and commercial index to estimate species richness and diversity. The halibut fishery is also highly selective and may not be the most effective tool for assessing overall species richness. The halibut survey and the commercial index use large hooks, which selects for larger groundfish species, particularly adults.

For the Gully specifically, species richness was generally higher in the commercial index than in the halibut survey (Figure 18-20). The maximum number of species caught in any year was 14 for the commercial index and 8 for the halibut survey. These differences, however, may be partly, if not entirely, due to differences in sample size between the index and the survey; sample size was 1 set per year for the halibut survey and 2-26 sets per year for the commercial index (Figure 18-21). The highest overall species richness was observed during the commercial index in 1998 where the sample size was 26 sets, approximately 40% higher than any other year. This suggests that observed species richness is likely an under-estimate of actual species richness. While a minimum sample size of 20-30 sets per year would provide a more reliable estimate of species richness (Figure 18-22), a sample size of 10 sets would likely catch most species and still provide useful information on the groundfish community.

From 1998 to 2010, species diversity decreased for both the halibut survey and the commercial index (Figure 18-23). However, the calculated values for H" are likely inaccurate estimates of H', again due to small sample size. In addition, measurements of error for the diversity indices are not available, so it is unknown whether or not diversity in the Gully has decreased significantly since 1998.

Length-frequencies

It was not possible to identify trends in length-frequencies for either the halibut survey or the commercial index. Length-frequency plots for halibut (Figures 18-24 and 18-25) reveal little about the size structure of the population, although the index is considerably better than the survey. Length-frequency data for non-target species was also extremely limited (Tables 18-1 and 18-2). This is partly due to small sample size, particularly for the halibut survey, but also because the sampling protocol is to collect length-frequency measurements for species in order of priority. While the protocol could be modified for the Gully if information on specific species was desired, current data suggests that length-frequencies do not provide useful information on fish communities in the Gully.

Bycatch

More bycatch species were caught in the commercial index than in the halibut survey. The top bycatch species in the commercial index were Atlantic cod, cusk, white hake, thorny skate, redfish, black dogfish and northern wolffish. Other species caught in some years include: spotted wolffish (*Anarhichas minor*), striped Atlantic wolffish (*Anarhichas lupus*), barndoor skate (*Dipturus laevis*), winter skate (*Leucoraja ocellata*), spiny dogfish (*Squalus acanthias*), turbot (*Reinhardtius hippoglossoides*), snow crab (*Chionoecetes opilio*), haddock (*Melanogrammus aeglefinus*) and monkfish (*Lophius* sp.) (Tables 18-3 and 18-4). The top bycatch species by weight in the halibut survey were cusk, white hake, thorny skate and redfish. Other species caught in some years include: northern wolffish, spotted wolffish, barndoor skate, winter skate, Atlantic cod, turbot and snow crab (Tables 18-5 and 18-6).

Many bycatch species are assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), such as cusk, or listed under SARA, such as Atlantic cod.

Evaluation of existing protocols for meeting indicator monitoring requirements

Comparison to logbook data

The commercial index is generally assumed to be fairly representative of the halibut fishery, but this has never been validated. Logbook data provides information on commercial landings and bycatch in the halibut fishery for the Gully MPA (Breeze 2008). A preliminary assessment of the data suggests that the commercial index does fish in similar areas and does catch similar species as the halibut fishery. According to logbook data, major bycatch species caught in the Gully when fishers target halibut include cusk and white hake and, to a lesser extent, Atlantic cod and redfish. Small landings of American plaice (*Hippoglossoides platessoides*), wolffish (*Anarhichas* spp.), turbot, haddock, monkfish, pollock (*Pollachius virens*), roundnose grenadier (*Coryphaenoides rupestris*) and porbeagle (*Lamna nasus*) have also been reported in some years. Future analyses should consider a more detailed comparison between the commercial index data and logbook data, but it is likely that the commercial index is useful for monitoring the halibut fishery in the Gully MPA.

Overall adequacy

The halibut survey and the commercial index do not, in their current state, effectively monitor ecosystem health and fish diversity in the Gully MPA. Results are generally inconclusive and unlikely to provide useful information over the medium term. However, the halibut survey and commercial index are the only source of information currently available on the large groundfish community in the Gully and, as such, they may be useful for identifying long-term (decadal) changes in fish populations.

A number of issues with the sampling regime need to be addressed if monitoring is to be effective. One of the major problems for both the halibut survey and the commercial index is that sampling does not occur every year. Yearly sampling of the Gully is needed in order to identify changes in the ecosystem over the short term. Other issues, particularly for the halibut survey, include small sample size and limited area coverage. For the commercial index, the lack of standardization does not ensure the same areas are fished every year. There can be a large location effect on catch rates and the diversity of species caught. For example, halibut comprised a much larger percentage of the catch at Station 85 than the average commercial index set. This potentially-large effect is the likely motivation behind the fixed-station design of the halibut survey.

The halibut survey and commercial index do seem to be monitoring a handful of longline-vulnerable species in the Gully. However, they are not good indicators of the Gully community and do not seem to be tracking ecosystem properties. Estimates of species richness and diversity are low as are the signal-to-noise ratios in catch rates. The large groundfish species caught in the halibut fishery tend to move over longer distances and probably move freely in and out of the Gully MPA. Therefore, monitoring within a small area like the Gully is subject to a high amount of observation error. In addition, natural variation is likely very high given the dynamics of the ecosystem. The halibut survey and observed portion of the commercial index may, therefore, be useful to monitor a larger ecosystem and larger MPAs.

An increase in effort to 20-30 sets per year would provide a more exhaustive estimate of species richness and diversity in the Gully. However, such a substantial increase in effort would present a number of logistical challenges and may damage the integrity of the ecosystem. An increase to 10 sets per year is a more reasonable goal and would still provide useful information on some species. These sets could be conducted during either the halibut survey or the commercial index. One option is to add nine more fixed stations throughout Zones 2 and 3 of the Gully MPA. The other option is to require fishers to have an at-sea observer on board when fishing a commercial index set in the Gully. The halibut survey and commercial index provide different information with regards to monitoring. The halibut survey is more useful for monitoring the ecosystem, whereas the commercial index can be used to monitor the impacts of fishing. Therefore, it is important to decide what kind of information is most useful for management purposes.

Future analyses should consider investigating data collected on port-sampled (non-observed) commercial index sets. The dockside monitoring protocol is distinct from the observer protocol and the data should be analyzed separately. The dataset could also be expanded by adding fixed stations in the immediate vicinity of the Gully MPA (e.g., station 122 in Figure 18-2). However, deciding which stations to include in the analysis is not a simple process. These stations may or may not be relevant for monitoring the Gully ecosystem. An investigation into the biotic and abiotic characteristics of each station and a comparison to habitats in the Gully would be required. A more relevant analysis may be to compare the Gully with other submarine canyons along the shelf edge.

Threats to ongoing monitoring

From 1998 to 2006, the halibut survey and commercial index were funded by the use of fishing quota. In response to the Larocque decision of 2006, DFO provided funding to partially support the survey ($300,000 per year for 77 stations). The continuation of this funding program is uncertain. This could have impacts on station coverage (e.g., Station 85) and the amount of commercial index fishing in the Gully. There are currently no long-term arrangements to ensure funding for the halibut survey and commercial index. Joint Project Agreements (JPAs) have been established over five-year periods. The current JPA ends in March 2012 and will need to be renegotiated. The industry has a vested interest in the halibut survey and commercial index, and will be interested in reaching another collaborative agreement with DFO.

Table 18-1: Length-frequency table by year for cusk, white hake, thorny skate and spotted wolffish caught in the halibut survey in the Gully (Station 85). The Gully was not surveyed and length measurements were not collected in missing years indicated by an asterisk (*). A dash (-) indicates that the Gully was surveyed, but that a length sample was not available.

Species	Year	Length (cm)																								
		48	51	52	54	55	56	57	58	59	60	61	65	66	67	70	71	73	79	82	83	85	89	90	99	108
Cusk	1998-2000	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	2001	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1	-	-
	2002	-	-	-	1	-	-	-	1	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-
	2003-2010	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
White hake	1998	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2000	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	2001	-	-	-	-	1	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2002	-	-	-	-	1	1	2	-	1	1	1	1	1	-	1	1	1	1	-	-	-	-	-	-	-
	2003-2010	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Thorny skate	1998	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1999-2010	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Spotted Wolffish	1998-2001	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	2002	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	1	-	1	1
	2003-2010	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 18-2a: Length-frequency table (35-66 cm) by year for Atlantic cod, cusk, white hake, and thorny skate caught in the commercial index in the Gully. The Gully was not surveyed and length measurements were not collected in missing years indicated by an asterisk (*).A dash (-) indicates that the Gully was surveyed, but that a length sample was not available.

Species	Year	Length (cm)																							
		35-39	40-44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66
Cod (Atlantic)	1998	-	-	-	1	3	2	2	2	2	5	6	3	6	4	10	13	11	9	9	13	13	9	19	10
	1999-2001	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	2002	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1	-	1	1	1
	2003-2010	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Cusk	1998	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
	1999-2001	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	2002	-	-	-	-	-	1	-	-	-	-	-	1	1	1	-	3	1	2	1	-	-	2	1	1
	2003-2010	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
White hake	1998	2	21	20	14	23	42	45	47	51	60	56	63	59	53	46	49	35	37	21	27	18	14	6	7
	1999-2001	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	2002	-	-	-	-	-	-	-	-	2	-	2	2	-	-	2	-	2	1	2	-	1	-	1	2
	2003	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
	2004-2010	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Thorny skate	1998	-	-	-	-	1	-	-	2	2	1	2	-	1	2	3	2	1	1	-	1	-	-	1	-
	1999-2002	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
	2004-2010	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 18-2b: Length-frequency table (67-98 cm) by year for Atlantic cod, cusk, and white hake caught in the commercial index in the Gully. The Gully was not surveyed and length measurements were not collected in missing years indicated by an asterisk (*).A dash (-) indicates that the Gully was surveyed, but that a length sample was not available.

Species	Year	Length (cm)																							
		67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90-98
Cod (Atlantic)	1998	9	16	19	9	5	7	8	5	2	1	7	3	1	-	3	-	1	1	-	-	1	-	-	-
	1999-2001	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	2002	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2003-2010	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Cusk	1998	-	1	-	1	-	1	-	2	-	1	1	-	-	-	-	1	1	2	-	2	1	1	-	1
	1999-2001	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	2002	-	-	1	1	1	3	-	4	3	5	1	1	1	4	4	1	4	2	2	4	1	1	1	4
	2003	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	1	-	1	-	-	1	-	2
	2004-2008	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	2009	-	-	1	1	2	-	1	-	-	2	1	-	2	-	2	1	3	1	-	-	-	2	-	8
	2010	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
White hake	1998	5	7	2	1	3	1	1	1	3	-	2	-	1	-	-	-	1	1	-	1	-	-	-	-
	1999-2001	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	2002	-	-	1	1	-	-	1	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-
	2003-2010	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 18-3: Raw catch weights (kg) by species and year for the commercial index in the Gully. The commercial index did not fish in the Gully from 1999 to 2001 and from 2005 to 2006 (indicated as NCI).

Species	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Halibut (Atlantic)	6799	NCI	NCI	NCI	1534	650	1728	NCI	NCI	166	1713	2604	1150	16344
Cusk	4686	NCI	NCI	NCI	634	427	85	NCI	NCI	118	363	828	44	7185
White hake	2628	NCI	NCI	NCI	250	46	182	NCI	NCI	36	80	3	46	3271
Cod (Atlantic)	853	NCI	NCI	NCI	39	0	5	NCI	NCI	0	49	5	77	1028
Black dogfish	400	NCI	NCI	NCI	133	0	6	NCI	NCI	0	57	94	7	697
Northern wolffish	140	NCI	NCI	NCI	160	0	80	NCI	NCI	0	67	212	0	659
Spotted wolffish	76	NCI	NCI	NCI	75	0	80	NCI	NCI	0	0	93	0	324
Thorny skate	162	NCI	NCI	NCI	6	2	75	NCI	NCI	0	34	18	0	297
Redfish unseparated	164	NCI	NCI	NCI	42	0	27	NCI	NCI	0	0	22	3	258
Barndoor skate	0	NCI	NCI	NCI	0	0	45	NCI	NCI	0	0	52	26	123
Winter skate	0	NCI	NCI	NCI	0	0	0	NCI	NCI	0	0	0	99	99
Spiny dogfish	68	NCI	NCI	NCI	15	0	0	NCI	NCI	0	0	0	0	83
Striped Atlantic wolffish	75	NCI	NCI	NCI	0	0	0	NCI	NCI	0	0	0	0	75
Turbot, Greenland halibut	12	NCI	NCI	NCI	22	0	8	NCI	NCI	0	0	5	0	47
Snow crab (queen)	10	NCI	NCI	NCI	0	0	0	NCI	NCI	0	0	0	9	19
Haddock	9	NCI	NCI	NCI	0	1	0	NCI	NCI	0	0	0	3	13
Monkfish, goosefish, angler	0	NCI	NCI	NCI	0	0	0	NCI	NCI	0	0	0	8	8
Total	16082	NCI	NCI	NCI	2910	1126	2321	NCI	NCI	320	2363	3936	1472	30530

Table 18-4: Estimated numbers caught by species and year for the commercial index in the Gully. The commercial index did not fish in the Gully from 1999 to 2001 and from 2005 to 2006 (indicated as NCI). Missing values represented by a dash (-) indicate that the species was caught, but the number of individuals was not recorded.

Species	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
White hake	1609	NCI	NCI	NCI	168	1	-	NCI	NCI	-	-	-	51	1829
Halibut (Atlantic)	572	NCI	NCI	NCI	95	45	110	NCI	NCI		88	133	152	1195
Cusk	205	NCI	NCI	NCI	119	7	-	NCI	NCI	-	-	27	9	367
Cod (Atlantic)	251	NCI	NCI	NCI	14	0	-	NCI	NCI	0	-	-	55	320
Black dogfish	180	NCI	NCI	NCI	62	0	-	NCI	NCI	0	-	-	-	242
Redfish unseparated	113	NCI	NCI	NCI	24	0	-	NCI	NCI	0	0	-	3	140
Thorny skate	43	NCI	NCI	NCI	3	1	-	NCI	NCI	0	-	-	0	47
Spiny dogfish	7	NCI	NCI	NCI	10	0	0	NCI	NCI	0	0	0	0	17
Spotted wolffish	9	NCI	NCI	NCI	6	0	-	NCI	NCI	0	0		0	15
Snow crab (queen)	9	NCI	NCI	NCI	0	0	0	NCI	NCI	0	0	0	3	12
Haddock	5	NCI	NCI	NCI	0	1	0	NCI	NCI	0	0	0	3	9
Northern wolffish	-	NCI	NCI	NCI	9	0	-	NCI	NCI	0	-	-	0	9
Turbot, Greenland halibut	-	NCI	NCI	NCI	5	0	-	NCI	NCI	0	0	-	0	5
Barndoor skate	0	NCI	NCI	NCI	0	0	-	NCI	NCI	0	0	-	3	3
Winter skate	0	NCI	NCI	NCI	0	0	0	NCI	NCI	0	0	0	3	3
Monkfish, goosefish, angler	0	NCI	NCI	NCI	0	0	0	NCI	NCI	0	0	0	1	1
Striped Atlantic wolffish	-	NCI	NCI	NCI	0	0	0	NCI	NCI	0	0	0	0	0
Total	3003	NCI	NCI	NCI	515	55	110	NCI	NCI	0	88	160	283	4214

Table 18-5: Raw catch weights (kg) by species and year for the halibut survey in the Gully (Station 85). Station 85 was not surveyed in 2006 or 2007 (indicated by N/S).

Species	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Halibut (Atlantic)	10	45	13	164	231	118	64	1128	N/S	N/S	54	316	211	2354
Cusk	0	7	0	3	34	14	60	120	N/S	N/S	0	6	0	244
White hake	0	0	0	0	0	12	0	140	N/S	N/S	0	0	0	152
Northern wolffish	5	12	0	4	15	23	40	20	N/S	N/S	5	2	0	126
Spotted wolffish	0	11	0	0	34	0	10	0	N/S	N/S	0	0	0	55
Thorny skate	0	10	0	0	0	9	2	28	N/S	N/S	0	1	0	50
Redfish unseparated	2	0	0	12	0	2	10	0	N/S	N/S	0	8	0	34
Barndoor skate	0	0	0	0	0	0	0	16	N/S	N/S	0	0	15	31
Winter skate	0	0	0	18	0	0	0	0	N/S	N/S	0	8	0	26
Cod (Atlantic)	0	0	0	0	0	0	0	4	N/S	N/S	0	6	0	10
Turbot, Greenland halibut	1	0	0	0	0	0	0	0	N/S	N/S	0	4	0	5
Snow crab (queen)	1	0	1	0	0	0	0	0	N/S	N/S	0	0	0	2
Total	19	85	14	201	314	178	186	1456	N/S	N/S	59	351	226	3089

Table 18-6: Estimated numbers caught by species and year for the halibut survey in the Gully (Station 85). Station 85 was not surveyed in 2006 or 2007 (indicated by N/S). Missing values represented by a dash (-) indicate that the species was caught, but the number of individuals was not recorded.

Species	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Halibut (Atlantic)	2	3	1	9	15	6	7	40	N/S	N/S	1	15	12	111
Cusk	0	2	0	1	7	4	-	52	N/S	N/S	0	-	0	66
White hake	3	3	0	3	13	11	-	12	N/S	N/S	-	-	0	45
Redfish unseparated	0	7	0	0	0	3	-	24	N/S	N/S	0	-	0	34
Northern wolffish	0	0	0	0	0	2	0	8	N/S	N/S	0	0	0	10
Spotted wolffish	0	2	0	0	5	0	-	0	N/S	N/S	0	0	0	7
Thorny skate	1	0	0	4	0	1	-	0	N/S	N/S	0	-	0	6
Cod (Atlantic)	0	0	0	0	0	0	0	4	N/S	N/S	0	-	0	4
Winter skate	0	0	0	0	0	0	0	4	N/S	N/S	0	0	-	4
Snow crab (queen)	1	0	1	0	0	0	0	0	N/S	N/S	0	0	0	2
Turbot, Greenland halibut	1	0	0	0	0	0	0	0	N/S	N/S	0	-	0	1
Barndoor skate	0	0	0	1	0	0	0	0	N/S	N/S	0	-	0	1
Total	8	17	2	18	40	27	7	144	N/S	N/S	1	15	12	291

Table 18-7: Catch weight as a percentage of the annual total catch by species and year for the halibut survey in the Gully (Station 85). 'Overall' indicates the percentage of the total catch summed over the entire sampling period (1998 to 2010).Station 85 was not surveyed in 2006 or 2007 (indicated by N/S).

Species	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Overall
Halibut (Atlantic)	52.63	52.94	92.86	81.59	73.57	66.29	34.41	77.47	N/S	N/S	91.53	90.53	93.36	76.25
Cusk	0	8.24	0	1.49	10.83	7.87	32.26	8.24	N/S	N/S	0	1.72	0	7.91
Northern wolffish	0	0	0	0	0	6.74	0	9.62	N/S	N/S	0	0	0	4.92
White hake	26.32	14.12	0	1.99	4.78	12.92	21.51	1.37	N/S	N/S	8.47	0.43	0	4.07
Spotted wolffish	0	12.94	0	0	10.83	0	5.38	0	N/S	N/S	0	0	0	1.78
Redfish unseparated	0	11.76	0	0	0	5.06	1.08	1.92	N/S	N/S	0	0.29	0	1.62
Thorny skate	10.53	0	0	5.97	0	1.12	5.38	0	N/S	N/S	0	2.15	0	1.09
Winter skate	0	0	0	0	0	0	0	1.10	N/S	N/S	0	0	6.64	1.00
Barndoor skate	0	0	0	8.96	0	0	0	0	N/S	N/S	0	2.15	0	0.83
Cod (Atlantic)	0	0	0	0	0	0	0	0.27	N/S	N/S	0	1.72	0	0.32
Turbot, Greenland halibut	5.26	0	0	0	0	0	0	0	N/S	N/S	0	1.00	0	0.15
Snow crab (queen)	5.26	0	7.14	0	0	0	0	0	N/S	N/S	0	0	0	0.06

Table 18-8: Catch weight as a percentage of the annual total catch by species and year for the commercial index survey in the Gully. 'Overall' indicates the percentage of the total catch summed over the entire sampling period (1998 to 2010). The commercial index did not fish in the Gully from 1999 to 2001 and from 2005 to 2006 (indicated as NCI).

Species	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Overall
Halibut (Atlantic)	42.28	NCI	NCI	NCI	52.71	57.73	74.45	NCI	NCI	51.88	72.49	66.16	78.13	53.53
Cusk	29.14	NCI	NCI	NCI	21.79	37.92	3.66	NCI	NCI	36.88	15.36	21.04	2.99	23.53
White hake	16.34	NCI	NCI	NCI	8.59	4.09	7.84	NCI	NCI	11.25	3.39	0.08	3.13	10.71
Cod (Atlantic)	5.30	NCI	NCI	NCI	1.34	0	0.22	NCI	NCI	0	2.07	0.13	5.23	3.37
Black dogfish	2.49	NCI	NCI	NCI	4.57	0	0.26	NCI	NCI	0	2.41	2.39	0.48	2.28
Northern wolffish	0.87	NCI	NCI	NCI	5.50	0	3.45	NCI	NCI	0	2.84	5.39	0	2.16
Spotted wolffish	0.47	NCI	NCI	NCI	2.58	0	3.45	NCI	NCI	0	0	2.36	0	1.06
Thorny skate	1.01	NCI	NCI	NCI	0.21	0.18	3.23	NCI	NCI	0	1.44	0.46	0	0.97
Redfish unseparated	1.02	NCI	NCI	NCI	1.44	0	1.16	NCI	NCI	0	0	0.56	0.20	0.85
Barndoor skate	0	NCI	NCI	NCI	0	0	1.94	NCI	NCI	0	0	1.32	1.77	0.40
Winter skate	0	NCI	NCI	NCI	0	0	0	NCI	NCI	0	0	0	6.73	0.32
Spiny dogfish	0.42	NCI	NCI	NCI	0.52	0	0	NCI	NCI	0	0	0	0	0.27
Striped Atlantic wolffish	0.47	NCI	NCI	NCI	0	0	0	NCI	NCI	0	0	0	0	0.25
Turbot, Greenland halibut	0.07	NCI	NCI	NCI	0.76	0	0.34	NCI	NCI	0	0	0.13	0	0.15
Snow crab (queen)	0.06	NCI	NCI	NCI	0	0	0	NCI	NCI	0	0	0	0.61	0.06
Haddock	0.06	NCI	NCI	NCI	0	0.09	0	NCI	NCI	0	0	0	0.20	0.04
Monkfish, goosefish, angler	0	NCI	NCI	NCI	0	0	0	NCI	NCI	0	0	0	0.54	0.03

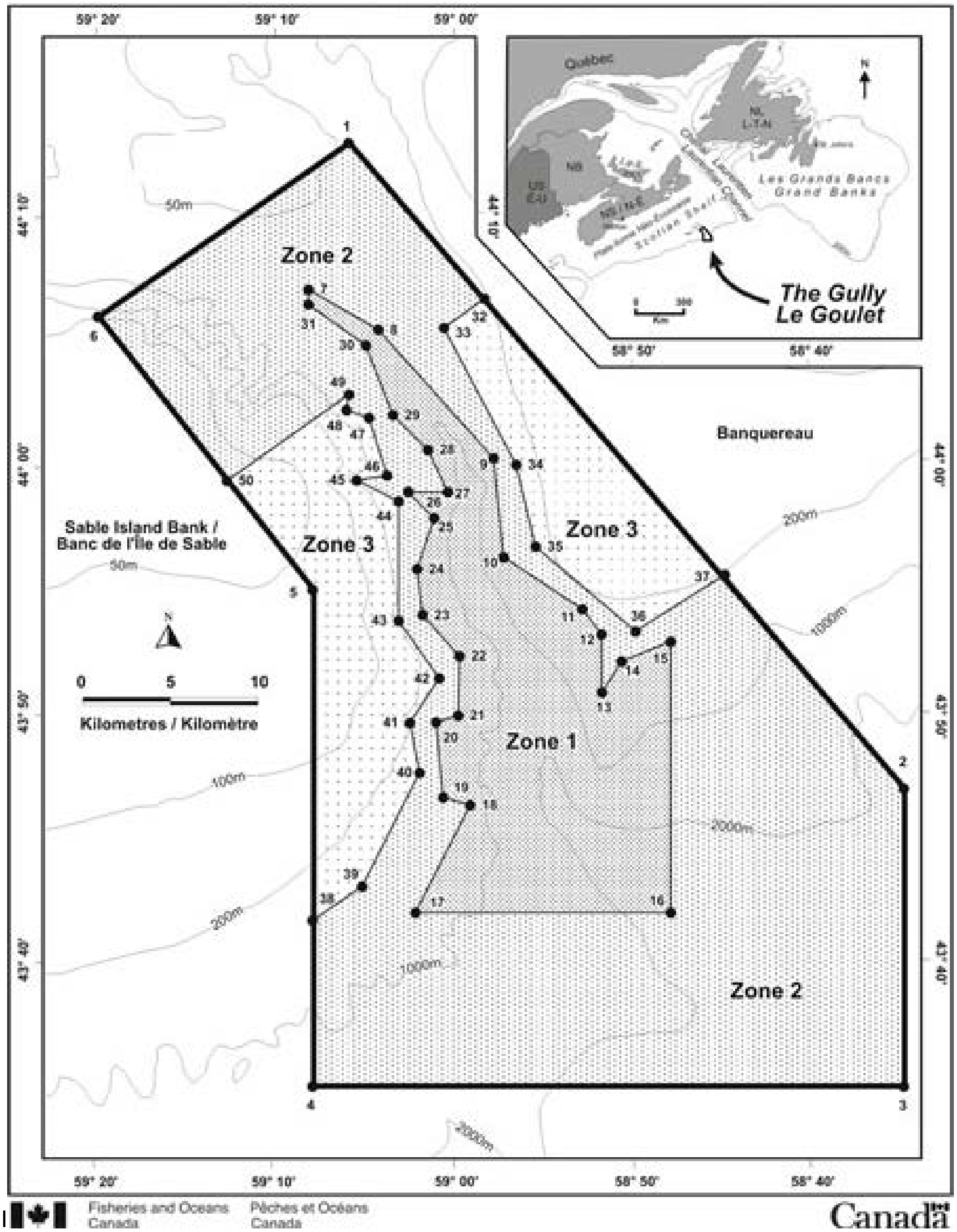


Figure 18-1: Zones of the Gully MPA (DFO 2008).

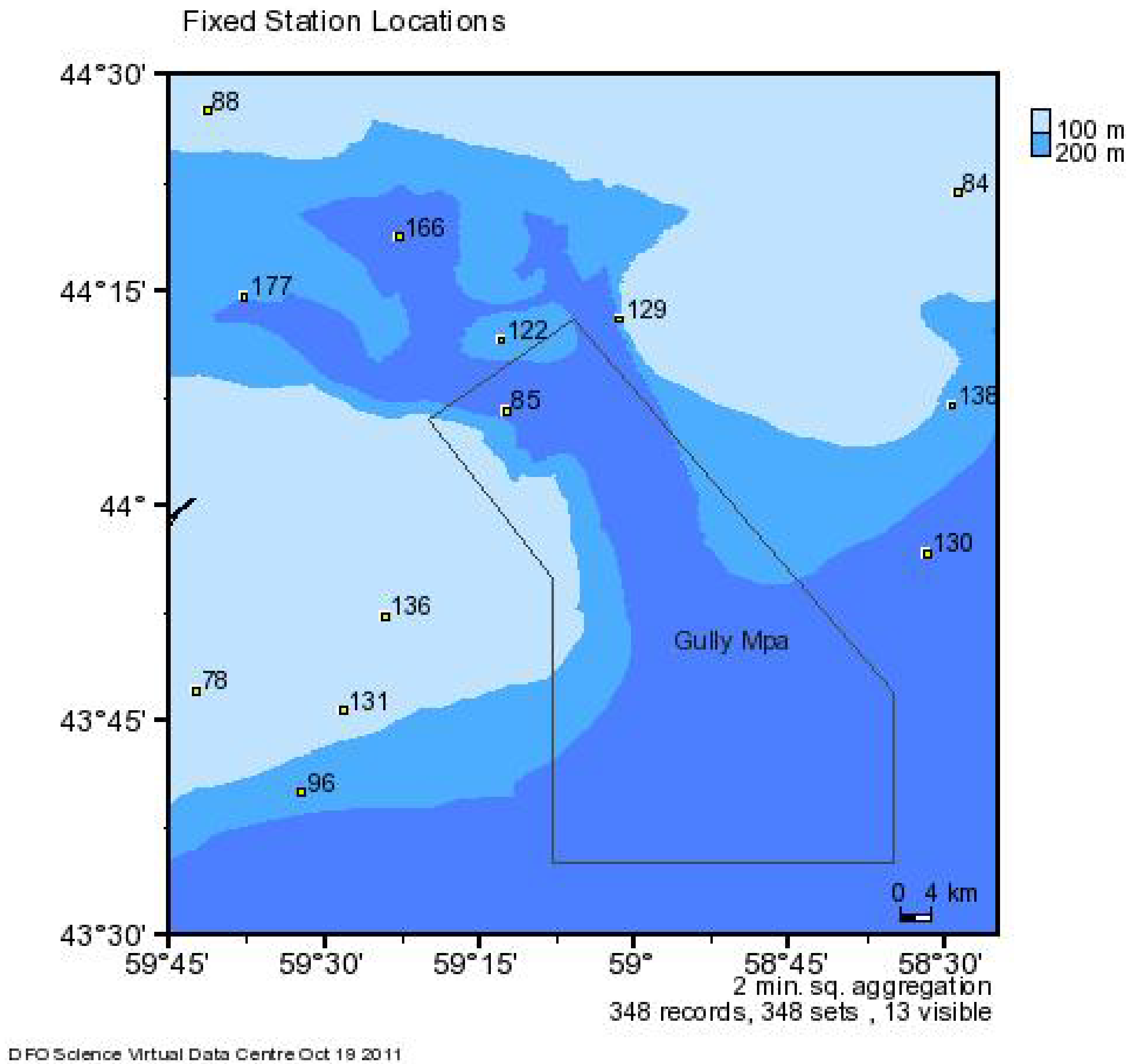


Figure 18-2: Industry/DFO longline halibut survey (the 'halibut survey') fixed-station locations in the Gully MPA and surrounding areas. Station 85 was the only station included in the analysis.

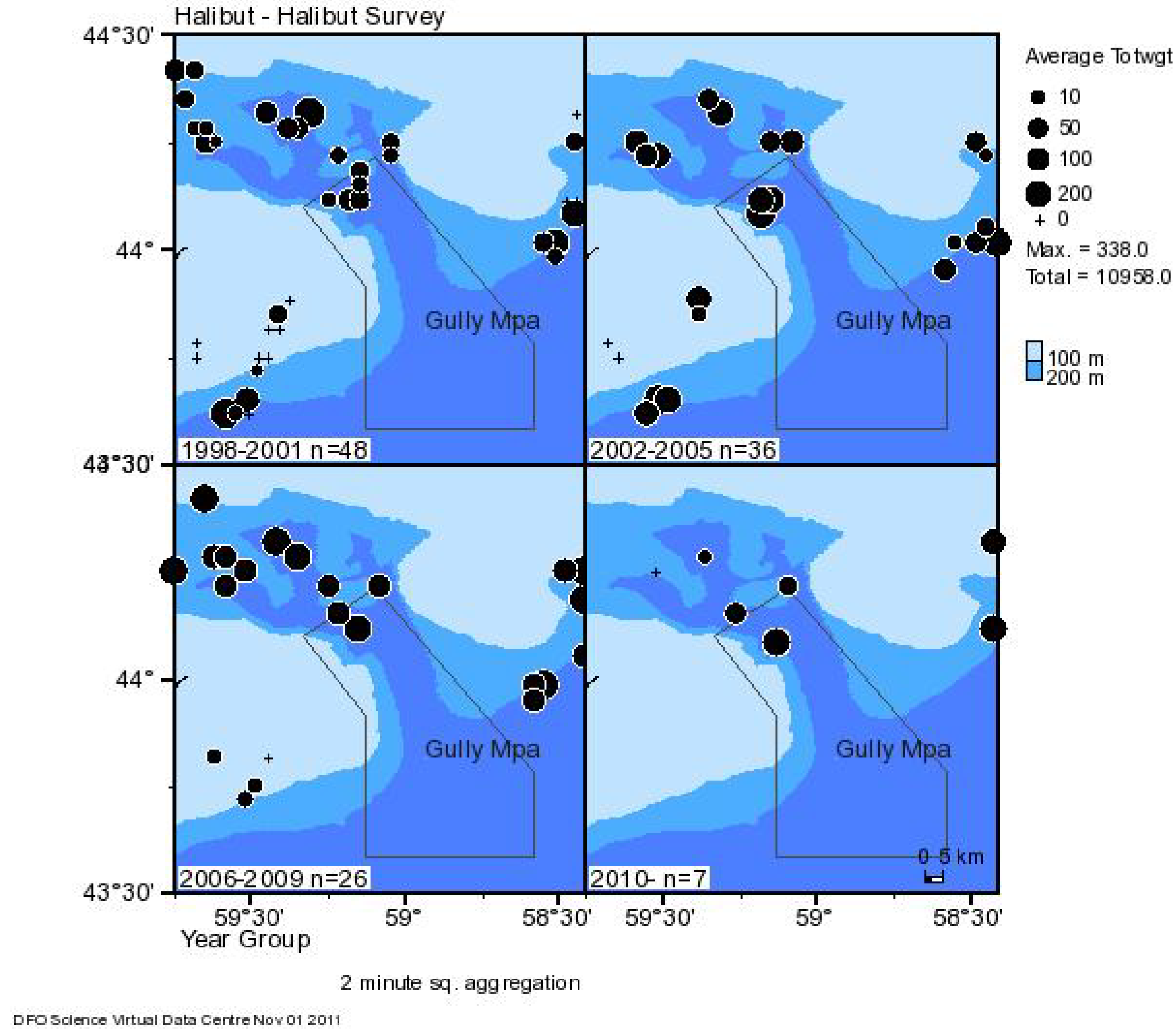


Figure 18-3: Catch distribution of Atlantic halibut (total weight in kg) caught from 1998 to 2010 in the halibut survey. The map boundaries include areas surrounding the Gully MPA, which were not included in the analysis (n= number of sets within the Gully MPA).

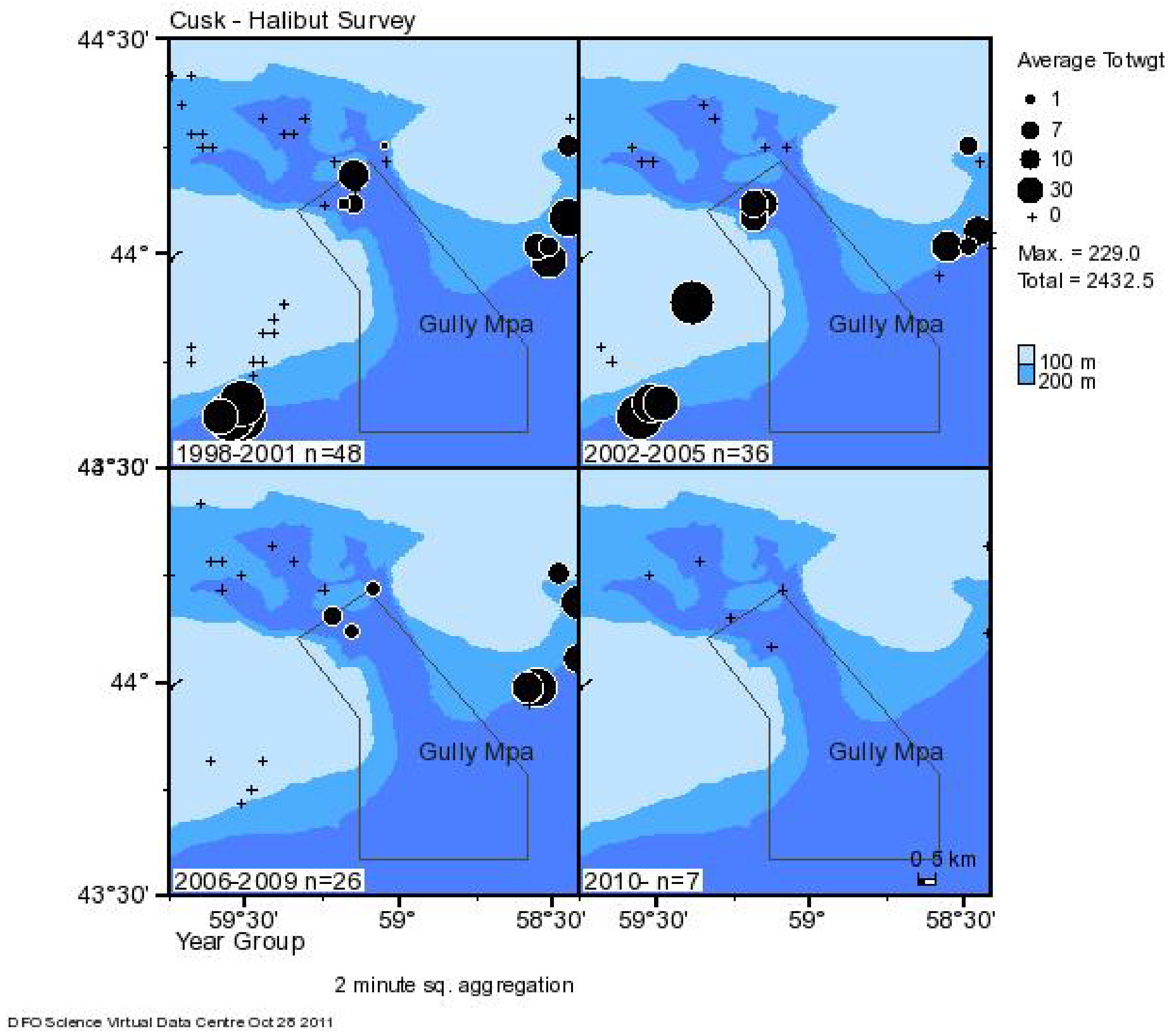


Figure 18-4: Catch distribution of cusk (total weight in kg) caught from 1998 to 2010 in the halibut survey. The map boundaries include areas surrounding the Gully MPA, which were not included in the analysis (n= number of sets within the Gully MPA).

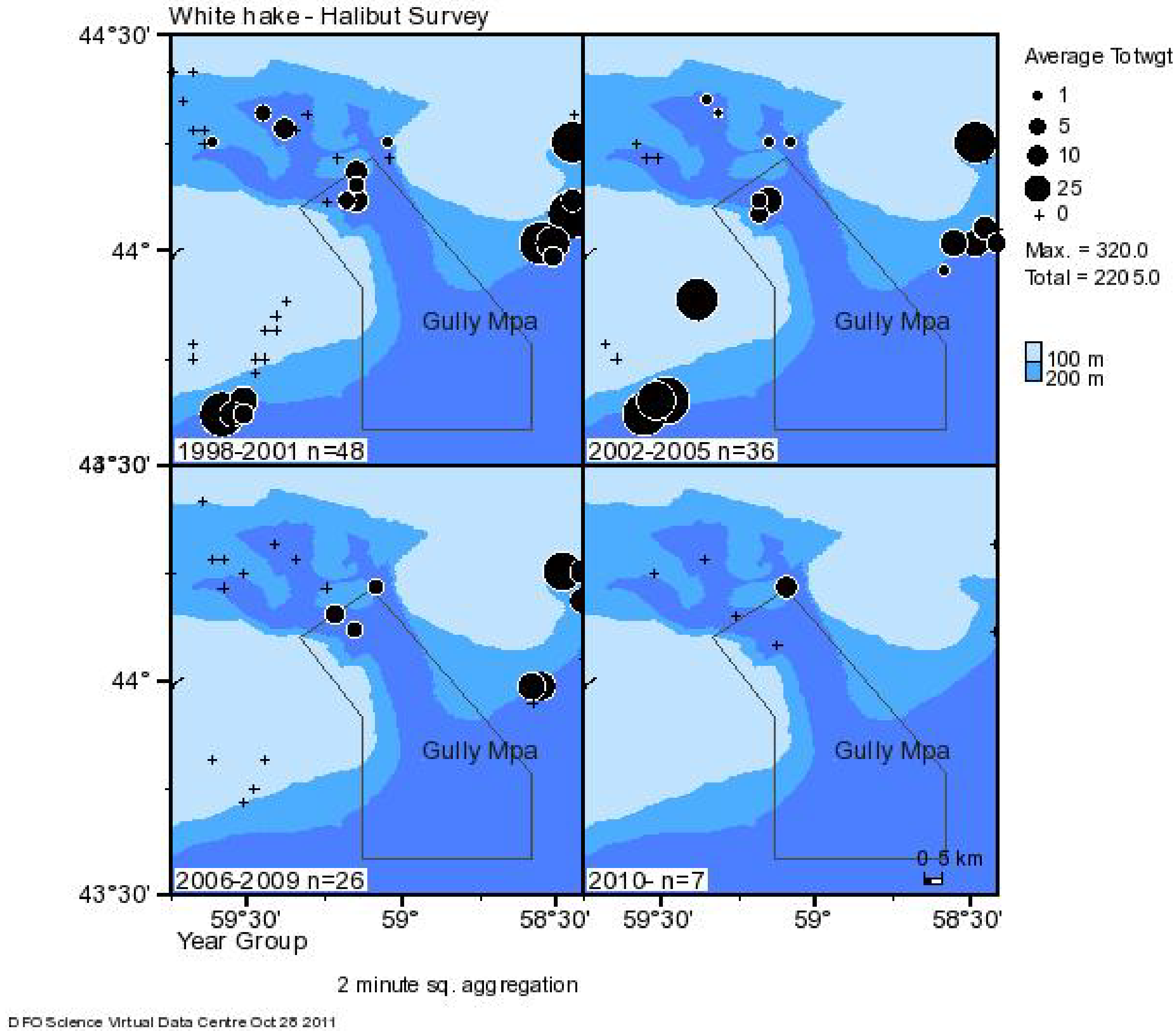


Figure 18-5: Catch distribution of white hake (total weight in kg) caught from 1998 to 2010 in the halibut survey. The map boundaries include areas surrounding the Gully MPA, which were not included in the analysis (n= number of sets within the Gully MPA).

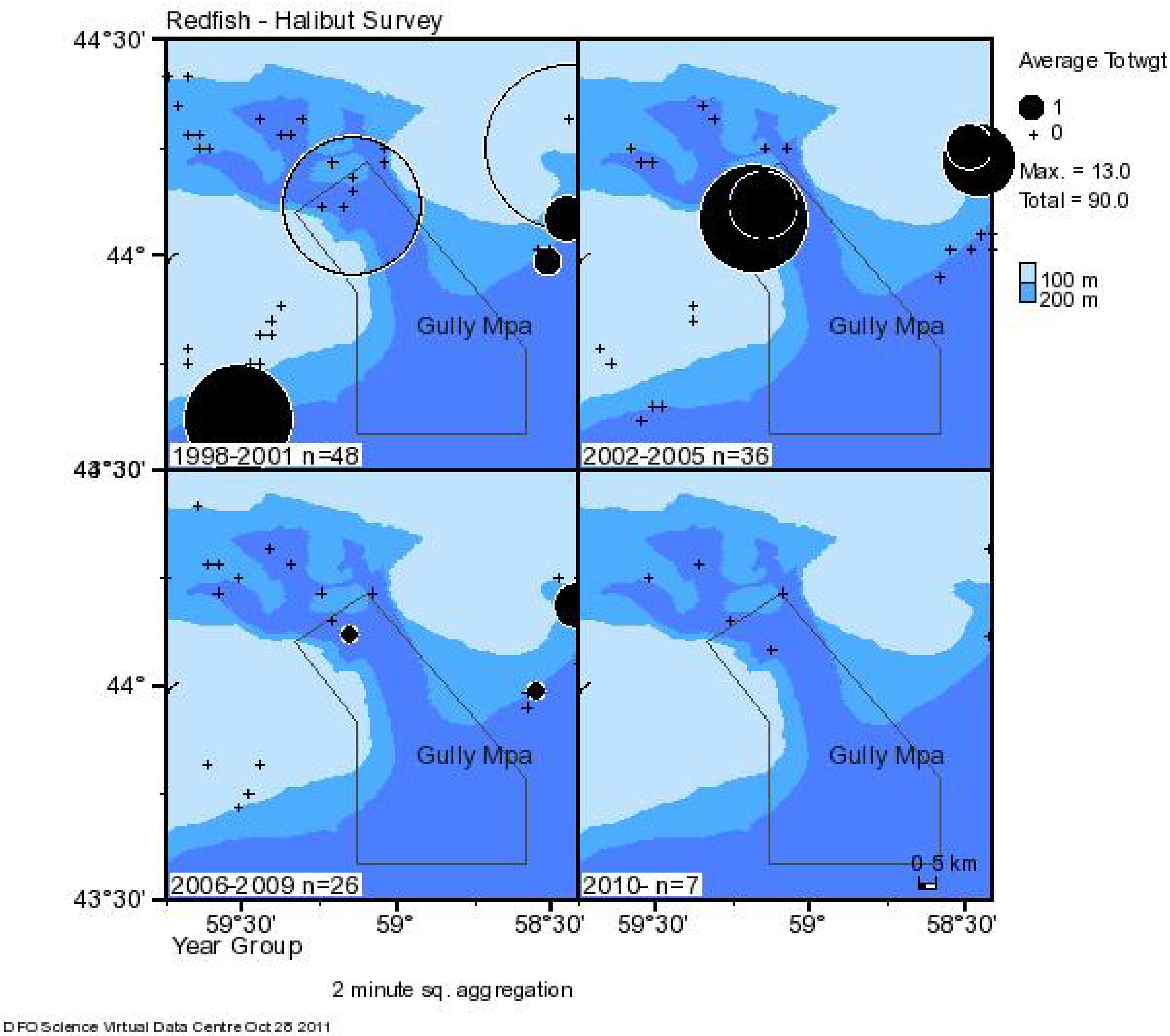


Figure 18-6: Catch distribution of redfish (unseparated) (total weight in kg) caught from 1998 to 2010 in the halibut survey. The map boundaries include areas surrounding the Gully MPA, which were not included in the analysis (n= number of sets within the Gully MPA).

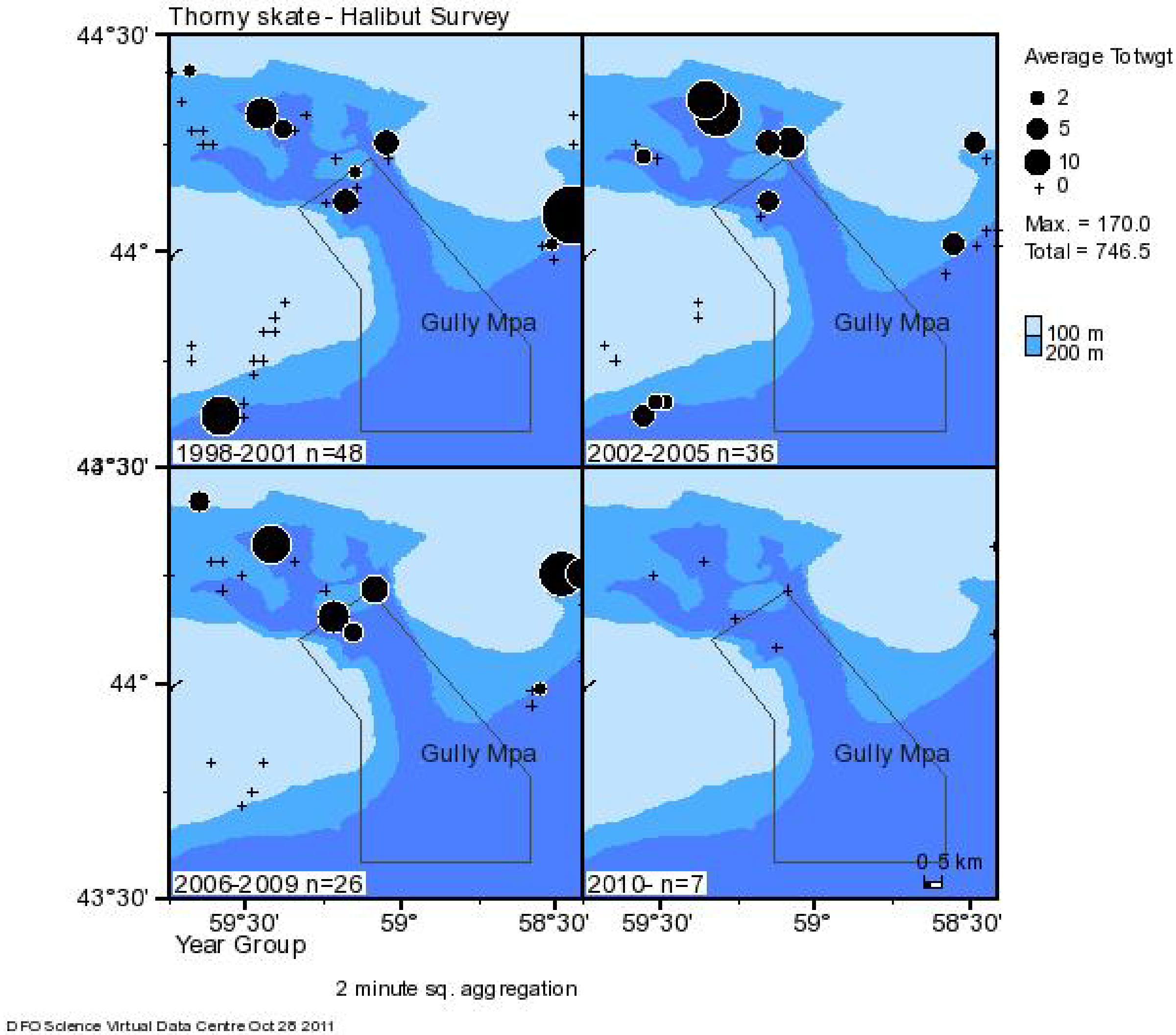


Figure 18-7: Catch distribution of thorny skate (total weight in kg) caught from 1998 to 2010 in the halibut survey. The map boundaries include areas surrounding the Gully MPA, which were not included in the analysis (n= number of sets within the Gully MPA).

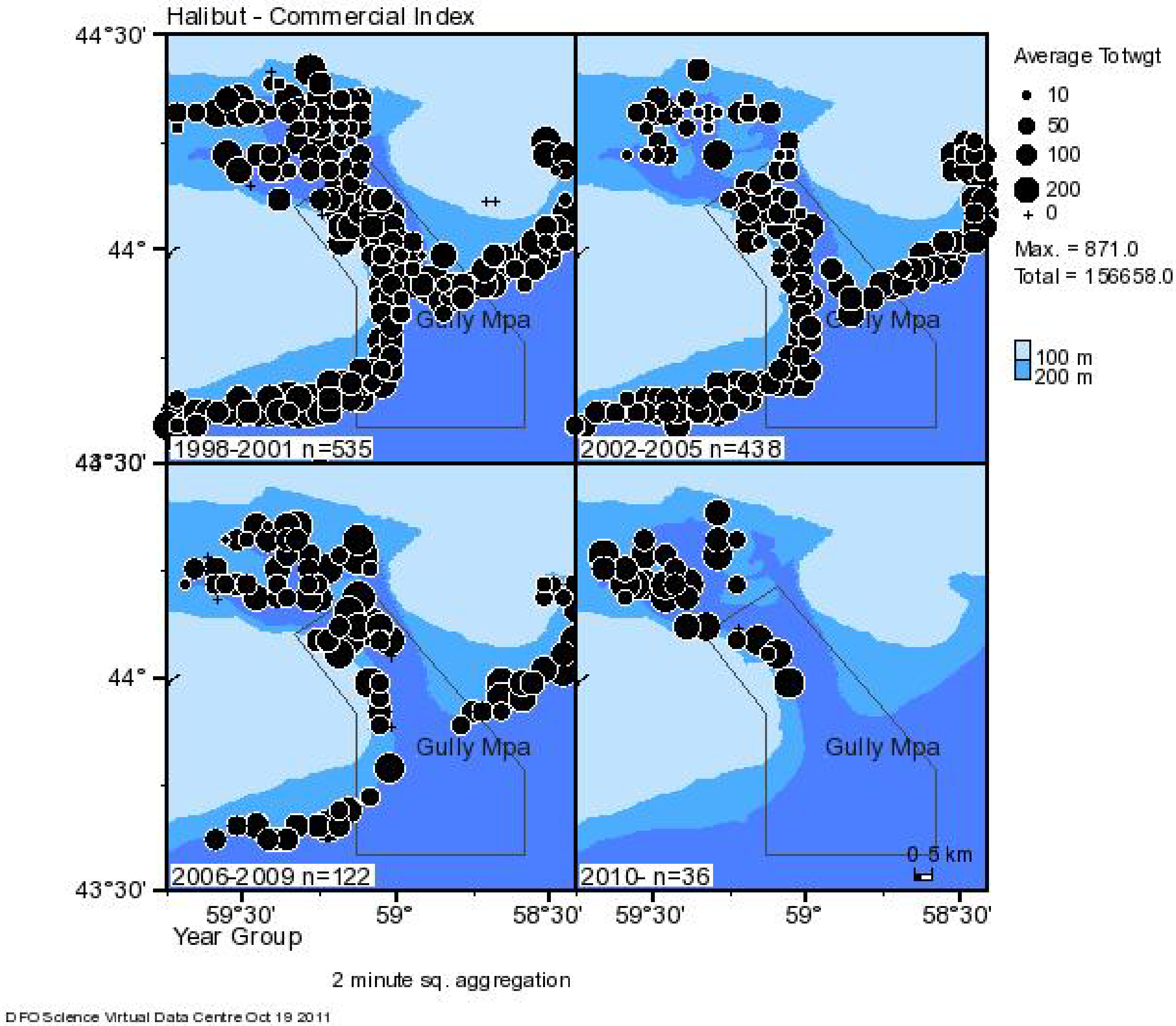


Figure 18-8: Catch distribution of Atlantic halibut (total weight in kg) caught from 1998 to 2010 in the commercial index. The map boundaries include areas surrounding the Gully MPA, which were not included in the analysis (n= number of sets within the Gully MPA).

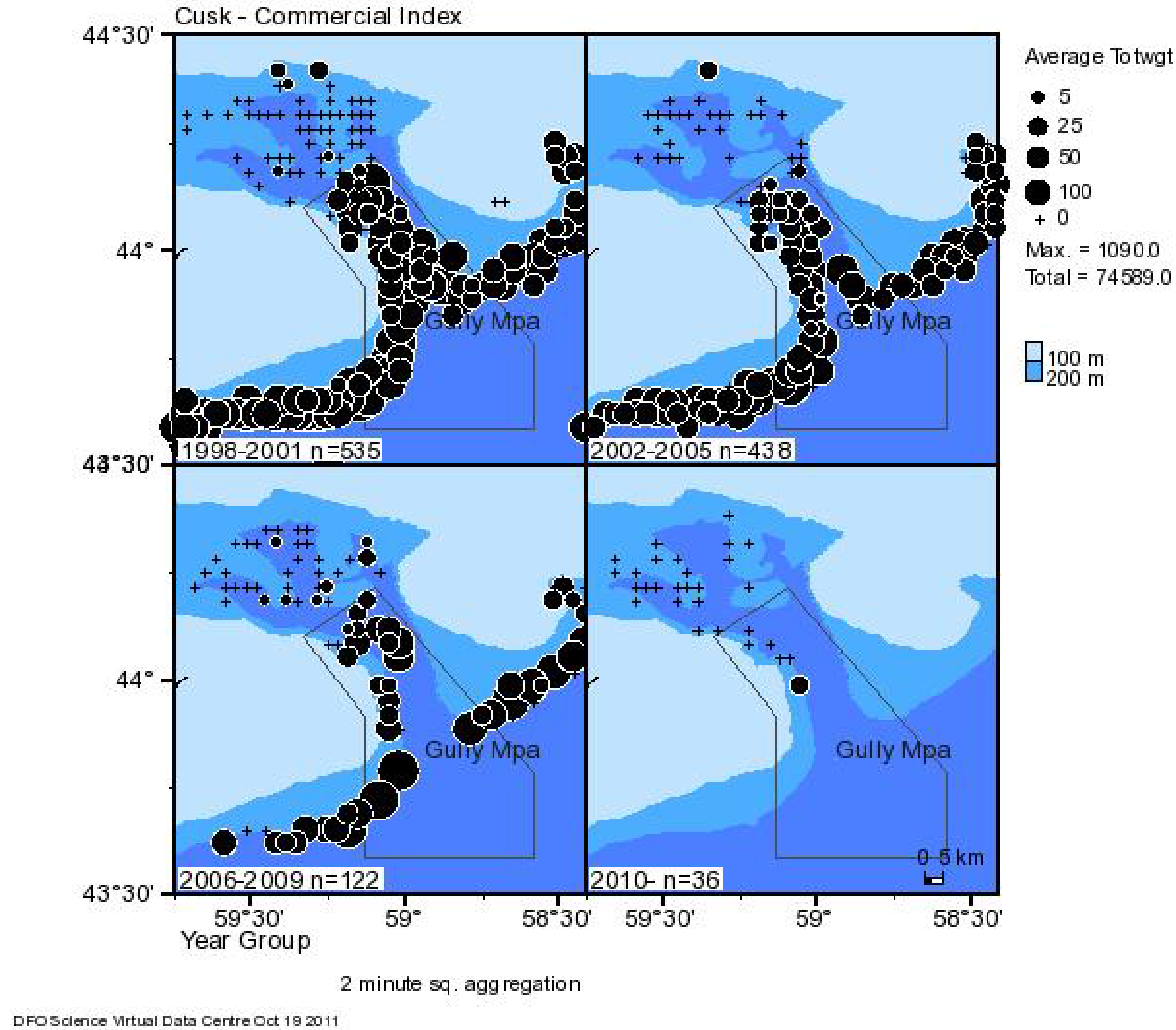


Figure 18-9: Catch distribution of cusk (total weight in kg) caught from 1998 to 2010 in the commercial index. The map boundaries include areas surrounding the Gully MPA, which were not included in the analysis (n= number of sets within the Gully MPA).

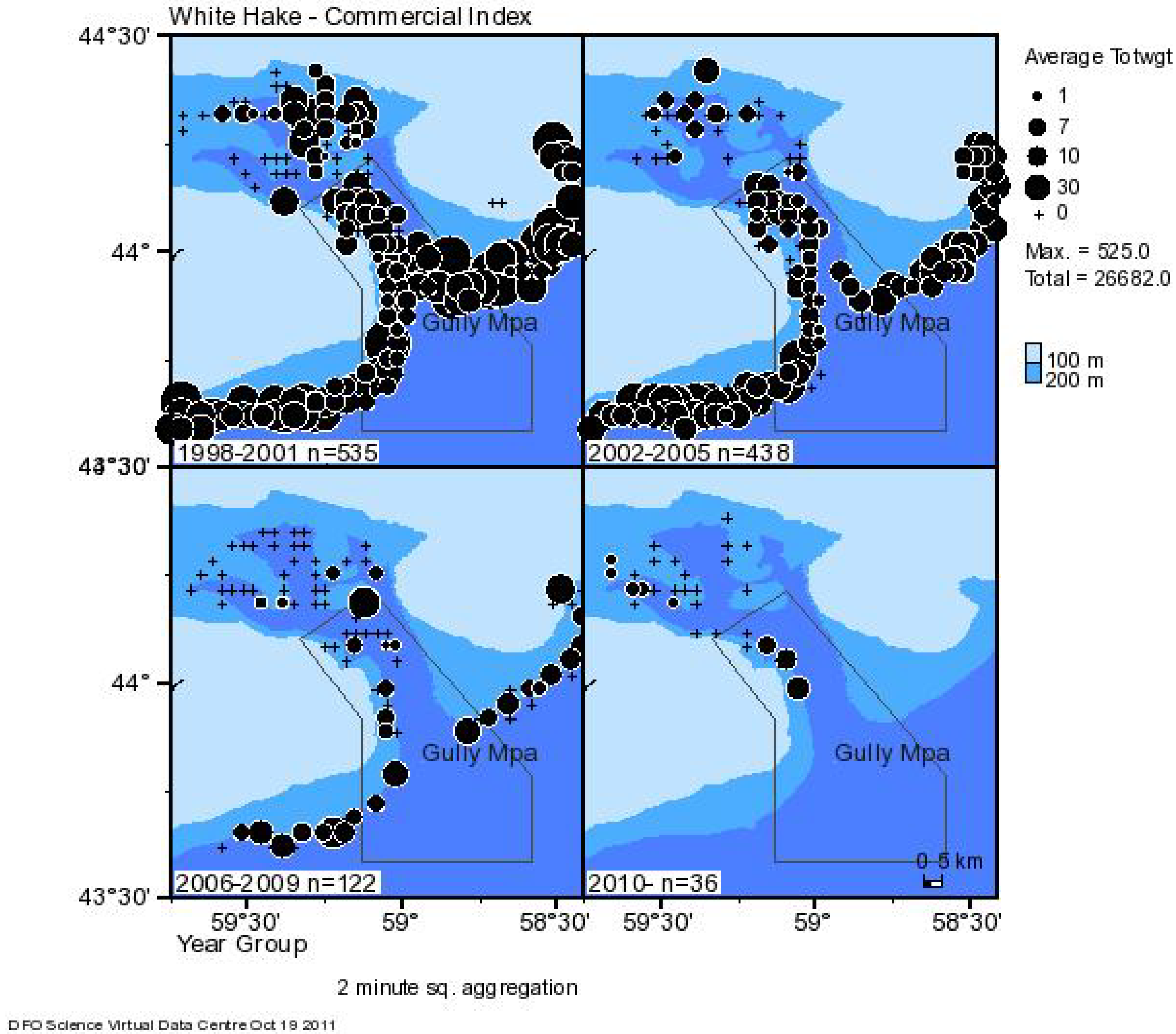


Figure 18-10: Catch distribution of white hake (total weight in kg) caught from 1998 to 2010 in the commercial index. The map boundaries include areas surrounding the Gully MPA, which were not included in the analysis (n= number of sets within the Gully MPA).

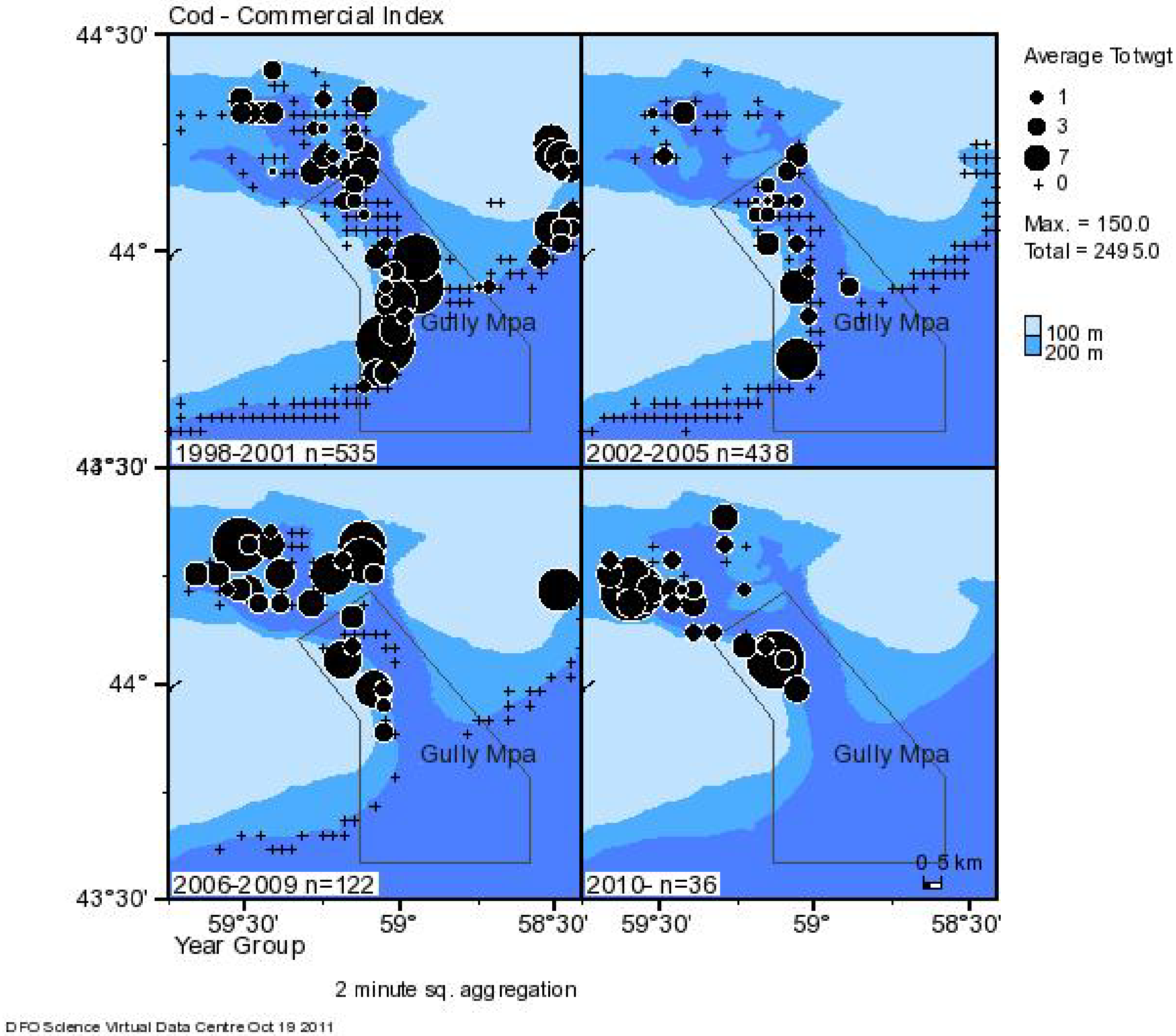


Figure 18-11: Catch distribution of Atlantic cod (total weight in kg) caught from 1998 to 2010 in the commercial index. The map boundaries include areas surrounding the Gully MPA, which were not included in the analysis (n= number of sets within the Gully MPA).

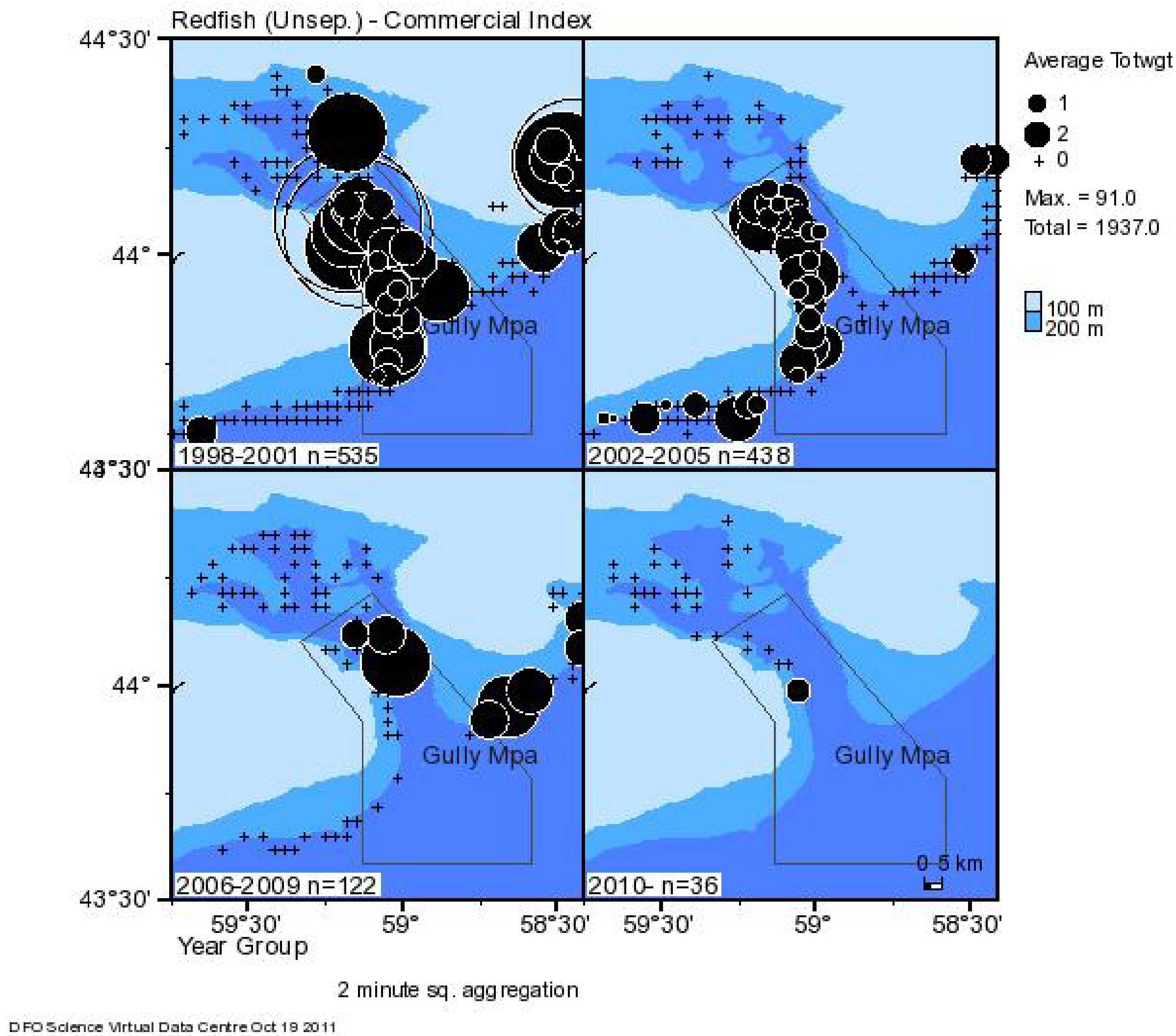


Figure 18-12: Catch distribution of redfish (unseparated) (total weight in kg) caught from 1998 to 2010 in the commercial index. The map boundaries include areas surrounding the Gully MPA, which were not included in the analysis (n= number of sets within the Gully MPA).

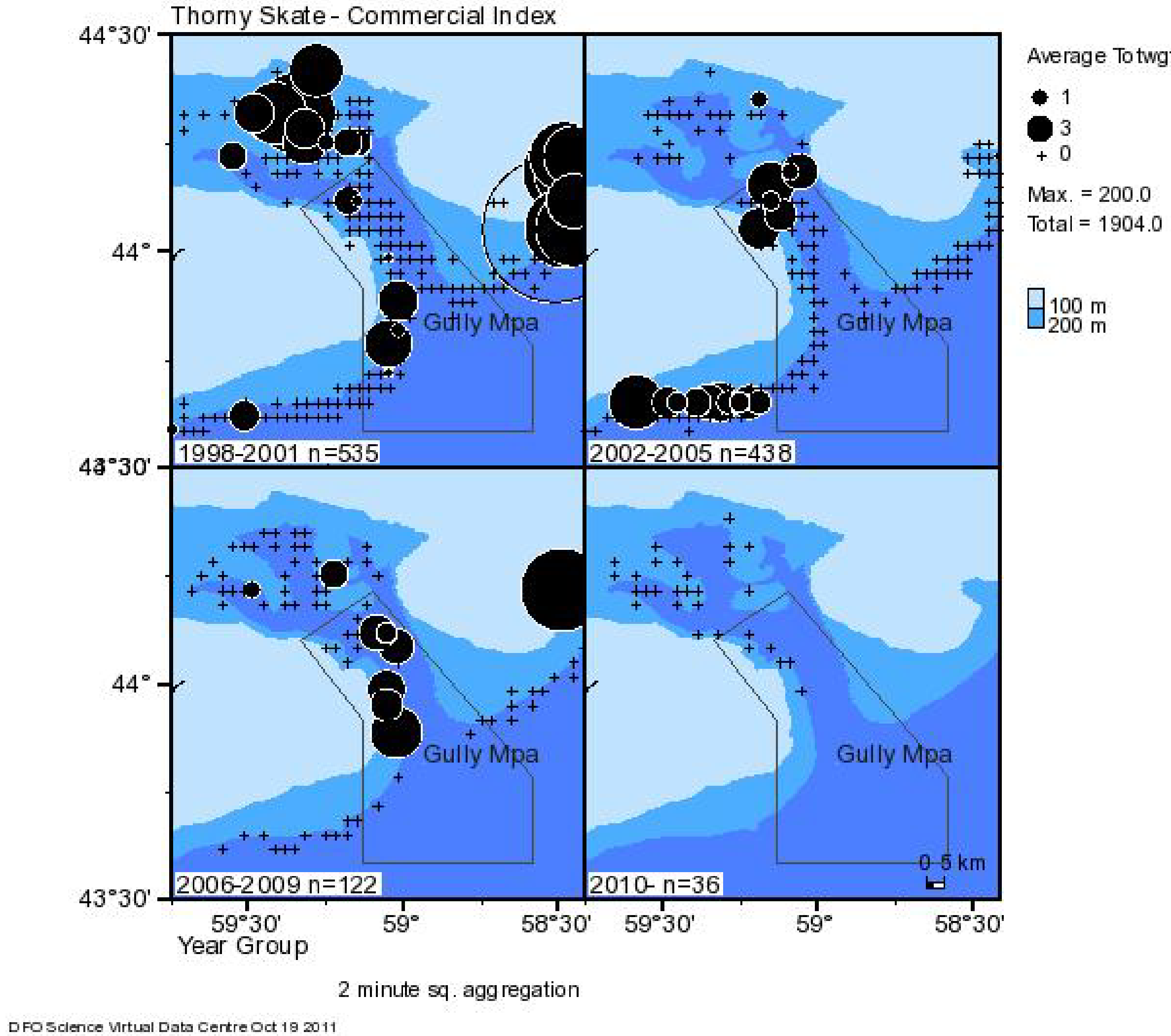


Figure 18-13: Catch distribution of thorny skate (total weight in kg) caught from 1998 to 2010 in the commercial index. The map boundaries include areas surrounding the Gully MPA, which were not included in the analysis (n= number of sets within the Gully MPA).

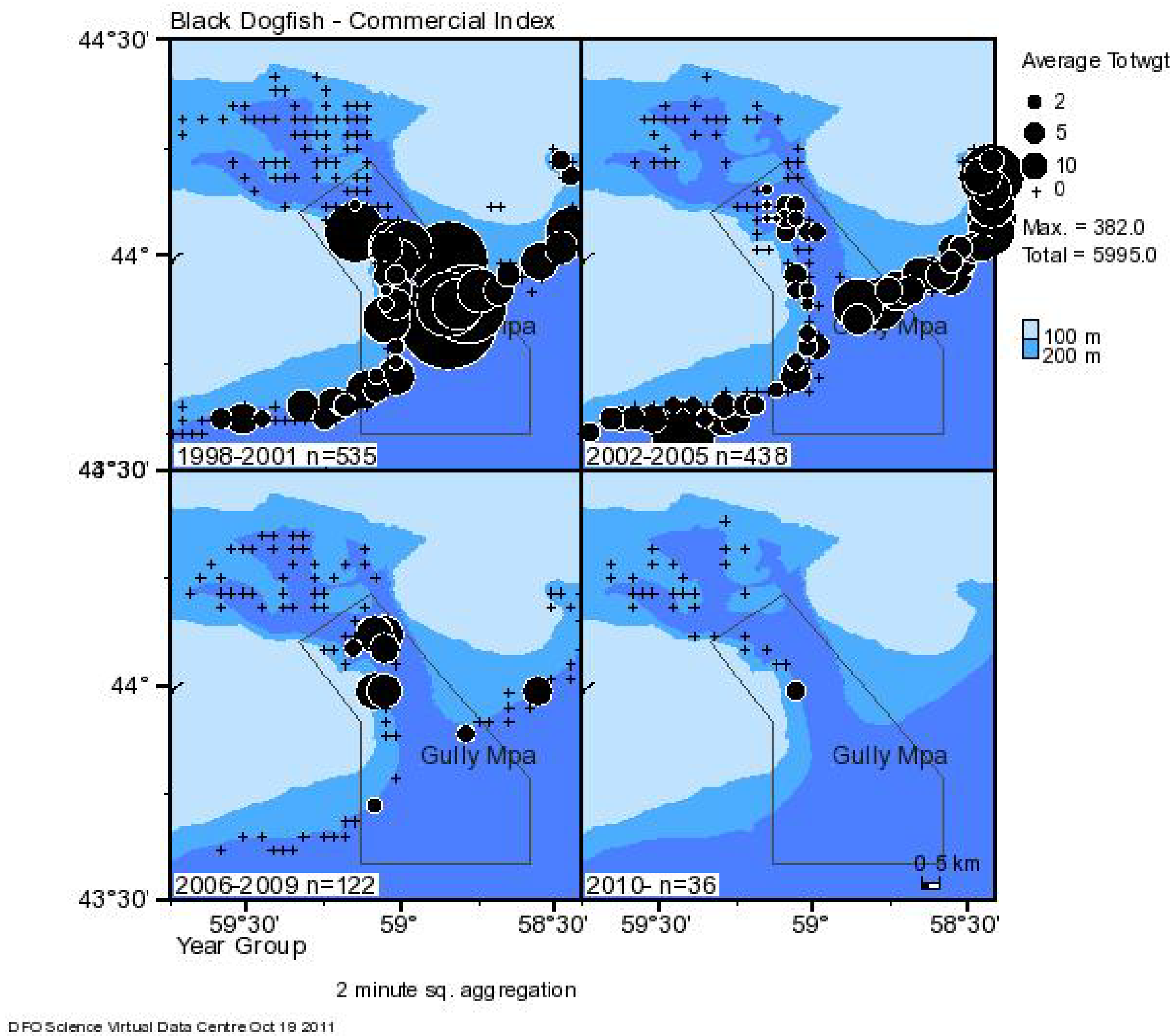


Figure 18-14: Catch distribution of black dogfish (total weight in kg) caught from 1998 to 2010 in the commercial index. The map boundaries include areas surrounding the Gully MPA, which were not included in the analysis (n= number of sets within the Gully MPA).

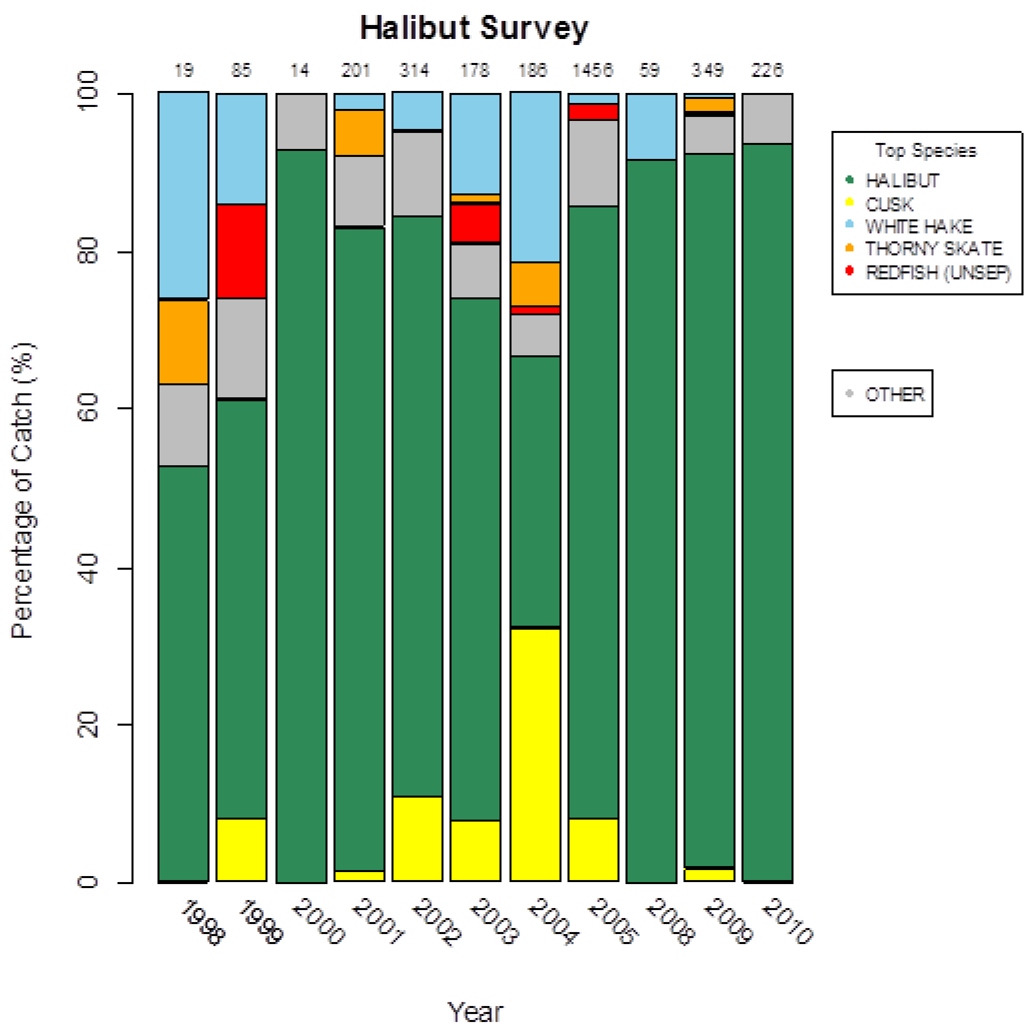


Figure 18-15: Percent of Atlantic halibut and bycatch species caught in the halibut survey (Station 85) from 1998 to 2010 in the Gully. The numbers above the bars indicate the total catch weights (kg). 'Top species' were caught in five or more years. For a complete species list see Table 18-7.

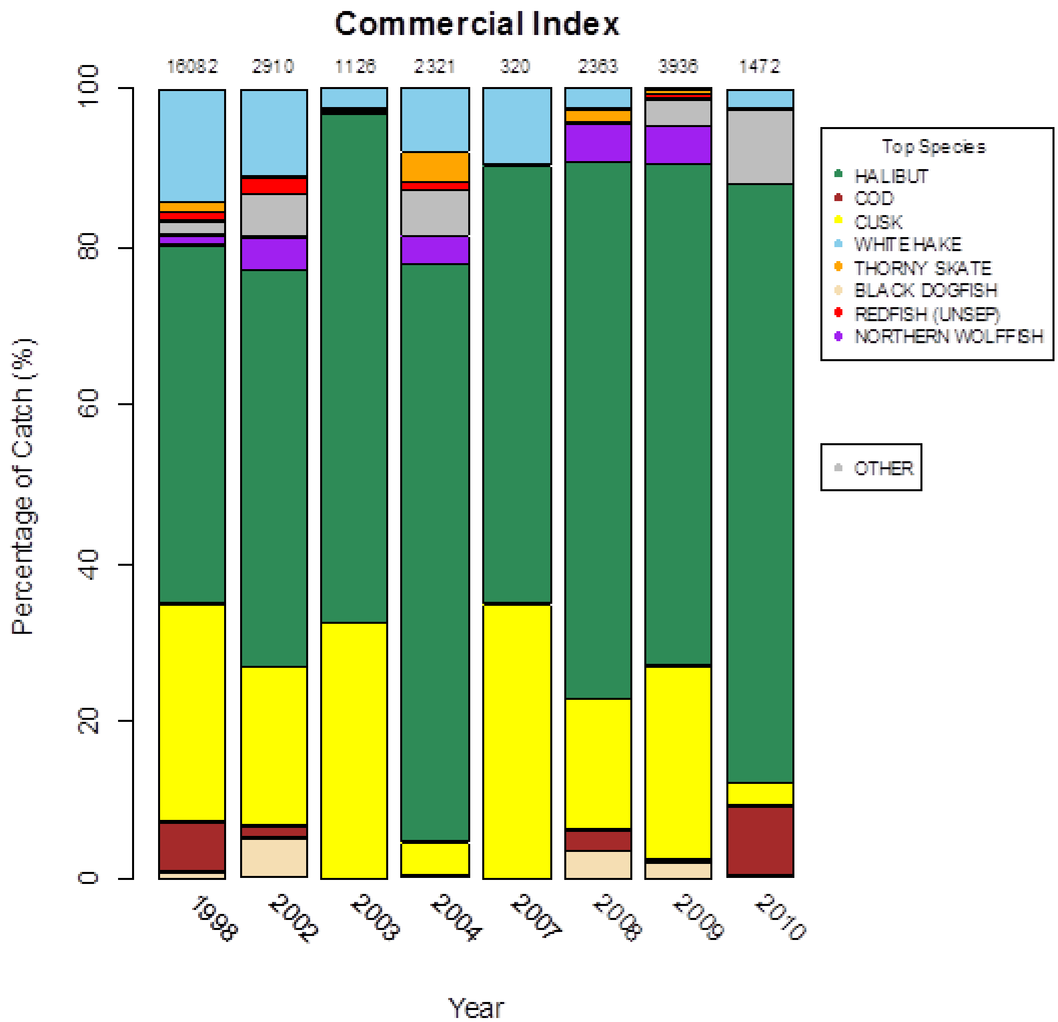


Figure 18-16: Percent of Atlantic halibut and bycatch species caught in the commercial index from 1998 to 2010 in the Gully. The numbers above the bars indicate the total catch weights (kg). 'Top species' were caught in five or more years. For a complete species list see Table 18-8.

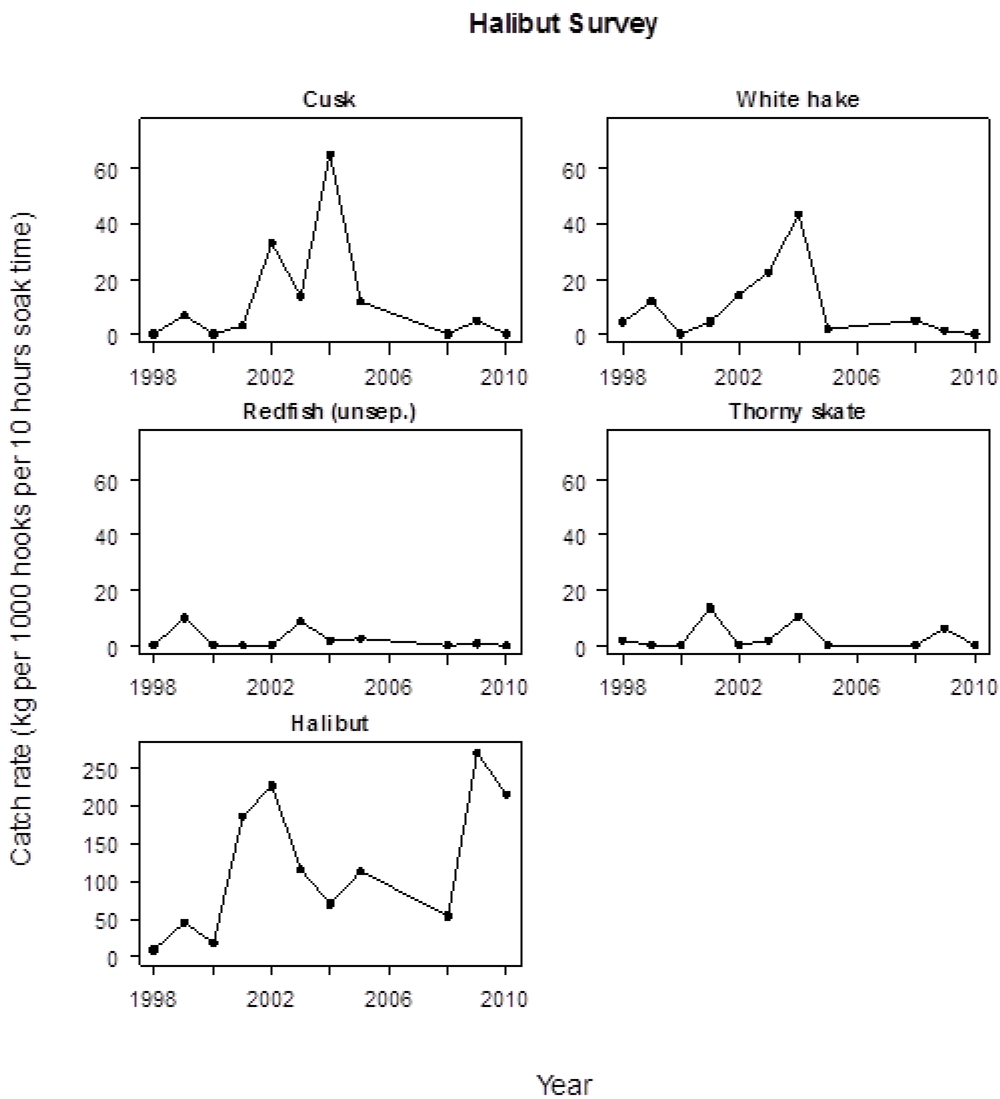


Figure 18-17: Annual catch rate (kg per 1000 hooks per 10 hours soak time) of halibut, cusk, white hake, and redfish for the halibut survey in the Gully. Note the difference in scale. No error bars are calculated because catch rate was calculated for only one fixed station (Station 85).

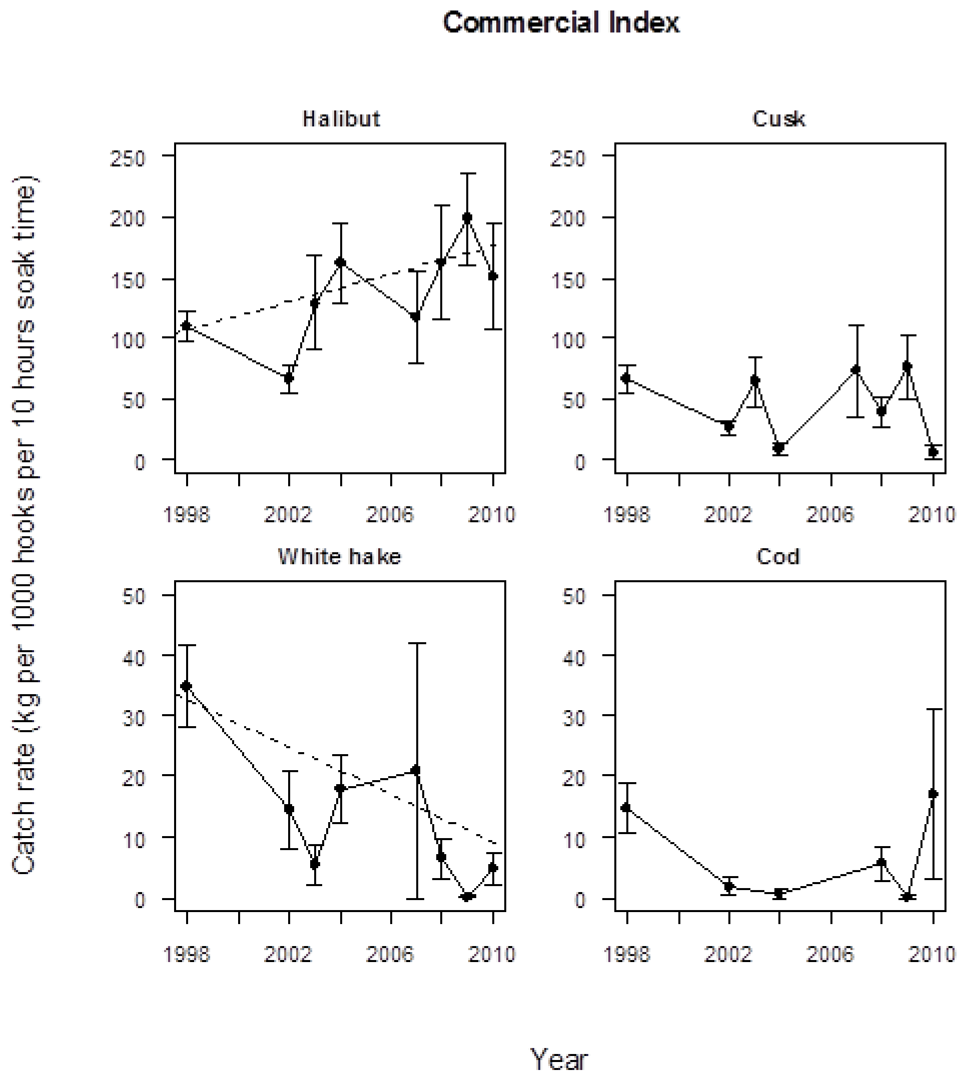


Figure 18-18: Annual catch rate (kg per 1000 hooks per 10 hours soak time) of Atlantic halibut, cusk, white hake, and Atlantic cod for the commercial index in the Gully (± 1SE). Note the difference in scale. Dotted lines indicate significance.

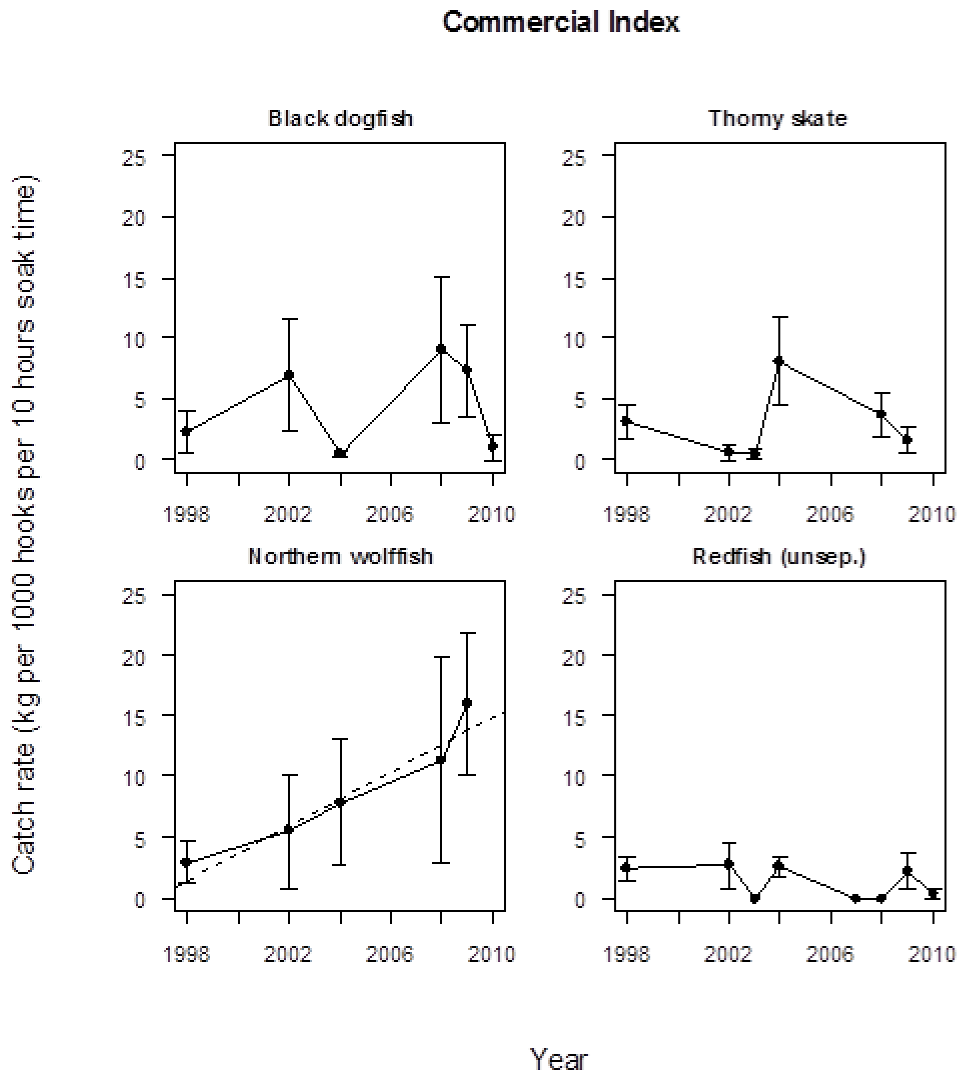


Figure 18-19: Annual catch rate (kg per 1000 hooks per 10 hours soak time) of black dogfish, thorny skate, northern wolffish, and redfish for the commercial index in the Gully (± 1SE). The dotted line indicates significance.

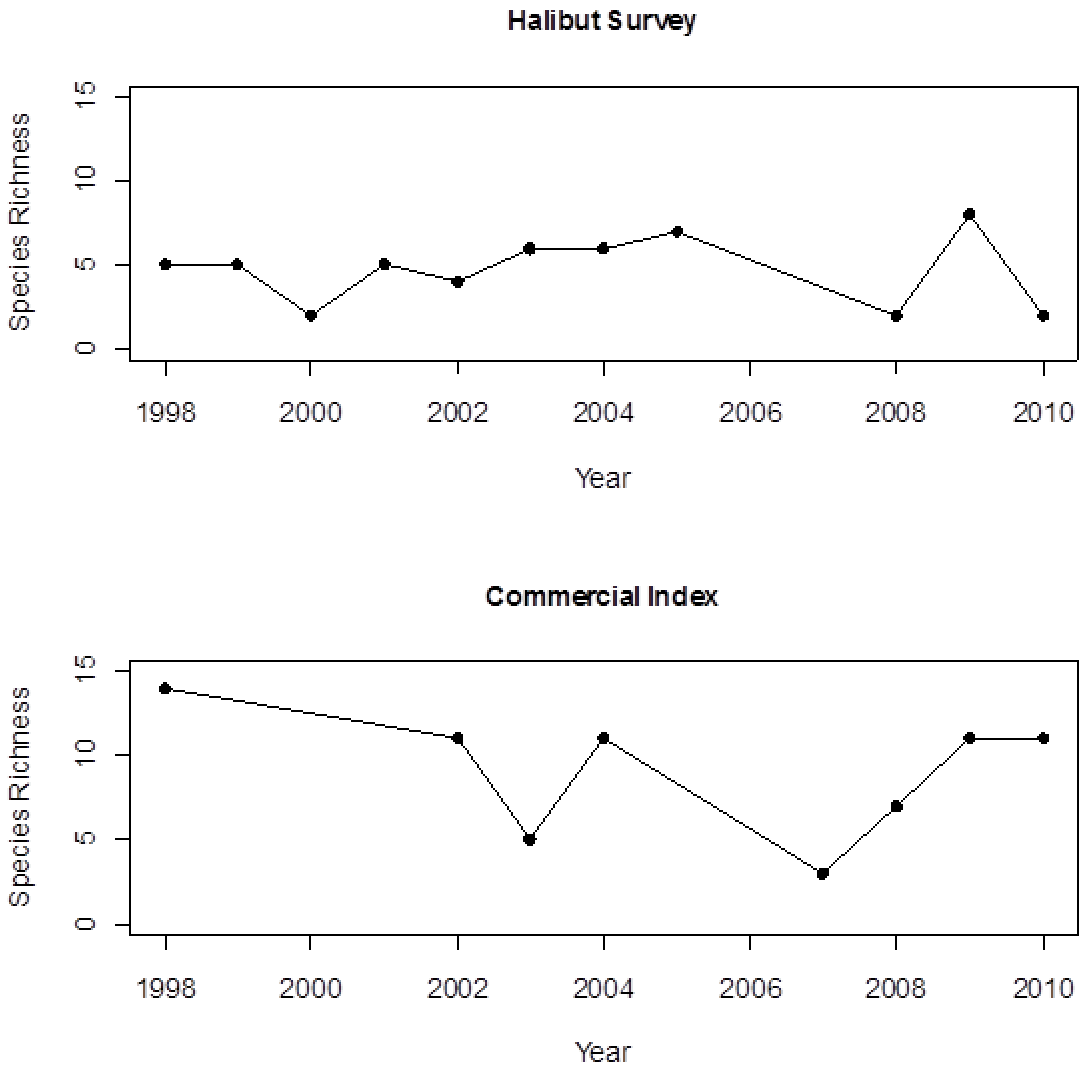


Figure 18-20: Species richness by year for the halibut survey and commercial index in the Gully. Note that the Gully was not surveyed in all years.

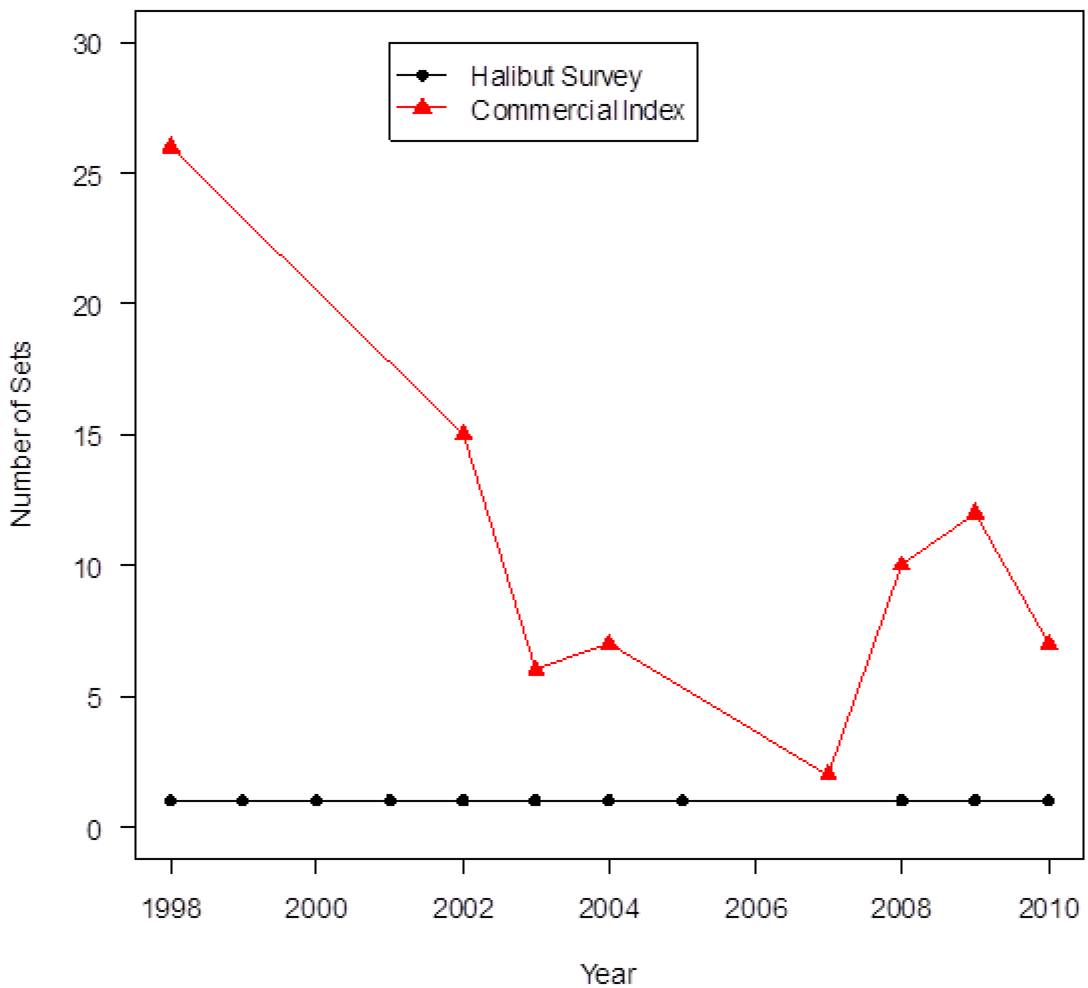


Figure 18-21: Number of sets for the halibut survey and commercial index in the Gully from 1998 to 2010.

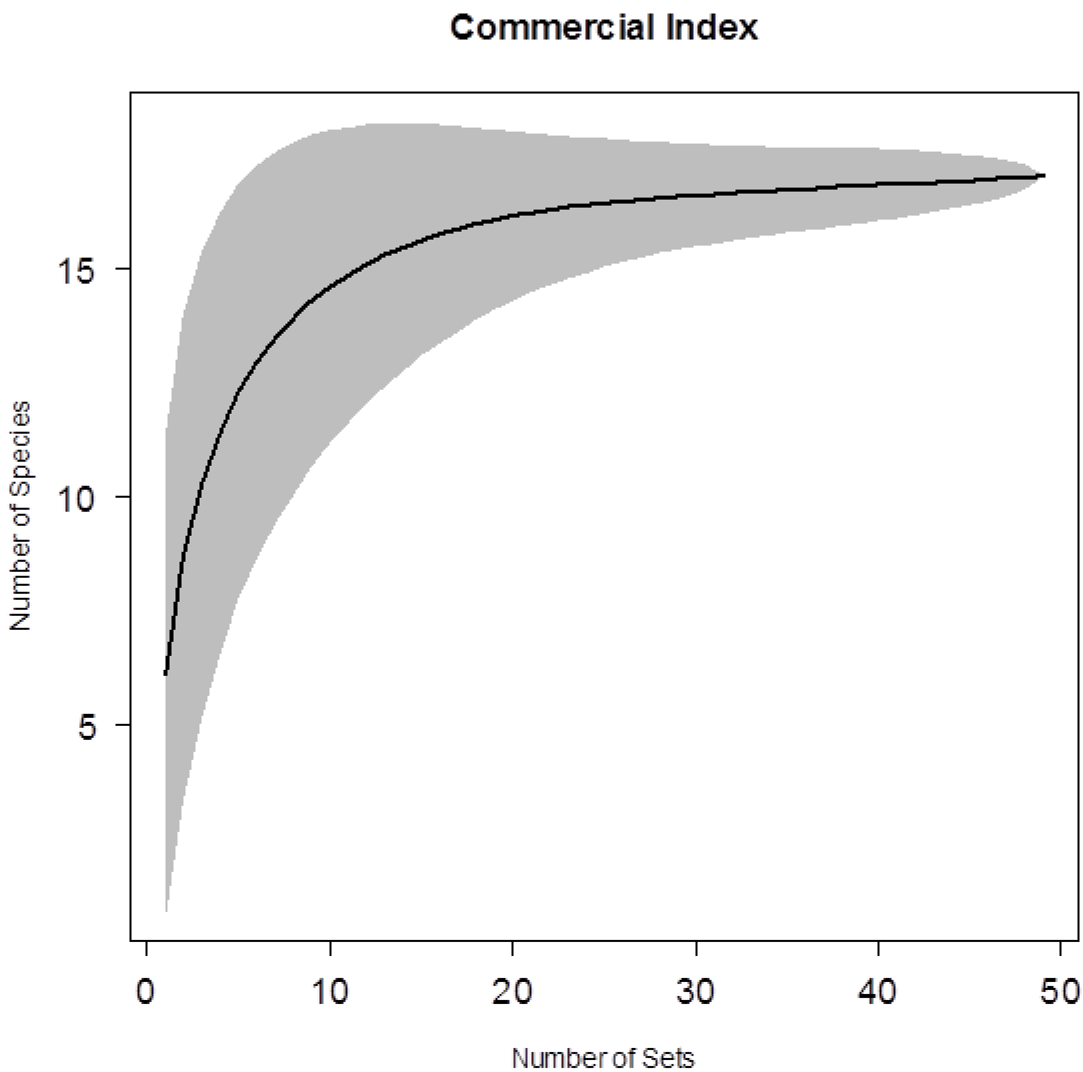


Figure 18-22: Species accumulation curve for the commercial index for all years in the Gully.

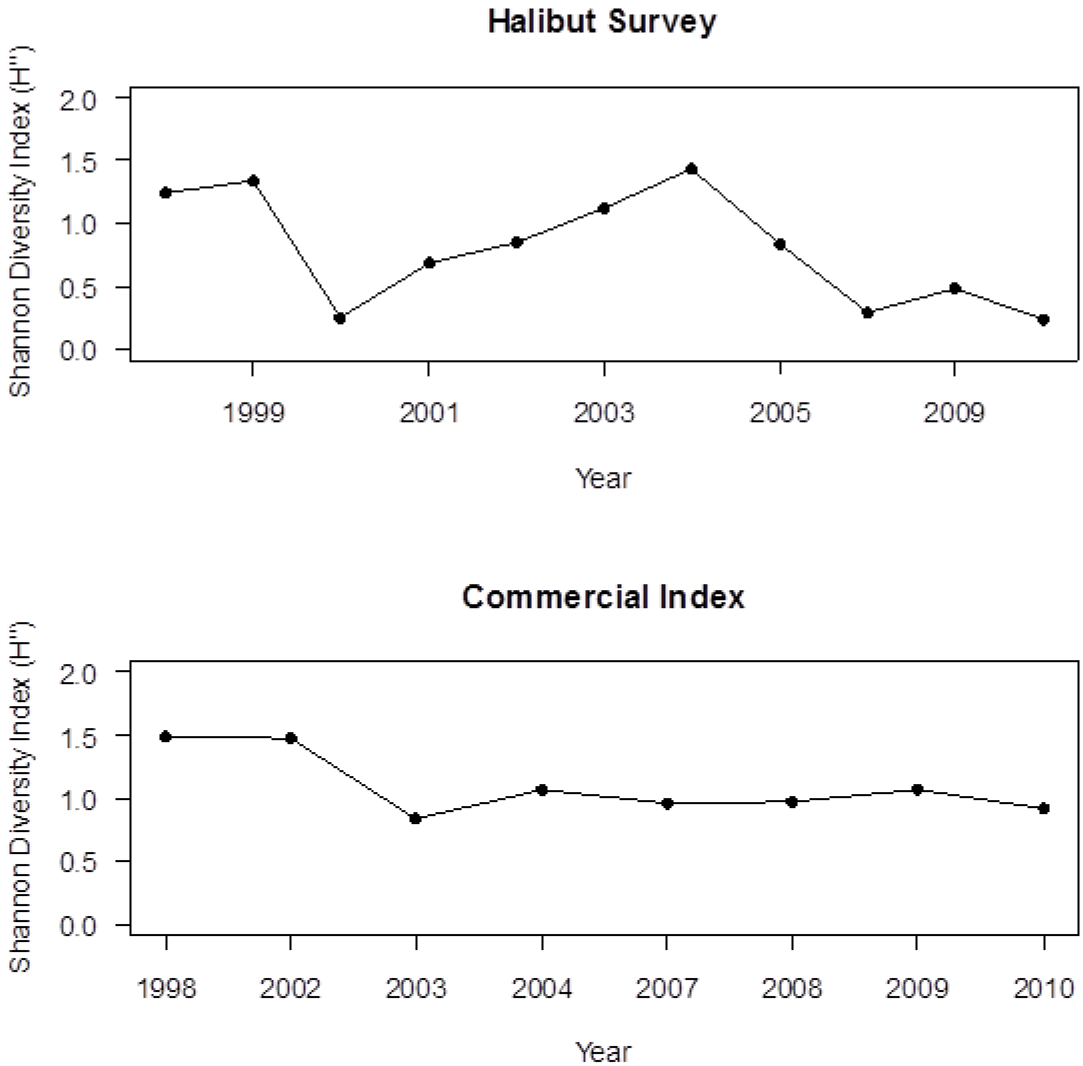


Figure 18-23: Species diversity (H”) by year for the halibut survey and commercial index in the Gully. Note that the Gully was not surveyed in all years.

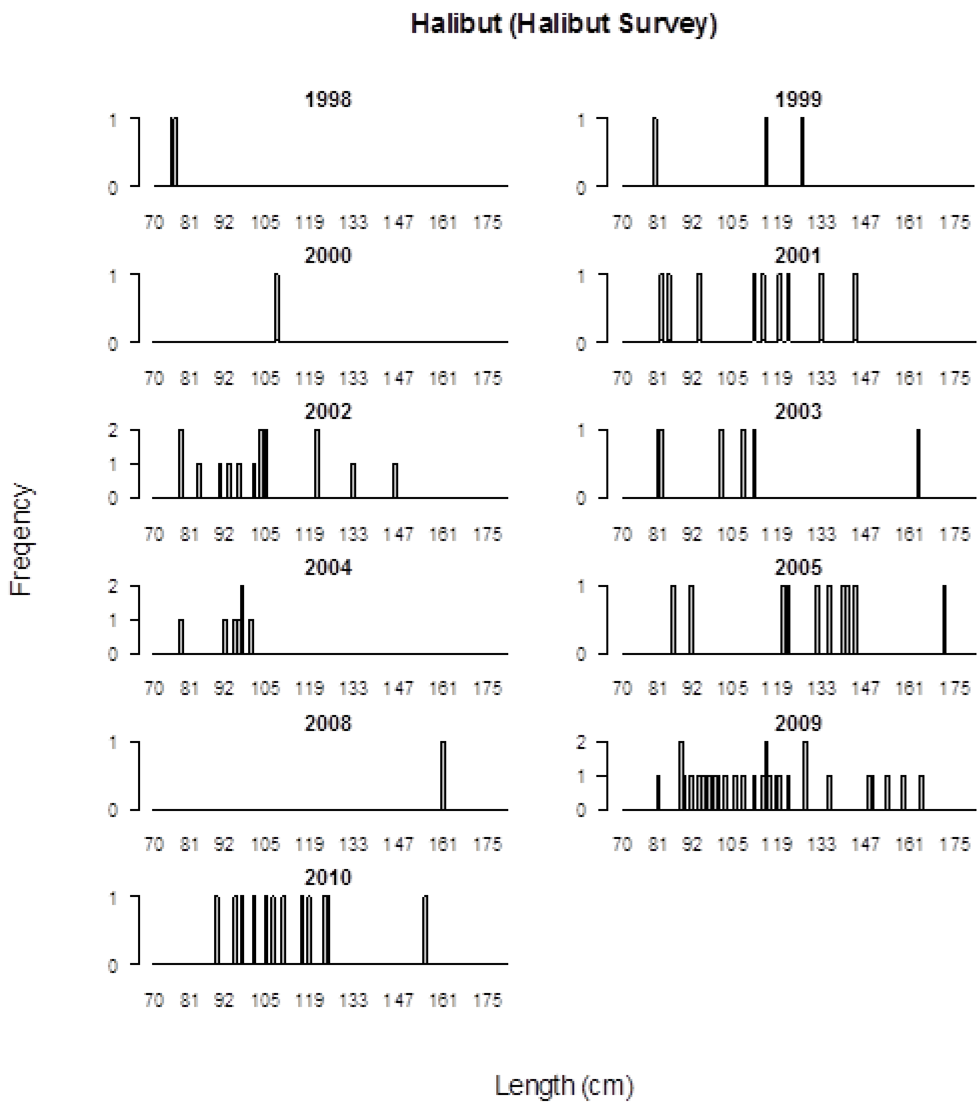


Figure 18-24: Length-frequency plots for Atlantic halibut caught in the halibut survey from 1998 to 2010 in the Gully. The Gully was not surveyed from 2006 to 2007.

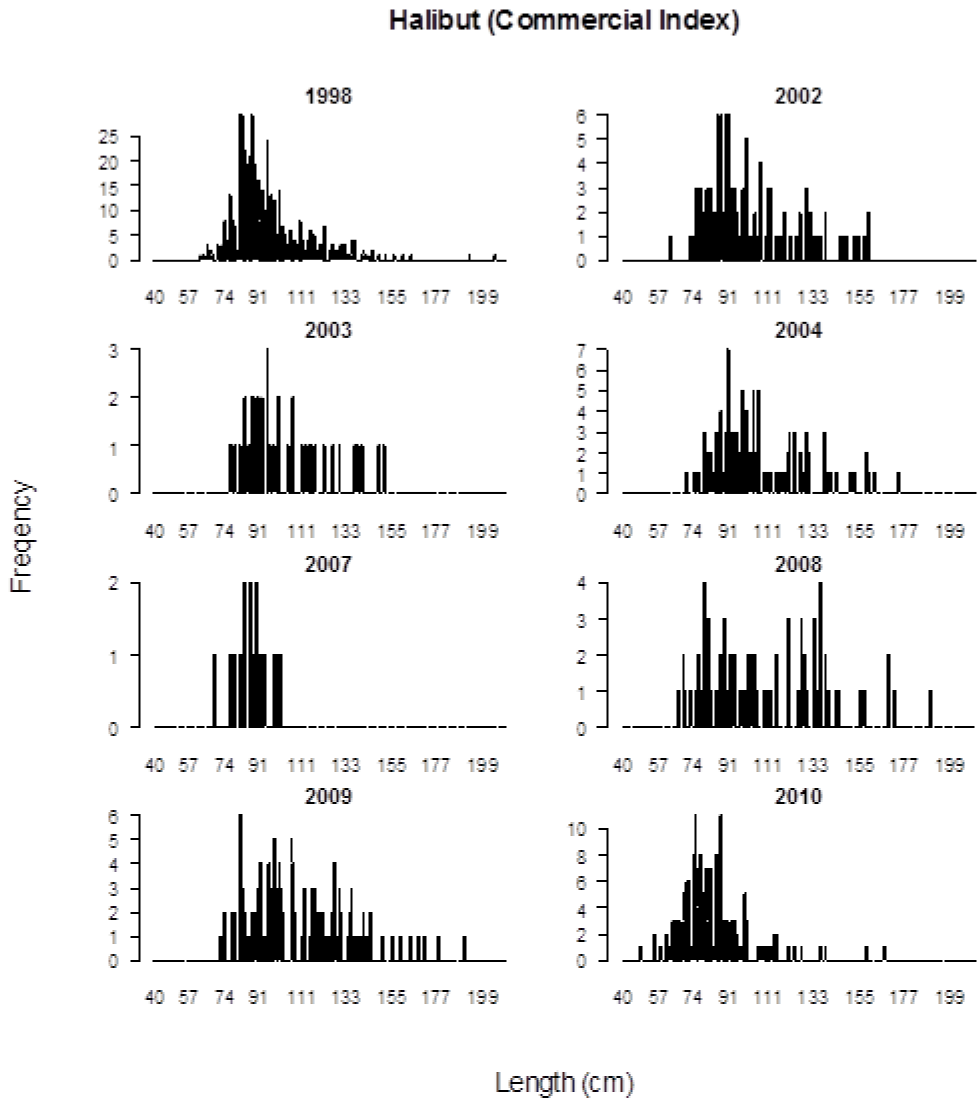


Figure 18-25: Length-frequency plots for Atlantic halibut caught in the commercial index from 1998 to 2010 in the Gully. The commercial index did not fish in the Gully from 1999 to 2001 and 2005 to 2006.

Indicator 19: Relative abundances, size distributions, and diversity of selected trap-vulnerable species in Zones 1 and 2 of the MPA

An evaluation of this indicator was not conducted.

Indicator 20: Relative abundances, size distributions, and diversity of selected mesopelagic nekton in Zones 1 and 2 of the MPA

An evaluation of this indicator was conducted and presented at the workshop, but the results are not included here.

MAINTAIN THE QUALITY OF THE WATER AND SEDIMENTS OF THE GULLY

Indicators 21 through 29 relate to maintaining both the water quality and the sediment quality in the Gully. This includes a wide variety of data, including characteristics of the water column (e.g., temperature, salinity, oxygen, pH, and light), sea surface properties, weather conditions, water movement, phytoplankton and zooplankton biomass, acoustic scattering and seabird abundance and distribution.

Indicator 21: Temperature, salinity, oxygen concentration, alkalinity, pH, light levels, chlorophyll pigments and nutrients in the water column within the MPA, including in close proximity to the seabed

Indicator 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

E. Head

Available data

Atlantic Zone Monitoring Program (AZMP)

Physical and chemical data from AZMP-dedicated cruises have been collected each spring and fall since 1999 (with some gaps due to operational problems). There is sampling at one station within the Gully MPA and three across the mouth of the Gully on most missions and at fixed stations along the Louisbourg and Halifax Lines on every mission (Figure 21-1).

Physical and chemical data are also collected at a subset of the trawl stations occupied during groundfish survey missions on the Scotian Shelf in March and July. Stations are assigned according to a ‘random stratified survey’ design; none are located within the Gully. Sampling started in 1999.

Atlantic Zone Off-Shelf Monitoring Program (AZOMP)

Physical and chemical data are collected at stations of the Extended Halifax Line, generally during the fall AZMP missions (late-September to early-October) and on annual AZOMP sampling missions to the Labrador Sea (late-May to early-June) (Figure 21-1). The Extended Halifax Line has been sampled regularly since 2008.

Dedicated Gully study (2006–2007)

Physical and chemical data were collected within the Gully in April 2006 and August 2007 in conjunction with work for Indicator 25.

Sampling prior to 1999

Physical and chemical data were collected during the Scotian Shelf Ichthyoplankton Program (SSIP) survey missions between 1978 and 1982, on missions made by Dalhousie University, Nova Scotia, scientists in July 1993 and by DFO scientists in July 1995, June and November 1996 and April, October and November 1997.

Data collection

AZMP

Profiles of temperature, salinity, oxygen, underwater light intensity and fluorescence are taken and water samples are collected at fixed depths for the determination of nutrient and chlorophyll concentrations. Water samples are collected at the surface to measure the concentration of Particulate Organic Matter (POM), phytoplankton pigment composition and absorption spectra. Profiles of pH have been taken on an irregular basis since 2008. The sensor requires ‘wet chemistry’ calibration for every trip (although water samples can be collected and transported to the Bedford Institute of Oceanography (BIO), Nova Scotia, for post-trip analysis) and can only be deployed to 1500 m (Johnson et al. 2013).

AZOMP

Profiles of temperature, salinity, oxygen and fluorescence are taken and water samples are collected at fixed depths for the determination of nutrient and chlorophyll concentrations. Water samples are also collected for measurement of pH and alkalinity.

The samples for Dissolved Inorganic Carbon (DIC), Total Alkalinity (TA), and pH were collected and stored in 500 mL glass bottles following the method prescribed by the U.S. Department of Energy (DOE 1994). The DIC was determined using gas extraction and a coulometric method with photometric detection (Johnson et al. 1985). Total alkalinity was measured by open-cell potentiometric titration with a five-point method (Haraldsson et al. 1997). For pH analyses, the absorbance of three wavelengths, 434-, 578-, and 730-nm was measured by the spectrophotometer (Dickson et al. 2007). Certified Reference Material (CRM) (supplied by Professor Andrew Dickson, Scripps Institution of Oceanography, San Diego, U.S.) was analyzed in duplicate every 20 samples for DIC/TA and every 30-40 samples for pH to evaluate accuracy.

Instrumentation and Sample Analysis

The instruments on the CTD package are as described in Mitchell et al. (2002), as are the methods for analysis of chlorophyll and nutrient samples. Particulate Organic Carbon (POC) and Particulate Organic Nitrogen (PON) concentrations in POM on filters are determined using a Perkin-Elmer CHN analyser, phytoplankton pigment composition is determined by High Performance Liquid Chromatography (HPLC) using the method of Head and Horne (1993), and absorption spectra are measured using a Shimadzu UV2101 PC double beam spectrophotometer.

Sampling prior to 1999

In general, sampling protocols were similar to those used on AZMP missions.

Results

Baseline values exist for the variables reported in AZMP, although only for the Louisbourg and Halifax lines. In general, they are the mean values over the duration of the program. Baseline values could also be calculated over the time series of measurements of variables made at the one fixed station that has been sampled bi-annually in the Gully.

No obvious long-term trends in monitored physical, chemical and biological variables have been detected over 12 years of AZMP sampling. In contrast, inter-annual variations are very high for some variables, such as the concentrations of chlorophyll in April due to the ephemeral nature of spring blooms and changes in the seasonal cycles of phytoplankton and zooplankton production.

There has been no analysis of data from the AZMP sampling station within the Gully, although, time series of physical variables from AZMP missions are reported annually at AZMP meetings and in government research documents. Field measurements of temperature are generally calculated as monthly averages over defined areas of the entire Scotian Shelf (Figure 21-2). Considerable variability is seen in the annual anomalies in a nearby region that is upstream of the Gully (Figure 21-3). Nitrate and chlorophyll concentrations are reported as average values for stations along standard sections and for near surface layers (Figure 21-4) and for nitrate in the subsurface layers. The entire suite of measured variables is compiled in a ‘scorecard’, for elucidation of overall trends (Figure 21-5). No obvious trends are apparent in these data.

The Gully is a unique area in many respects, and the dedicated study in 2006 and 2007 indicated that the physical environment is poorly understood.

Evaluation of existing protocols for meeting indicator monitoring requirements

The AZMP provides sampling opportunities in the Gully in March, April, July and October. Assuming that this program is sustained, slight modifications in sampling, such as the addition of one or two stations within the Gully, could improve its contribution to Gully monitoring needs. This would require a commitment of increased support in terms of ship time and funding for sample and data analysis.

Hydrographic, nutrient, and phytoplankton data collected in the Gully since 1999 have largely remained unexamined. These time series should be analyzed and put in the context of the AZMP standard reporting of data from the Louisbourg and Halifax lines. This will capitalize on the sampling that has already been carried out, help define baseline levels for variables particular to the Gully and assist in refining the Gully Monitoring Program (e.g., by identifying whether there is a need for more sampling stations). More specifically, the major requirements at this time are: 1) all samples collected in the Gully to date be analyzed; 2) data be archived; 3) results collected to date be synthesized and reported; and 4) results obtained going forward be reported annually in a standard format. The most appropriate place to report these results appears to be the AZMP reporting pathway. The research documents produced each year already include data from the Louisbourg and Halifax Lines. Data from Gully stations could be reported within these documents, perhaps in an appendix (so as to conserve the current format of the AZMP research documents), and used to provide information for additional annual Gully-orientated synthesis reports.

Threats to ongoing monitoring

AZMP has carried out a minimal Gully monitoring sampling effort over the last 12 years, but it cannot be guaranteed that this will continue without dedicated funding. With ever increasing financial constraints being put on programs, non-core elements from AZMP sampling missions, such as sampling in the Gully, could be eliminated.

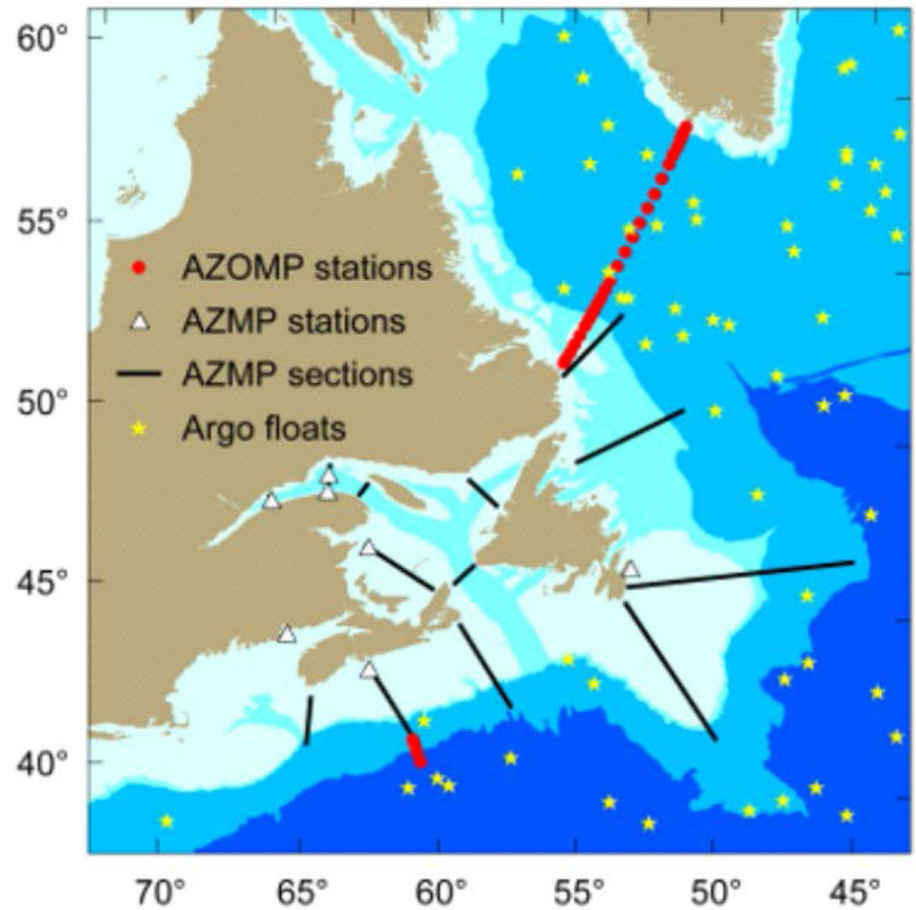


Figure 21-1: Standard sections sampled that are routinely sampled during AZMP and AZOMP missions. The three AZMP lines on the Scotian Shelf and the one in Cabot Strait are sampled by staff from the Bedford Institute of Oceanography, as are the AZOMP stations.

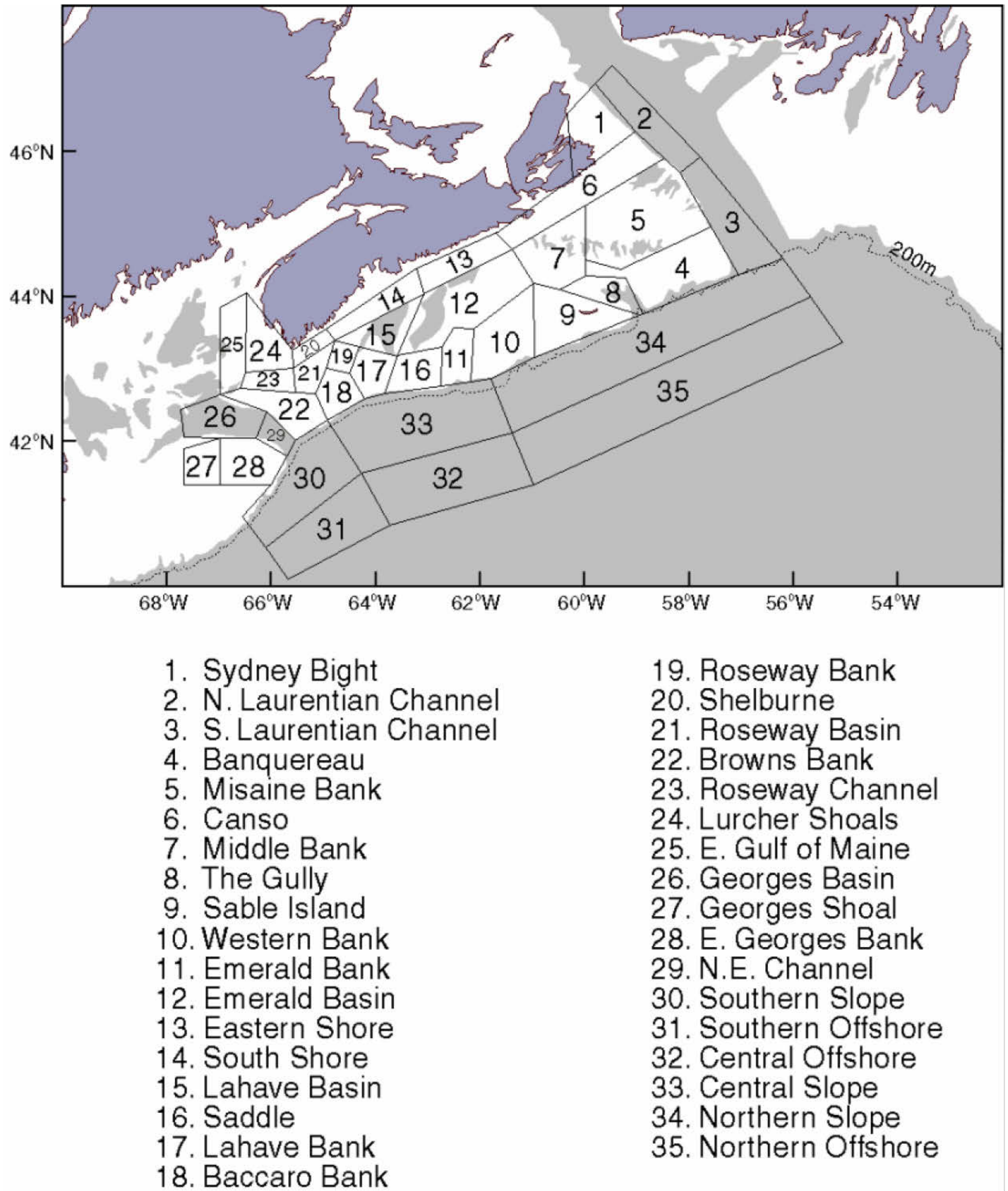


Figure 21-2: Areas of the Scotian Shelf for which physical data are averaged and reported (selected areas only) in AZMP.

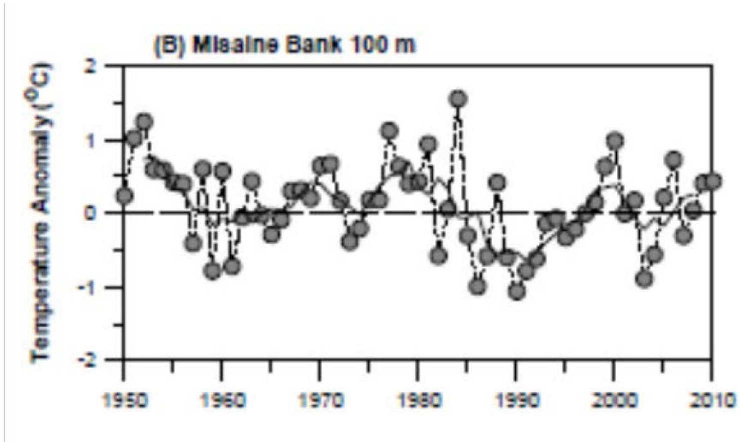


Figure 21-3: Temperature anomalies for Misaine Bank on the Eastern Scotian Shelf.

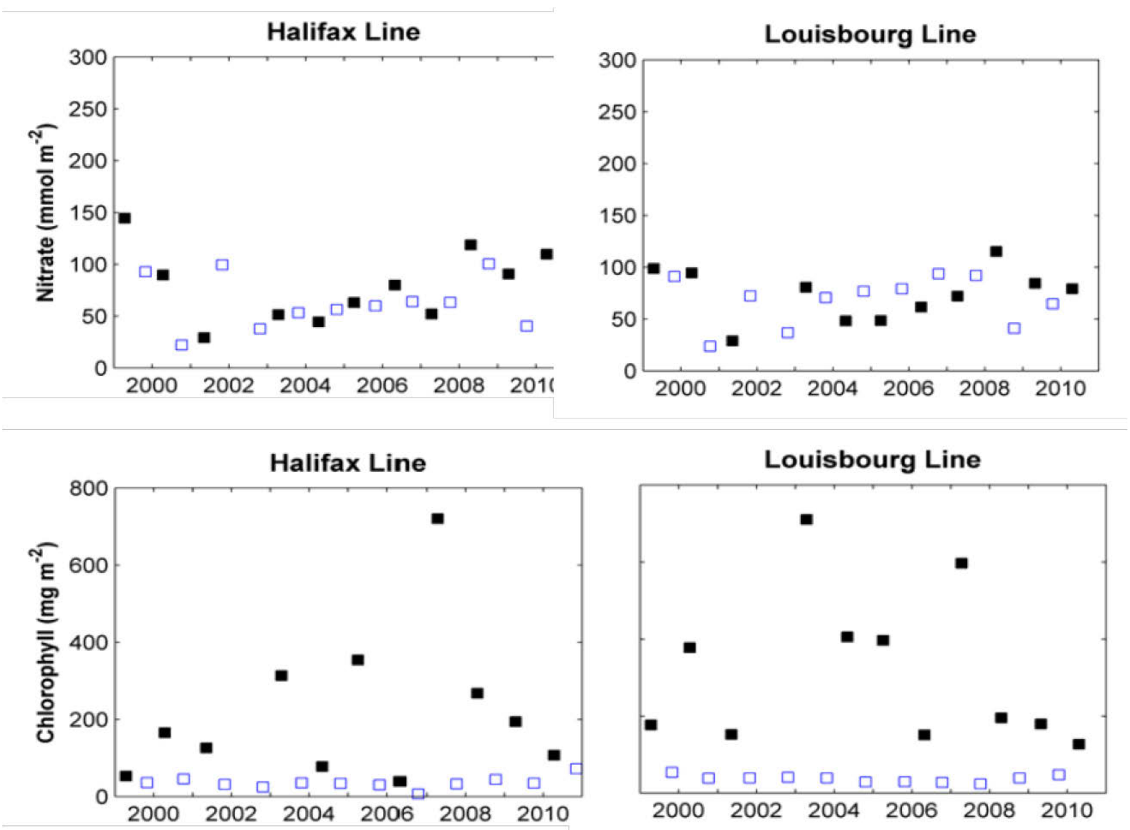
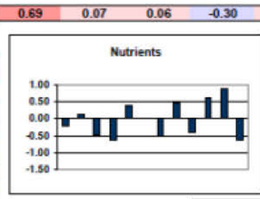


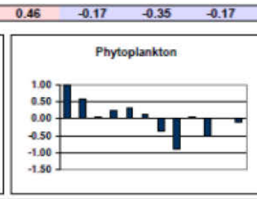
Figure 21-4: Time series for 0-50 m nitrate concentrations (upper panels) and 0-100 m integrated chlorophyll concentrations (lower panels) averaged over all stations along AZMP sections in spring (black squares) and fall (open blue squares). From Johnson et al. (2012).

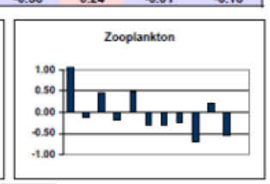
SCORECARD-Maritimes 2010

Variable	Station	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
NO3_0-50m (mmol m^{-3})	Hfx-2	-2.18	1.16	1.25	-0.74	-0.19	0.09	-0.58	0.28	0.19	1.19	0.39	-0.87
	P-5	-1.01	-0.49	-0.59	0.72	1.13	0.06	-0.88	1.44	-0.40	0.09	1.49	-1.54
	CSL	1.52	-1.57	-0.91	0.05	-1.09	-0.41	0.42	-0.07	1.04	1.27	0.16	-0.36
	LBL	1.78	-0.69	-1.17	-1.97	0.48	-0.37	-0.28	0.65	0.93	0.59	0.02	
	HL	2.03	-0.82	0.14	-1.23	-0.68	-0.73	-0.30	0.11	-0.40	1.77	-0.31	0.41
	BBL	0.08	-0.58	-0.84	-0.91	0.67	-0.34	0.15	0.27	-1.78	1.98	1.17	
NO3_50-150m (mmol m^{-3})	Hfx-2	-0.66	0.80	-0.83	0.15	1.49	-0.76	-1.06	1.71	-0.68	-0.30	1.03	-0.88
	P-5	-0.84	-0.45	-1.26	0.88	1.07	-0.31	-0.60	1.12	-0.43	0.42	1.69	-1.28
	CSL	-0.02	1.73	-0.92	-0.72	-0.12	1.24	-0.68	0.11	-1.27	0.62	1.16	-1.13
	LBL	0.48	1.55	-1.28	-0.94	0.70	-0.61	0.45	0.37	-1.91	-0.11	0.39	
	HL	0.42	0.65	-0.14	-0.72	-0.10	-0.77	-1.98	0.46	-1.11	1.09	1.48	0.73
	BBL	-1.96	-0.21	0.12	-0.99	1.21	1.13	-0.45	0.23	-1.02	-0.09	0.91	
NO3-Win(J-M)_0-50m (mmol m^{-3})	Hfx-2	-1.81	0.49	1.15	-1.24	1.06	0.84	-0.04	-0.45	0.21	-0.03	1.05	-1.21
	P-5	-0.88	0.12	-1.44	-1.06	-0.05	1.32	-1.14	0.51	1.12	0.22	1.53	-0.24
CHL_0-100m (mg m^{-2})	Hfx-2	2.58	0.75	0.48	-0.23	0.37	-0.56	-0.54	-1.15	-0.82	-0.86	-0.10	0.07
	P-5	1.38	1.68	0.56	0.19	-0.58	0.21	-0.82	-1.23	-0.47	-1.07	-0.90	1.07
	CSL	0.85	0.99	-0.75	2.42	-0.04	-0.39	-0.72	-1.25	-0.09	-0.40	0.07	-0.68
	LBL	1.05	0.45	-0.43	0.74	1.85	-0.35	-0.29	-1.47	-0.03	-0.21	0.40	
	HL	-0.49	0.44	-0.47	-1.08	0.37	-0.49	0.23	-2.14	1.65	0.73	0.38	0.86
	BBL	1.20	-0.52	0.10	-1.26	1.93	-1.28	-0.87	-0.63	0.92	0.07	0.54	
Bloom-Timing (Year-Day)	Hfx-2	-0.31	0.45	0.64	-0.50	1.40	0.36	-0.21	-0.31	0.36	1.21	-0.69	-2.40
	P-5		-0.37	-1.02	-0.09	-0.11	-1.37	0.59	1.25	-0.11	-0.02	-0.83	2.08
Bloom-Magnitude (mg m^{-2})	Hfx-2	-1.15	-0.80	-0.69	-0.33	1.00	0.84	0.72	-0.86	1.96	-0.82	0.75	-0.62
	P-5		2.10	-0.97	-0.49	0.26	-0.27	-0.92	0.33	1.11	0.53	-1.29	-0.38
Bloom-Duration (Days)	Hfx-2	1.25	0.50	0.50	0.66	0.13	0.34	-0.99	-1.21	-0.46	-0.62	1.57	-1.69
	P-5		-1.01	1.66	-1.07	-0.52	1.12	0.52	-0.41	-0.68	-0.63	-0.41	1.44
C. finmarchicus (Indiv m^{-2} * 10^3)	Hfx-2	0.88	0.71	1.77	-0.25	0.37	-0.89	-1.15	-0.84	-0.26	1.04	-1.56	0.18
	P-5	-1.06	-1.16	1.44	-1.16	0.62	0.02	0.53	1.88	-0.73	-0.02	0.20	-0.57
	CSL	1.24	-1.20	-1.15		1.54	-0.18	0.21	-0.32	0.95	-0.46	-1.27	0.65
	LBL	1.41	-1.03	-0.73	1.62	-1.12	-0.16	-0.63	-0.37	-0.59	1.06	-0.54	1.08
	HL	2.02	0.35	-0.69	-1.37	0.64	-1.25	0.11	0.18	-0.83	0.43	1.07	-0.65
	BBL	-0.10	-1.01	0.71	0.64	1.64	-1.07	-0.98	0.59	-1.06	1.05	0.70	-1.10
Pseudocalanus (Indiv m^{-2} * 10^3)	Hfx-2	1.51	0.39	0.04	-0.26	1.04	1.04	0.29	-1.80	-1.31	0.51	-0.57	-0.87
	P-5	0.31	0.51	2.16	0.21	-0.05	-0.69	-0.87	-1.13	-0.35	0.75	-1.52	0.67
	CSL	0.81	-1.42	-0.51		2.08	-0.20	-0.38	-0.61	-0.09	0.66	-1.08	0.75
	LBL	2.38	-1.15	0.62	1.11	0.09	-0.61	-0.83	-0.03	-0.43	0.28	-0.85	-0.59
	HL	1.71	0.68	0.37	0.32	0.59	-0.46	-0.36	-1.08	-0.64	0.00	-0.33	-0.65
	BBL	1.21	-0.02	2.04	-0.33	1.47	-0.71	-0.69	-0.52	-0.86	-0.23	-0.97	-0.38
Copepods (Indiv m^{-2} * 10^3)	Hfx-2	1.89	0.90	0.70	-1.43	-0.04	0.13	0.68	-1.00	-1.38	-0.24	0.44	-0.66
	P-5	-0.11	1.22	1.57	-0.77	0.51	-0.24	-1.28	0.72	-1.05	-0.38	-1.24	1.08
	CSL	1.21	-1.34	-1.03		1.17	0.29	0.25	-1.01	-0.36	-0.01	-0.74	1.57
	LBL	2.70	-0.75	0.28	-0.93	0.29	-0.62	-0.03	0.12	-0.81	0.65	-0.81	-0.08
	HL	2.62	0.82	-0.19	-0.75	-0.06	-0.98	0.66	-0.54	-0.68	-0.54	0.23	-0.59
	BBL	1.28	1.37	0.45	0.13	1.29	-1.29	-0.53	-0.24	-1.07	0.53	-0.55	-1.36
Non-copepods (Indiv m^{-2} * 10^3)	Hfx-2	2.80	0.17	-0.09	-0.90	-0.27	0.21	0.61	-0.56	-0.92	0.01	-0.30	-0.76
	P-5	0.96	1.06	1.09	0.24	-1.09	-0.41	-1.29	-0.54	-0.56	-0.38	-0.87	1.78
	CSL	1.36	-0.97	-0.74		0.51	1.51	-0.68	0.11	-1.27	-0.50	-0.54	1.22
	LBL	0.87	-0.98	1.74	0.61	-0.97	-0.30	-0.02	1.34	-0.96	0.56	-0.90	-0.99
	HL	2.89	0.20	-0.57	-0.33	0.09	-0.30	0.55	-0.79	-0.62	0.11	-0.59	-0.65
	BBL	2.01	0.75	-0.52	-0.40	1.37	-1.03	0.66	-0.98	-0.96	0.14	-0.81	-0.24
Nutrients		-0.22	0.12	-0.48	-0.62	0.40	0.03	-0.50	0.48	-0.39	0.62	0.87	-0.64
Phytoplankton		0.99	0.58	0.04	0.24	0.31	0.12	-0.38	-0.91	0.07	-0.51	0.01	-0.11
Zooplankton		1.27	-0.13	0.45	-0.18	0.47	-0.31	-0.29	-0.26	-0.69	0.22	-0.55	-0.01
OVERALL		0.69	0.07	0.06	-0.30	0.46	-0.17	-0.35	-0.17	-0.36	0.24	-0.01	-0.16

Anom	Scale
> 2.5	
2 to 2.5	
1.5 to 2	
1 to 1.5	
0.5 to 1	
0 to 0.5	
-0.5 to 0	
-1 to -0.5	
-1.5 to -1	
-2 to -1.5	
-2.5 to -2	
< -2.5	







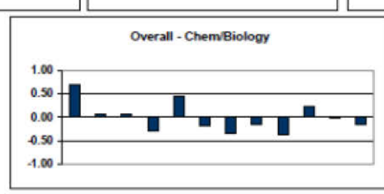


Figure 21-5: DFO Maritimes Region scorecard. Time series of chemical and biological variables from 1999 to 2010. A white cell indicates missing data. Red (blue) cells indicate higher (lower) than normal nutrient, phytoplankton, zooplankton levels or later and longer (earlier and shorter) than normal duration of phytoplankton blooms. Reference period is 1999 to 2008. The numbers in the cells are the anomaly values. CSL: Cabot Strait Line; LBL: Louisbourg Line; HL: Halifax Line; BBL: Browns Bank Line.

Indicator 23: Physical (temperature, salinity, wind, height) and biological (ocean colour) sea surface properties in the MPA and the surrounding region determined by satellite observations

E. Head

Available data

Remotely sensed sea surface chlorophyll (SSC) and sea surface temperature (SST) data are available on an ongoing basis for the entire northwest Atlantic, including the Scotian Shelf and the Gully. The Gully is not, however, one of the standard areas for which time series measurements are compiled and reported annually.

Ocean colour

Satellite measurements of ocean colour were made from 1978 to1986 using the Coastal Zone Color Scanner (CZCS). Thereafter, remote sensing of ocean colour did not occur until the fall of 1997 when the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) came on line; it ceased functioning in 2010. In 2002 the Moderate Resolution Imaging Spectroradiometer (MODIS) Aqua and Medium Resolution Imaging Spectrometer (MERIS) colour sensors came on line (the latter currently non-functioning).

Temperature

SSTs based on remote sensing and *in situ* observations are available from a variety of sources including the NASA website (1960 to present) and the St. Lawrence Global Observatory (1980s to present). SST data obtained by *in situ* observation are found in DFO climate databases.

Remotely sensed SST has been reported in the Atlantic Zone Monitoring Program (AZMP) since fall 1997

Data collection

The algorithms for the conversion of remotely sensed ocean colour to SSC are constantly being updated by the National Aeronautics and Space Administration (NASA). They vary among sensors and throughout the lifetime of a given sensor, based on changes in orbits, sensitivity, etc. Reprocessing of existing data occurs on a regular basis. The Remote Sensing Group at BIO can provide information as to the state of operations at any given time.

The SST conversion algorithms are more robust than those for SSC, but a description of the satellite data processing routines is beyond the scope of this document.

Data analysis

In general, the Remote Sensing Group at BIO compiles data over two-week intervals to generate maps of SSC and SST for the northwest Atlantic and calculates values for standard satellite ‘boxes’ throughout the region (Figure 23-1). Time series of values for the standard boxes are available on request through application to Carla Caverhill. Maps are also generated from the AZMP SST data to complement those for SSC. These maps are displayed on the BIO Operational Remote Sensing website. Daily SST maps are also available on the AZMP website under climate indices. For the Gully specifically, time series of SSC were generated using highly spatially resolved data collected by MERIS over a box specially defined to represent the Gully between 2009 and 2011. This sensor had greater spatial resolution than any of the others, which made it especially suitable for use in the relatively small area chosen to represent the Gully (Figure 23-2).

Results

Baseline values exist for SST and SSC over bi-weekly, monthly and annual time scales through AZMP, although only for the Eastern Scotian Shelf (ESS) and Central Scotian Shelf (CSS) satellite boxes, not the Gully MPA itself. These are mean values averaged over the duration of the sampling period. Baseline values could also be calculated for the Gully satellite box.

The Gully box data showed the familiar short-term increases in chlorophyll concentration associated with the spring bloom (Figure 23-2). Seasonal cycles were ‘spiky’, however, perhaps partly because there were relatively few data points contributing to each measurement; this demonstrates the problems that arise when applying satellite technology to small areas (only a relatively small number of pixels contribute to each data point). Bloom characteristics for the Gully box between 2009 and 2011 (Figure 23-2) do not closely resemble those seen for the Eastern Scotian Shelf box (Figure 23-3).

Time series for SST for several of the standard satellite boxes on the Scotian Shelf and in the Gulf of Maine, including the Eastern Scotian Shelf, have shown upward trends since 1985, although with considerable inter-annual variability (Figure 23-4).

There was a weak ($p < 0.05$) upward trend in the annual average concentration of SSC for the Eastern Scotian Shelf satellite box between 2004 and 2011, and considerable inter-annual variability in the timing and intensity of the spring bloom during those years (Figure 23-2). Annual average SSTs for the same satellite box did not change consistently from 2004 to 2010, although they did show a general slight upward trend with high values in both 2006 and 2010.

Evaluation of existing protocols for meeting indicator monitoring requirements

Satellite observations can and should be compiled for a Gully ‘standard area’ in order to fulfill the Gully MPA monitoring needs. Maps of satellite measurements of SSC and SST have been made for two-week periods since fall 1997 and between 1978 and 1986, but data have not been put together to give long-term time series specifically for the Gully MPA. This is due in part to inadequate spatial resolution of some of the satellite sensors and in part (for SSC) due to cross-calibrating problems between different sensors. This means that while the patterns of seasonal variations in chlorophyll may be comparable, giving a complete time series of the timing of the spring bloom, the actual concentrations achieved may not be completely comparable among sensors. Nevertheless, an effort aimed at optimizing the methodology could be undertaken, which would allow construction of time series data and reporting of ongoing satellite measurements in support of Gully MPA monitoring.

The MERIS satellite has now failed, so high resolution ocean colour data are not currently available, although another sensor is being developed for launch in late-2014.

Threats to ongoing monitoring

Satellites have finite lifetimes and are built and launched by foreign countries. SSC and SST measurements are, therefore, vulnerable to decisions in which Canada has no say. The integrity of the program is, therefore, at risk, although hopefully a small one, since this situation will not change.

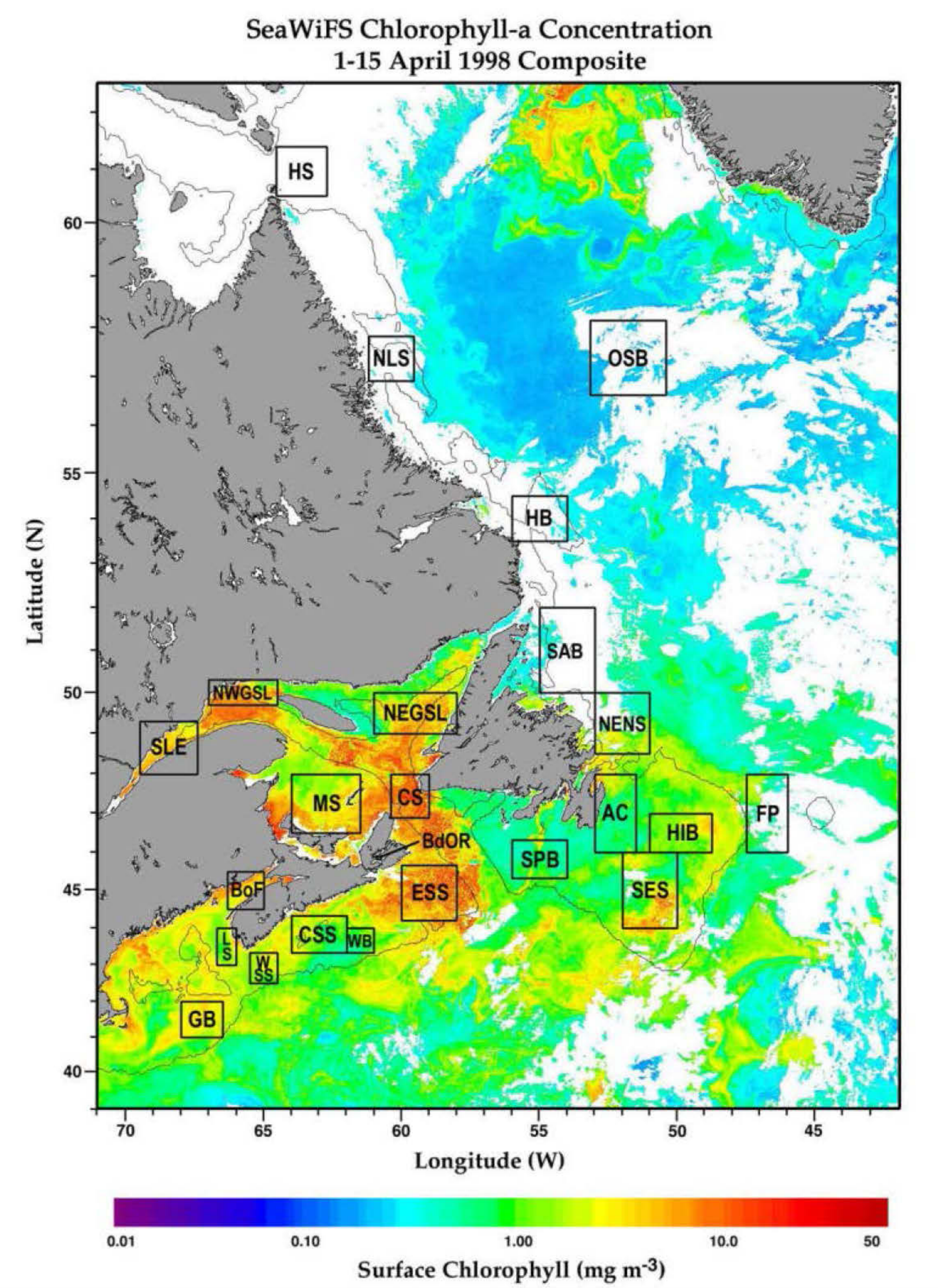


Figure 23-1: Standard boxes for which SSC is calculated for two-week periods in AZMP using measurements made by ocean colour–sensing satellites.

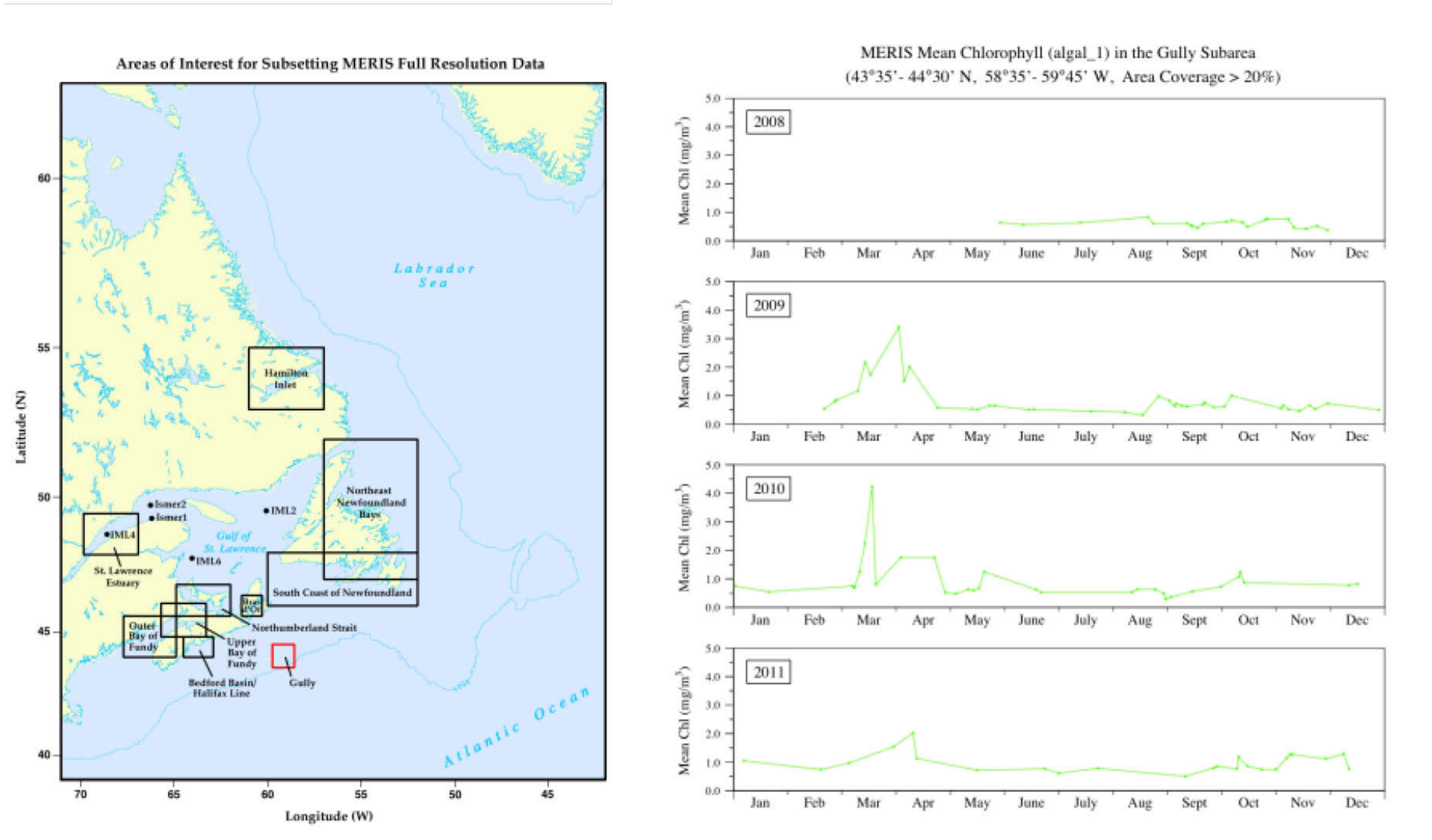


Figure 23-2: Area for which MERIS ocean colour data were analyzed (left panel, red box). Estimates of chlorophyll concentration based on the MERIS data, averaged for bi-weekly intervals between 2008 and 2011 (right panels).

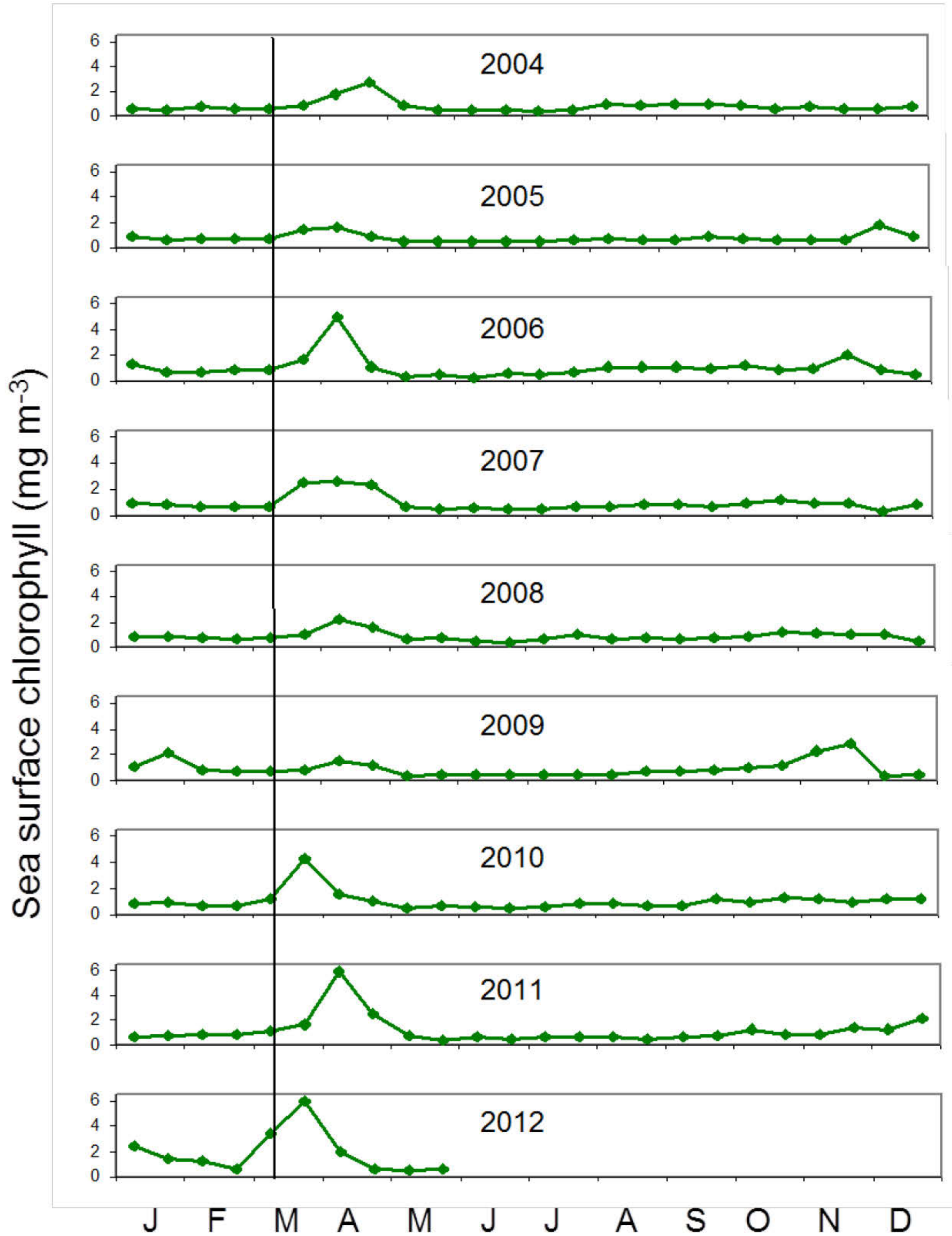


Figure 23-3: SSC on the Eastern Scotian Shelf as estimated from measurements made by the MODIS/Aqua ocean-colour satellite. The bloom was earliest in early March in 2012 (black vertical line) and most intense in early April 2011 and late March 2012.

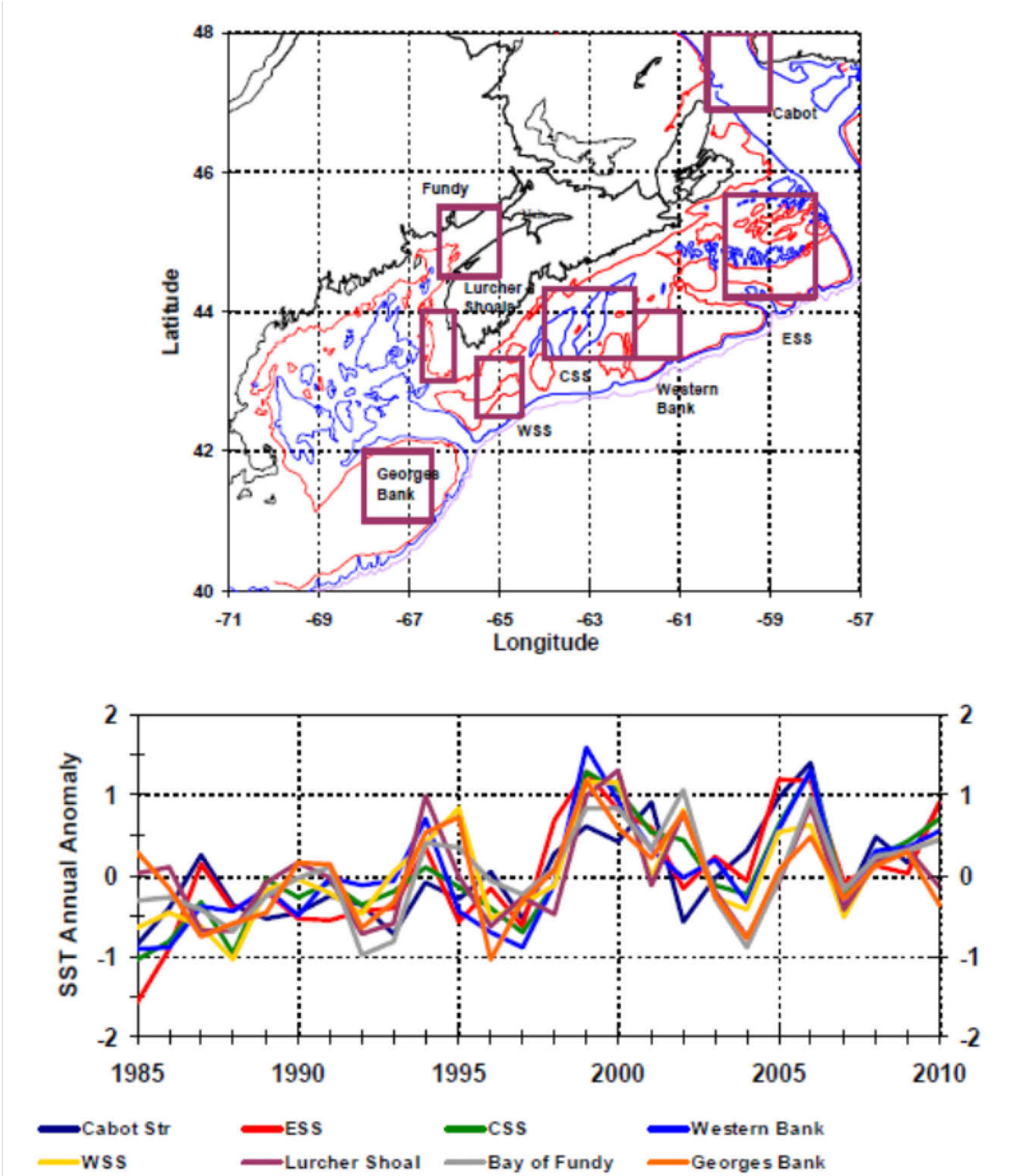


Figure 23-4: Scotian Shelf-Gulf of Maine areas used for extraction of SST (upper panel). Annual SST anomalies derived from satellite imagery compared to their long-term means (lower panel). From Hebert et al. (2011).

Indicator 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

An evaluation of this indicator was not conducted.

Indicator 25: Three-dimensional distribution and movements of water masses within and around the MPA

B.J.W. Greenan

Available data

The 2006–2007 field program consisted of four moorings (deployment April 23–24, 2006; recovery August 3, 2007) and two shipboard conductivity, temperature, depth (CTD) surveys (April 22–26, 2006 and August 2–8, 2007). The CTD surveys included nutrient, chlorophyll, bacteria, phytoplankton and zooplankton sampling as well as lowered-acoustic Doppler current profiling.

Data collection

CTD surveys

A CTD survey on the grid shown in Figure 25-1 was required to provide a larger-scale setting of the environment for the moorings. This survey is also necessary at the beginning and end of the deployment to check for sensor drift on the mooring instruments. Standard AZMP sampling protocols were followed. Such an extensive CTD grid used in this process study is not necessary for long-term monitoring of water masses in the Gully.

Profiles of water properties were obtained using a Sea-Bird 911 CTD rosette equipped with dual temperature, conductivity, oxygen and fluorescence sensors, as well as a single Photosynthetically Active Radiation (PAR) sensor. The CTD surveys were completed for sites SG1–SG21 in 2006 and SG1–SG29 in 2007 (Figure 25-1). The temperature and conductivity sensors were calibrated annually in a standards lab at BIO. Salinity samples were collected during the surveys using the CTD rosette and were subsequently analyzed with an Autosal salinometer; these results were incorporated into the calibration of the CTD data. The oxygen, fluorescence and PAR sensor outputs are based on the manufacturer's calibration for each instrument.

Nutrients

Nutrient samples were collected in the Gully during deployment and recovery cruises. It has been suggested that physical processes such as enhanced mixing could drive greater primary productivity in the Gully and result in greater biodiversity (Harrison and Fenton 1998). This could lead to different nutrient profiles in the upper layers of the Gully compared to those in surrounding areas. Consequently, archived nitrate, silicate, and phosphate data from three adjacent regions surrounding the Gully – Banquereau Bank to the northeast; Middle Bank to the north-northwest; and Sable Island Bank to the southwest (Figure 25-1) – were examined. Polygons defining these areas are shown in the online hydrological atlas of the Scotian Shelf and Gulf of Maine.

Current meter moorings

One mooring was deployed at each of sites SG2 (1050 m), SG10 (475 m), SG11 (1640 m) and SG12 (723 m). The moorings consisted of one upward-looking Teledyne RDI 300 kHz Workhorse Acoustic Doppler Current Profiler (ADCP), three to six Aanderaa RCM8 current meters, two to four Sea-Bird SBE37 MicroCAT temperature/conductivity sensors and two to three Vemco Minilog temperature recorders (Table 25-1). The moorings were designed to provide near-complete depth coverage; a sub-surface Braincon float, equipped with an upward-looking ADCP, provided the main buoyancy. For the moorings on the Gully slopes (SG10 and SG12), there was no instrumentation above the Braincon; on SG2 and SG11, a streamlined buoyancy package equipped with a MicroCAT was placed 45 m above the main float. All moorings were deployed with either a three- or four-trainwheel anchor and a Benthos 965A acoustic release.

The ADCPs recorded vertical profiles of currents in 24 bins of 4 metres; samples were recorded hourly with a setting of 80 pings per ensemble in burst mode. The estimated resolution of the ADCP with this setup is summarized in Table 25-2. The time series were binned into 25 m averages for analysis purposes. The RCM8s recorded single point currents and temperatures hourly; some shallower RCM8s also recorded pressure and salinity. The Minilogs recorded temperature hourly; the MicroCATs recorded temperature, salinity and pressure in 10-minute intervals. Three different MicroCAT pressure sensors, with resolutions of 0.02, 0.04 and 0.06 dbar and accuracies of 1, 2 and 3 dbar, were paired with the temperature and salinity sensors. Nominal resolutions and accuracies of these sensors are summarized in Table 25-2.

Bottom depths change profoundly over short horizontal distances within the Gully so moorings SG2 and SG12 were deployed 100 m deeper than intended compromising the resolution of near-surface currents. The array provided high quality data for the full deployment with a few exceptions. Firstly, the surface to 150 m depth range was not well sampled at SG2, SG11 and SG12; only SG10 had significant data return from the upper 150 m. Secondly, the upper 200 m part of the mooring at SG11 broke away on June 17, 2007, due to a wire failure, resulting in the temporary loss of an ADCP, one Minilog and two MicroCATs. All remaining instruments continued to function, however, their data were compromised due to the loss of the primary buoyancy. Backup buoyancy allowed the recovery of these instruments on August 3, 2007. The upper part of this mooring was recovered by a fisher and returned to BIO with data intact. A third significant issue arose from the unexpectedly strong currents along the canyon axis; currents caused substantial knockdown of moorings SG2 and SG11. The SG11 (bottom depth 1640 m) mooring frequently had knockdowns as large as 500 metres. This complicated the processing and quality control of the data from these sites. In this paper, the standard depths of the RCM8s and Minilogs were determined from the pressure record of the closest MicroCAT using the known distances between instruments. Further, the 4 m resolution ADCP data were binned and averaged every 25 ± 2 m to minimize gaps in the records. As a result of the large mooring knockdowns, the flotation in the streamlined buoyancy above the Braincon on the SG2 and SG11 moorings imploded during deployment causing the upper MicroCAT and Minilog to sink about 90 m deeper than intended. A Minilog on SG2 also imploded because it exceeded its design depth. Finally, the MicroCAT at SG11 (660 m) did not record salinity or pressure and the MicroCAT at SG2 (225 m) did not record salinity.

While knockdown of the SG11 and SG2 moorings caused vertical displacement of the individual instruments, it did not cause significant data quality issues. This can be partially attributed to the manner in which the instruments are mounted on the mooring; the ADCPs were installed in streamlined buoyancy packages which maintain a specified orientation into the flow. The pitch/roll time series for the ADCPs indicated that none of the instruments exceeded 10 degrees tilt during the deployments. The RCM8s were mounted in gimbals, which ensured that they remained close to vertical even if the mooring tilted during knockdown.

Data analysis

All shipboard profile data and moored time series were processed using standard methodologies employed by the Ocean Data and Information Services (ODIS) group at BIO. These procedures include spike removal and checks for other quality control issues such as low signal to noise. The data are archived in a self-described ASCII file in the Ocean Data Format (ODF) and are publically available.

The 25-m binned ADCP and the RCM8 data were used and any ADCP bin with less than 60% data return was excluded. The velocity data were rotated such that the resulting components were in the along- and across-Gully directions, which were assigned to be 330° and 60°, respectively. The results were linearly-interpolated between moorings for those depths above the seabed on the canyon walls at SG12 and SG10. For depths below this, the velocity and variance were linearly-interpolated with depth along the central mooring; this result was then assumed to represent the flow at that depth across the canyon and was extrapolated from the site of the central mooring towards the canyon walls.

Harmonic tidal analyses of the RCM8 and the ADCP 25-m binned currents time series were conducted using the t-tide package (Pawlowicz et al. 2002) and MATLAB. Spectral analyses of the currents time series were done using the Hamming window of 1024 points sampled hourly and Welch's averaged modified periodogram method.

Archived nutrient data were recovered from the online database BioChem maintained by the Integrated Science Data Management group (ISDM) (DFO 2013; Gregory and Narayanan 2003). Archived data are presented for April to May and July to August because of the timing of the 2006 (late-April) and 2007 (early-August) cruises. The comparisons are for 0–250 m only because the three adjacent regions are on the shelf and are shallow relative to the maximum depth of the Gully. Moreover, this is the depth range where primary productivity is expected to play an important role. While identical vertical profiles indicate that the inventory of nutrients is the same, it does not necessarily mean that the vertical fluxes and primary productivity are equivalent.

Results

The current meter time series is limited to the period of 23 April 2006 to 3 August 2007.

An analysis of archived data which focused on the circulation, current variability, cross-shelf exchange, tides and low frequency variability of hydrographic properties suggested that circulation in the Gully contributes to localized retention of materials and large-scale, cross-shelf transport (Petrie et al. 1998). However, many of the conclusions depended solely on computer simulations of the circulation with few supporting data. While current meter databases do not contain records from within the Gully, nearby data indicate that in the upper 50 m of ocean mean flows are less than 0.15 m/s (23 of 25 records, 15 of which are <0.1 m/s) and predominantly towards the southwest. The currents generally decrease with increasing depth, with a median speed of 0.04 m/s for the combined 50–100 m and 100–150 m layers. These records also provide some evidence of the clockwise circulation around Sable Bank to the west of the Gully.

Temperature, salinity, density and oxygen saturation

Temperature, salinity, density and oxygen saturation sections across the mouth of the Gully indicate a three-layer structure in 2006 and 2007 (Figure 25-2 and Figure 25-3). The upper 100 metres features varying temperatures and salinities in response to the annual changes in heat flux and freshwater inflow (Petrie et al. 1996); oxygen saturations were generally >90% in 2006 and >80% in 2007. Temperatures and salinities were highest in the layer from about 100 m to 350 m during both years due to the presence of Warm Slope Water (WSW). WSW is characterized by temperatures between 9°C and 13°C and salinities between 34.73 and 35.6 (Gatien 1976; Petrie and Drinkwater 1993). This 100 m to 350 m layer also features a minimum of oxygen saturations whose relatively low values are also characteristic of WSW (Petrie and Yeats 2000). The deeper part of the section is dominated by Labrador Slope Water (LSW), which is characterized by temperatures between 4°C and 9°C, salinities of 34.3 to 35.0 (Gatien 1976; Petrie and Drinkwater 1993) and higher oxygen saturations. In both years, the density surfaces are relatively flat, indicating no strong baroclinic circulation during the surveys.

The along-Gully variation of temperature and salinity can be simplified by averaging the profiles across the sections from the depth of the rim (200 m) then displaying their depth dependence (Figure 25-4 [A-D]). The section-to-section variability in vertically averaged layers was also examined. Figure 25-4 (A, C and D) – 2006 salinity, 2007 salinity and temperature – show the same pattern, namely increasing, depth-averaged values from the head to the mouth of the Gully that were strongly linear (2006 salinity: r^2= 0.99; 2007 salinity: r^2= 0.95; 2007 temperature: r^2= 0.96). This amounted to changes of 0.055 and 0.087 for salinity in 2006 and 2007, and 0.43°C for temperature in 2007. The depth range was from 200–1000 m to 881 m in 2006 and to 866 m in 2007; these were the deepest depths at the shallowest sections for stations 1 to 3. Similarly for shallower depths, the 0–200 m averaged salinities were strongly linear (r^2= 0.97 for both years) with increases of 0.45 (2006) and 0.43 (2007) from the head to the mouth of the Gully. Increasing salinities offshore in both layers implies two-way exchange between them, similar to classical estuarine dynamics. However, linearity is not expected if the mixing were uniform along the axis of the Gully; moreover, the salinity structure in the 200–400 m depth range, particularly in 2007, implies more complex mixing processes are occurring than one might conclude from gross layer averages.

Figure 25-5 (A and B) show the temperature–salinity (T–S) structure in the 200–1000 m range. In both years, LSW is the dominant water mass in this depth range, a consequence of the large-scale advection pattern in this region (Petrie and Drinkwater 1993) (although there is a minor contribution from WSW). This supports findings that the fauna of the Gully is dominated by cold temperate species typical of mid- to high-latitudes in the North Atlantic. In 2006, the T–S structure showed an orderly pattern: the section at the mouth of the Gully (Stations 14–21) generally featured higher temperatures and salinities than the other sections. This pattern progresses systematically with decreasing temperatures and salinities towards the head of the Gully (Stations 1–3) where the lowest values are found. The detailed variability in the Gully is more complex, with overlapping T–S structure for the middle sections between 200 and 275 m (7.35–7.25°C) and roughly 475–575 m (5.5–5.1°C); the outermost sections' T–S structure overlaps between approximately 275 m and 390 m (7.25–5.95°C). Finally, the inner three sections' properties overlap over varying depth ranges, which span 430 m (Stations 1–3) and 990 m (Stations 9–14). Consequently, deep along-Gully isopycnals tend to be shallowest at the mouth and head and deepest at the two middle sections. The overlapping T–S structure between sections implies an advective connection; however, the differences may be due to more complex spatial variability in the flow field.

Similar behaviour is seen in the 2007 survey, though overall, the waters are fresher and cooler than in 2006. Moreover, the layering appears to be simpler with the only appreciable overlap of T–S properties between the two outer sections observed in the range of 220–360 m (7.8–5.9°C). Deep isopycnals along the Gully axis tended to be flat. In both years, the 1000 m observations converge to a temperature of about 4.2°C and a salinity of 34.9, with both values slightly higher at the mouth of the Gully.

An examination of T–S variation across the Gully for each section did not reveal a consistent pattern in either 2006 or 2007.

Nutrients

Figure 25-6 shows that the concentrations of nutrients in the Gully for both periods are comparable to those in the three adjacent areas. There are slight deviations (determined by averaging the observations in 10 m bins beginning with 0 m); spring phosphate levels are slightly lower (on average -0.1 μM; a typical standard deviation for the adjacent areas is 0.3 μM) as are summer silicate values (-1.3 μM; a typical SD is 3 μM) in the Gully. Overall it is concluded that the 0–250 m nutrient profiles in the Gully are not significantly different from those in the adjacent shelf areas. Comparisons of standing crops of chlorophyll (not shown) show no significant differences between the levels observed in 2006 and 2007 and archived data from the adjacent shelf. The similar nutrient profiles and standing crops of chlorophyll imply that primary productivity in the Gully is not enhanced relative to that of the surrounding areas.

Current

The overall mean current velocity and variance for the Gully spanned by moorings SG10, SG11 and SG12 are presented in Figure 25-7.

The across-canyon mean speed (U_{60}) is enhanced near the bottom at SG12 and SG11. The flow shallower than 500 m is characterized by two features: 1) in the mid-layer, the U_{60} flow ranges from 0.01 m/s on the eastern side of the Gully to near zero on the western side and 2) at shallower depths, the flow is directed to the southwest (negative U_{60}) at a rate of 0.02 m/s, which is consistent with nearby archived current observations near the shelf edge (Figure 25-8). Current magnitude from between the shallowest depth and 200 m averaged -0.04 m/s at SG10 and SG11 and -0.01 m/s at SG12.

The along-Gully mean component (V_{330}) indicates that below 500 m the flow is predominantly towards the head of the canyon. There is a layer around 200 or 300 m of on-shelf flow in the western section that weakens eastward, becoming negative on the eastern wall. On the western side, a wedge of current is primarily off-shelf below about 300 m. This pattern suggests a rim-depth eddy over the canyon may exist; however, it is difficult to make a definitive statement based on the available dataset.

The variance of the across-canyon component is highest at shallow depths, decreasing to about half its maximum value at roughly 250 m. Analysis of the time series for the 222 m RCM8 at SG10 indicates that 60% of the variance can be attributed to the tidal/inertial band, 35% to the 1–10 day wind-driven band, and 5% to lower frequencies. Previous studies of the role of meteorological forcing on the low-frequency variability and circulation of the Scotian Shelf were carried out by Petrie and Lively (1979) and Smith and Petrie (1982). Topographic steering of the circulation in the deep Gully and the restrictive nature of the sidewalls leads to the low variance observed in the U_{60} component. The variance in the along-canyon velocity, V_{330}, increases with depth at the SG11 mooring site, over the canyon thalweg, as a result of bottom-intensified tidal amplification. There is no increase in variance evident from the mooring records on the canyon sidewalls. Peak variance in the along-canyon direction is about five times larger than that observed in the across-canyon direction.

The mean along-Gully transport through moorings SG10, SG11 and SG12 over the entire mooring period from 200 m to the bottom was 35,500 m^3/s toward the head of the Gully. At mooring SG2, near the head of the Gully, the mean velocity was also positive at 0.004 m/s. These results imply net upwelling over the section of the Gully from the outer array to the head and the potential for on-shelf flow.

A progressive vector diagram (PVD) (Figure 25-9) created from the hourly time series provides an overview of the flow at each of the four mooring sites. The lines have been colour-coded to be representative of above-rim (<200 m), mid-depth (200–500 m) and deep (>500 m) layers. The above-rim flow at SG2 (canyon head) is primarily in the northwest direction (along the canyon axis) but weakens at shallower depths. Northwestward flow is generally observed at other depths except currents at 562 m and 761 m, which are to the southeast and east, respectively.

The mooring array (Figure 25-9 [B, C and D]) indicates that the above-rim flow is primarily to the southwest (across the canyon) in agreement with the archived data (Figure 25-8). The above-rim currents appear to weaken from east to west across the canyon; the flows at SG11 and SG12 are perpendicular to the canyon axis, whereas at SG10 the flow has a stronger off-shelf component. For SG11, the flow below 500 m is primarily along the canyon axis towards the shelf but weaker than at SG2. The low-frequency current on the western side (SG12) rotates clockwise with increasing depth for the upper 220 m and is strongest at that depth; below this, the flow rotates counter-clockwise. At SG10 for depths exceeding 200 m, the circulation rotates counter-clockwise to westward flow near the bottom.

The low frequency (subtidal) and total variance of the current meter data were computed for each of the four mooring sites, and for moorings on the Scotian Slope adjacent to the Gully (Figure 25-10). The subtidal variance generally decreases with increasing depth at all sites. It is evident that the two mooring sites along the Gully axis (SG2 and SG11) are unique because the total variance increases markedly with depth. The total variance at SG11 (Figure 25-10 [B]) reaches a maximum 0.062 m^2/s^2 at 50 m above the seabed. The SG2 total variance profile (Figure 25-10 [A]) is more noisy, however, its magnitude is approximately three times larger than at SG11, reaching a peak value of 0.15 m^2/s^2 at 761 m, approximately 300 m above bottom. At the east and west mooring sites, the total variance profile mirrors the low-frequency profile and is about twice as large. It was evident from the raw data that the source of this enhanced variance seen at SG2 and SG11 was tidal variability.

At the Halifax tide gauge, the K1 tidal amplitude is 0.1038 m and the O1 amplitude is 0.0483 m (Philip MacAulay, Canadian Hydrographic Service, BIO, pers. comm.). If these elevations were solely due to on-shelf flow, then barotropic tidal currents of approximately 0.0015 m/s for K1 and about half that for O1 at the SG2 mooring would be expected. A tidal analysis of the individual current meter time series is presented in Figure 25-11 for the tidal constituents K1 and M2. The K1 tidal velocities increase with depth and indicate that the Gully acts to amplify these high-frequency flows (Swart et al. 2011). At the SG2 site (761 m), the K1 major axis current is the largest at about 0.31 m/s, and the O1 flow is 0.26 m/s. At SG11 (1542 m) the K1 component is 0.19 m/s, while the O1 major current is 0.16 m/s. These flows far exceed the expected on-shelf currents that could account for the surface tide at Halifax. The tidal ellipses at SG2 and SG11 are aligned with the local topography, especially below the rim (>200 m). The sites on the canyon walls (SG10 and SG12) have lower tidal velocities compared to those at similar depths along the axis; these sites also show no indication of bottom-enhancement of the diurnal tides. Based on all of the current meter data, the O1 constituent is approximately 0.82 of the K1 amplitude; this is consistent at both the SG2 and SG11 sites (r^2= 0.99 for K1 versus O1 amplitude).

For depths >200m at SG2, the tidal excursions range from 4.4 km (O1, 355 m) to 8.5 km (K1, 761 m); excursions of this length at the head of the Gully could force an alternating upslope–downslope flow and enhance vertical mixing. At SG2, the K1 and O1 phase shifts by about 30° as it decreases with depth. There is an average offset of 27° between the K1 and O1 tidal constituents. Similar trends in phase are observed at SG11 with an average K1–O1 offset of 23°. The orientation of the K1 and O1 diurnal constituents is virtually identical at all depths below the canyon rim and shifts to higher values as depth increases; the trend with depth is more evident at the SG2 location.

The semi-diurnal M2 constituent also shows the influence of topography through the orientation of the tidal ellipses below 500 m (Figure 25-11 [B]); however, these ellipses are not as rectilinear as those of the diurnal tides. There is also some evidence of amplification of the M2 component with depth. At SG2, for depths >200 m, the M2 major component increases from 0.049 m/s at 355 m to 0.116 m/s at 761 m before decreasing to 0.063 m/s near the bottom. At SG11, the M2 major currents increase from 0.04 m/s at 444 m to 0.094 m/s at 1549 m. As for K1 and O1, the M2 major flows exceed the expected on-shelf current of about 0.017 m/s. The diurnal constituents in the deep layer are significantly larger at SG2 compared to SG11; this is not the case for M2 where the magnitude is similar at both sites. The orientation of the M2 tidal ellipses is quite variable above 500 m.

The change in phase with depth of the M2 constituent is significantly more variable than observed for the diurnal constituents. However, below 400 m, the phase decreases with depth which is consistent with the trends observed for K1 and O1. The orientation of the M2 ellipses is relatively constant with depth, however there is large variability at mid-depth at both SG2 and SG11.

Depth-averaged spectra were generated for the two Gully mooring sites along the canyon axis (SG2 at the head and SG11 at the centre) and for three sites on the Scotian Slope (Figure 25-12). These spectra were based on observations from 150 m (well below the mixed layer) to the deepest current meter from the site (typically 50 m above the seabed). These results indicate that the Gully is indeed a unique ocean environment in which rarely observed compound tidal frequencies (e.g., M2+K1= MK3), generated by non-linear interactions among diurnal and semi-diurnal components, are clearly evident at both SG2 and SG11. The analysis of slope mooring sites is substantially different from the two Gully sites with the only common features being spectral peaks at the semi-diurnal frequencies (N2, M2 and S2) and weaker peaks at diurnal periods. The slope sites also have a significant response at the inertial frequency, as well as a modest peak at the diurnal frequencies O1 and K1. The largest peak in the Gully mooring spectra are at these diurnal frequencies.

At the two Gully sites, the ratios of the response (spectral estimate) to the forcing (Halifax sea level), the gains, were determined for the diurnal components O1 (period 25.819 h) and K1 (23.934 h). If the response to forcing was the same, then the ratio of the gains should be 1. For SG2 at the head of the Gully, the gain for O1 divided by the gain for K1 was 1.44; for SG11 it was 1.46. This implies that the resonance frequency for the Gully is closer to the O1 frequency than to that of K1.

Rough estimates of the potential of the M2, K1 and O1 tidal constituents to generate harmonics can be made through consideration of the non-linear terms such as:

$$v(M2)\partial v(K1)/\partial y$$

where v represents the along-Gully current and y the distance. Using the spectral estimates, one can predict the spectral energies at frequencies corresponding to MK3 and MO3. Alternatively, the distance, y, required to give the observed spectral energy can be estimated. For the SG2 mooring at the head of the Gully, the distances are 1.5 km and 1.6 km for MO3 and MK3, respectively; for the outer mooring, SG11, the distances are 5.2 km and 6 km. These are reasonable given the proximity of SG2 to the head of the Gully and SG11's more distant location.

The spectral energy distributions at both SG2 and SG11 are very similar except for the energy level, which is measurably higher at the head of the canyon. Spectral peaks are clearly evident at frequencies as high as almost seven cycles per day (MK7). Beyond this, the variance is a factor of about three times higher at the canyon head versus the deep central mooring at SG11, consistent with the profiles of total variance (Figure 25-10). The unique topography of the Gully is obviously a key factor in the non-linear interaction of tidal constituents, which produces the spectra observed (overtides and compound tides) at SG2 and SG11.

Key questions

Previous studies, such as in Harrison and Fenton (1998), have raised a number of key questions related to the Gully which include the following:

- Is there evidence of significant retention which could explain the inferred enriched productivity?
- Is there significant transport of slope water onto the Scotian Shelf?
- How does the current variability compare to the nearby slope regions?
- Is there evidence of enhanced internal tides and waves?
- Is the Gully an area of stronger vertical mixing and upwelling potential that would support higher primary productivity?

These questions are addressed in the remainder of this section.

It has long been speculated that one of the possible explanations for the high biodiversity and productivity of the Gully was that the mean circulation fostered enhanced retention of water within the Gully, and that this would enable biological communities to thrive. The current meter data collected in the upper 200 m, as part of this mooring program, indicates that the Gully has little impact on the upper ocean circulation, which is predominantly influenced by the shelf-break current flowing to the southwest. Similarly, Hunkins (1988) noted that the southwestward, near-surface flow over Baltimore Canyon appeared unaffected by canyon topography. Noble and Butman (1989) also found dominant southwestward flow over the inner portion of Lydonia Canyon which transitioned seaward to northeastward flow; this was likely caused by the presence of warm-core eddies. For the Gully, this decoupling does not appear to be related to the seasonal stratification as the 50–100 m currents in surrounding areas strongly resemble those in the 0–50 m layer (Figure 25-8). Moreover, Shan et al. (2013) show the Gully only weakly affects the flow for depths less than 200 m. Upper layer (<200 m) flow is to the southwest at all three outer moorings and ranges from 0.01 m/s (SG12) to 0.04 m/s (SG10 and SG11); this gives a transit time of about three days which is considerably less than retention times of >40 days for specific areas of the Gully determined from numerical simulations (Petrie et al. 1998). At SG2, the mean flows are to the northeast at about 0.01 m/s, leading to a transit time of about 12 days and indicating a longer retention time at least near the head of the Gully. An analysis of the satellite SST and ocean colour imagery does not provide any indication of differences between the Gully and the surrounding region. The annual means and annual harmonics of SSTs for the nearby Banquereau, Middle and Sable Island Banks are within 0.5°C of the Gully values and the annual harmonic phases are within 0.03 months. If there were enhanced mixing by a factor of two over the Gully compared to the surrounding Banks, then differences of SST exceeding 1°C could occur from June to September with a maximum difference of about 3–4°C in August. Differences of these magnitudes are not generally seen. Overall, the evidence seems to indicate that if there are processes occurring at depth to generate enhanced productivity, they are not influencing the surface waters over the Gully.

There is some evidence supporting the presence of a rim-depth eddy between 200 and 300 m; however, given the sparse spatial coverage of the moorings, it is difficult to be conclusive. The PVDs (Figure 25-9) indicate that the depth-averaged mean velocity below the Gully rim (<200 m) is on the order of 0.01 m/s. With a distance of around 30 km from the mouth to the head of the canyon, the advective time scale is approximately 30 days—significantly longer than the observed residence time above the canyon rim. S. Shan (Dalhousie University, unpublished data) suggests that particles released in their computer simulation near the canyon head are retained in the Gully much longer than other areas of the canyon.

The mean 200 m to bottom transport towards the head of the Gully through the SG10, SG11 and SG12 array was estimated as 35,500 m^3/s. Hunkins (1988) also observed deep flow towards the head of Baltimore Canyon; in contrast, Noble and Butman (1989) found weak (spatial average of -0.006 m/s) along-canyon mean flow with a slight tendency for flow out of the canyon. For the Gully, the bottom transport implies an upwelling velocity of $1.7x10^{-4}$ m/s over the area from the mooring to its head near SG2. This upwelling could give rise to a nitrate flux into the upper 200 m of $2–4x10^{-3}$ $kg/m^2/day$ (Figure 25-6). If distributed uniformly over the upper 200 m, this flux could generate a chlorophyll concentration of around 1.7 mg $Chl/m^{3,}$ which is a significant amount (Greenan et al. 2002). However, a flow of 0.01 m/s out of the western side of the Gully alone from SG2 to SG11 (19 km by 200 m) could offset the upwelled nitrate flux. For depths less than 200 m, the mean flows at all mooring sites are ≥0.01 m/s. Thus, the 0–200 m currents could on average advect this nitrate flux from the region before it entered the euphotic zone, reducing its impact over the Gully, potentially becoming a nutrient source for areas downstream.

A plot of the along-axis density field based on the deployment and recovery cruises shows very little evidence of upwelling occurring within the canyon (i.e., the isopycnal surfaces are flat from the Gully mouth to the head), despite the long-term observation that the mean flow is directed towards the head of the Gully. While these only represent two snapshots, the results are consistent for both cruises.

An intrusion of colder, fresher water at 290 m depth was observed at the SG11 mooring site for the period of January 1, 2007, to April 6, 2007. Through investigation of the correlation between the temperature at 290 m with MicroCAT measurements at 355 m (SG2), 444 m (SG11) and 562 m (SG2), estimates of upper bounds on the vertical eddy diffusivity (K_v), as well as the mean horizontal flow speed (v) between SG11 and SG2, can be provided. Based on the maximum correlation for lagged time series for the 290 m and 444 m temperature time series, K_v is an estimated $180x10^{-4}$ m^2/s, which is about 20 times the typical value observed on the Scotian Shelf (Umoh and Thompson 1994). The speed of propagation of the cold, fresh intrusion from SG11 to SG2 is estimated to be 0.02 m/s based on the distance between the two mooring sites and the time lag observed. This is consistent with the current meter measurements.

The linear increases of salinity in both the shallow (0–200 m) and deep (>200 m) layers towards the mouth of the Gully as described above, suggest estuarine-like dynamics with mixing between the two layers. An advective-diffusive balance was considered:

$$v\, \partial S/\partial y = K_v\, \partial^2 S/\partial z^2$$

where v is the deep flow towards the head of the canyon, y is the along-canyon direction, and z is the vertical coordinate. Using the average of the salinity gradients from above, and estimating the $\partial^2 S/\partial z^2$ term across the 200 m interface (averaging over each section), $K_v= 0.9x10^{-4}$ m^2/s, 200 times less than the value estimated from tracking the cold, fresh event described above is obtained. However, if the mean upwelling velocity, $w= 2x10^{-4}$ m/s is incorporated, $K_v= 55x10^{-4}$ m^2/s, in better agreement with the other estimate of $180x10^{-4}$ m^2/s is obtained. Greater vertical mixing is necessary to overcome the mean upwelling to produce the salinity gradient in the lower layer. These estimates represent a high rate of vertical mixing likely driven by the exceptionally strong tidal flows, particularly the diurnal components. However, this simple salt balance based on vertically averaged properties, which has worked for other canyons gives, at best, a sense of the level of mixing. From the averaged profiles, it is evident that the salinity gradient changes sign in the upper 400 m (Figure 25-4) which casts doubt on the estimates of vertical salinity gradients based on representing the Gully as two layers. Moreover, there is both vertical and horizontal current shear in the Gully. The vertical mixing appears to be strong.

A principal component analysis (PCA) of the monthly mean of along-Gully currents was carried out for each of the mooring sites using data from 150 m to bottom to determine the overall coherency of the low frequency circulation (Figure 25-13). For the outer array alone, the PCA1 accounts for 56% of the variance; loadings were generally in phase for SG11 and SG12, but out of phase for SG10. The loadings were high for depths <400 m and mirror the pattern of the mean, along-Gully flow (Figure 25-7 [B], Figure 25-13 [A]). The time series of PCA1 has a large amplitude for the initial month but weak variability thereafter; the amplitudes are negative for all but one month (Figure 25-13 [B]). Seasonal variability is thus not a major factor and the currents described by this mode, change sign only for that one month. For all other months, the flow is towards the head of the Gully where loadings are negative and towards the mouth where they are positive. It is not surprising then that the loadings which describe coherent variability resemble the mean flow and that there is a tendency for upwelling at the head of the Gully. If SG2 is included in the analysis, then the PCA1 for the whole array accounts for 44% of the variance, 80% by the first three modes. Overall, this indicates highly coherent low-frequency current variability in the Gully. For comparison, the PCA1 for the Lydonia canyon moorings only accounted for 25% of the variance (Noble and Butman, 1989).

Current variance along the axis of the Gully for depths greater than 200 m is high, showing peaks of 0.15 m^2/s^2 at mooring SG2 (head) and 0.062 m^2/s^2 at SG11 (Figure 25-7, Figure 25-10). Baltimore and Lydonia canyons have values of about 0.014 m^2/s^2, as much as a factor of 10 lower than observed in the Gully (Hunkins 1988; Noble and Butman 1989). On the other hand, in Hudson Canyon current variances reach approximately 0.05 m^2/s^2, which is comparable to those observed in the Gully. For the 200 m to bottom depth-averaged spectra (Figure 25-12), about 95% of the variance is accounted for by the tides. Tidal flows are noted as strong or as the strongest components in the current fields in Baltimore, Hudson and Lydonia canyons (Hunkins 1988; Hotchkiss and Wunsch 1982; Noble and Butman 1989) and as contributing 90% of the overall variance in Monterey Canyon (Xu and Noble 2009).

A computation of the ratios of variance from the SG11 and slope moorings (Table 25-3) provides some further insight into the differences between the Gully and surrounding slope region. It is evident that at low frequencies (less than diurnal), the depth dependence of the Gully and slope variance is similar. In sharp contrast, the diurnal ratios range from 4.1 at 150 m to 548 at 1500 m, reflecting the resonant or near-resonant conditions that prevail in the Gully. At the inertial frequency, the variance in the Gully ranges from 0.2 to 0.8 of the slope value, indicating the inhibiting effect of the Gully walls in the generation of currents at this frequency. For the semi-diurnal and higher frequencies, the ratios in the upper 1000 m are relatively constant at about one and two, respectively, and then jump to about a factor of 10 at 1500 m. It is evident from this analysis that the Gully is quite a distinct environment from the surrounding slope region, and that this is in large part attributable to amplification of the diurnal and semi-diurnal tides along the Gully axis. Length scales (L= 35 km, W_{head}= 1/10 W_{mouth}, R= 14 km) suggest that the diurnal tide should be resonant in the canyon. Swart et al. (2011) used an analytical framework to explain the mechanisms behind the strong diurnal currents observed by the moored array. They suggested that an along-shelf barotropic flow sets up a double Kelvin wave response in the canyon, generating along-canyon velocities that are subsequently amplified by resonance. The double Kelvin wave model predicts that the velocity will increase from the canyon walls to a maximum at the centre of the Gully; this is consistent with the observations from the Gully mooring array. The nature of the velocity profile in the along-canyon direction depends on the canyon geometry, the forcing frequency, and the strength of the stratification. Swart et al. (2011) state that the Gully represents a special case in this regard, as the diurnal frequency is very near to resonant for the observed stratification.

A surprising feature of the spectra from sites SG2 and SG11 is the occurrence of a large number of peaks corresponding to overtides (higher harmonics) and compound tides (resulting from the interaction of two or more astronomical constituents); peaks that are typically seen in near-shore areas (Parker 1991; Aubrey and Speer 1985; Speer and Aubrey 1985), but not in the offshore at depths up to 1500 m. This underlines the unique tidal response in the Gully in comparison to other submarine canyons (Xu and Noble 2009; Hotchkiss and Wunsch 1982). Hunkins (1988) notes that quarter-diurnal tides were evident at sites near the head of Baltimore Canyon, but no indication of strength was given. This implies that tidal resonance is the likely source of energy driving the enhanced vertical mixing indicated by the simple models which have been employed. The strength of the compound tides at moorings SG2 in particular and SG11 also implies tidal residual flows of about 0.01 m/s, which could contribute significantly to the long-term mean flow (Figure 25-7).

Shan et al. (2013) have developed a high-resolution, nested model to study the circulation and hydrography of the Gully. This model suggested that the deep portion of the canyon is characterized by a weak, but persistent, northwestward flow indicating cross-shelf transport of deep slope water into the Gully. This is consistent with the moored current meter records from the array. The model also demonstrated significant tide-topography interaction within the canyon and suggested that circulation and hydrography above the canyon rim is influenced significantly by wind forcing.

Evaluation of existing protocols for meeting indicator monitoring requirements

Each section in the Gully was only sampled once and, therefore, represents a snapshot of the hydrographic variability over a four-day period in 2006 and a six-day period in 2007. Representative mean currents in the 200 to 1000 m depth interval, (i.e. below the rim of the Gully) are on the order of 0.01 m/s (Figure 25-7). Given the Gully's length of about 30 km along the deep central axis, an advective time scale would be about 30 days. Repeat sections over this time scale might give a reasonable average and allow interpretation of the section-to-section variability. The present CTD dataset may not allow this; nonetheless, it is useful to examine sections to determine if consistent patterns emerge.

The use of current meter measurements as a tool to meet monitoring requirements for this indicator is not currently clear. This would be an expensive method for long-term monitoring. It is recommended that monitoring of long-term changes in water mass structure be carried out via the AZMP annual sampling, which takes place in the Gully during the spring and fall of each year.

The optimal set-up of the mooring would be to have an ADCP at about 100 m below the surface. This would provide velocity measurements in the upper water column with a vertical resolution of about 5 m. This will enable monitoring of circulation above the rim of the canyon. While the moored current meter data is providing new insights into the fundamental physics of the mean circulation and high-frequency variability of currents in the Gully, it would not be a high priority to deploy more current meter moorings at this point. Support of investigations and field observations of mixing in the Gully would improve the understanding of these processes and help with the assessment and interpretation of annual observations.

A combination of acoustic profiling and single-point current meters is required for full water column coverage in the Gully. It is necessary to sample currents on at least an hourly basis to avoid aliasing of high-frequency variability which is driven by internal tides and non-linear interactions of diurnal and semi-diurnal tidal constituents. Similarly, temperature and conductivity should also be measured on an hourly basis using instruments similar to the Sea-Bird SBE37 MicroCAT.

A fairly exhaustive analysis of the physical oceanographic data collected as part of the 2006–2007 field program has been carried out and is summarized in Greenan et al. (2013). Further analysis of the Lowered ADCP dataset to estimate mixing rate in the deep Gully could prove very useful. Analyses of the biological and chemical data collected during the cruise are fairly rudimentary at this point and could probably benefit from further investigation. Long-term monitoring of the T–S structure would provide an important indicator of potential changes occurring in the physical structure of the Gully circulation. Such information can like be obtained using the seasonal CTD surveys carried out by the AZMP.

Threats to ongoing monitoring

The lack of understanding of the fundamental physical processes which control circulation and vertical mixing in the Gully will limit attempts to develop monitoring indicators. A solid foundational knowledge of the inter-relationship of physics and ecosystem dynamics will be required to evaluate the utility of the chosen indicators.

Table 25-1: Summary of the Gully mooring configuration. Nominal depths (m) of the instruments are indicated by the numbers in each of the mooring columns. Numbers with asterisks (*) indicate that the RCM8 did not have sensors installed for pressure or conductivity. Water depth (z) at each of the mooring sites is given by the number in brackets at the top of each column.

Instrument	Parameters	SG2 (z=1054 m)	SG11 (z=1640 m)	SG12 (z=723 m)	SG10 (z=476 m)
Vemco Minilog	Temperature	208 250 273	154 203 230	245 270	123 148
Aanderaa RCM8	Speed Direction Temperature Conductivity Pressure	355 562* 761* 1007*	290 444* 635* 945* 1249* 1542*	345 546 673*	222 323* 424*
TRDI Workhorse ADCP (300 kHz)	Speed Direction Temperature Pressure	225	178	220	95
Sea-Bird SBE37 MicroCAT	Temperature Conductivity Pressure	188 225 562 761	134 178 444 635	220 546	95 424

Table 25-2: Summary for each instrument type of the estimated accuracy (Acc) and resolution (Res) of the variables speed, direction, temperature and conductivity. A dash (-) indicates no value; N/A indicates 'not applicable'.

Instrument	Speed		Direction		Temperature		Conductivity	
	Acc	Res	Acc	Res	Acc	Res	Acc	Res
RDI ACDP	0.5%	0.1 cm s^{-1}	2°	0.01°	0.4°C	0.01°C	-	-
Sea-Bird SBE37 MicroCat	-	-	-	-	0.002°C	0.001°C	0.003 mS cm^{-1}	0.0001 mS cm^{-1}
Aanderaa RCM8	N/A	> of 4% spd or 1 cm s^{-1}	5°	0.35°	0.05°C	0.02°C	0.074 mS cm^{-1}	0.074 mS cm^{-1}
Vemco Minilog	-	-	-	-	0.2°C	0.1°C	-	-

Table 25-3: Ratio of SG11 to Slope variance from moored current meter data at various depths listed on the column headings. The rows represent different frequency bands.

Frequency Band	150 m	500 m	1000 m	1500 m
Low Frequency	0.6	1.1	1.1	1.8
Diurnal	4.1	94	140	548
Inertial	0.4	0.2	0.3	0.8
Semi Diurnal	0.5	1.7	1.5	7.5
High Frequency	2.3	2.3	1.5	9.5

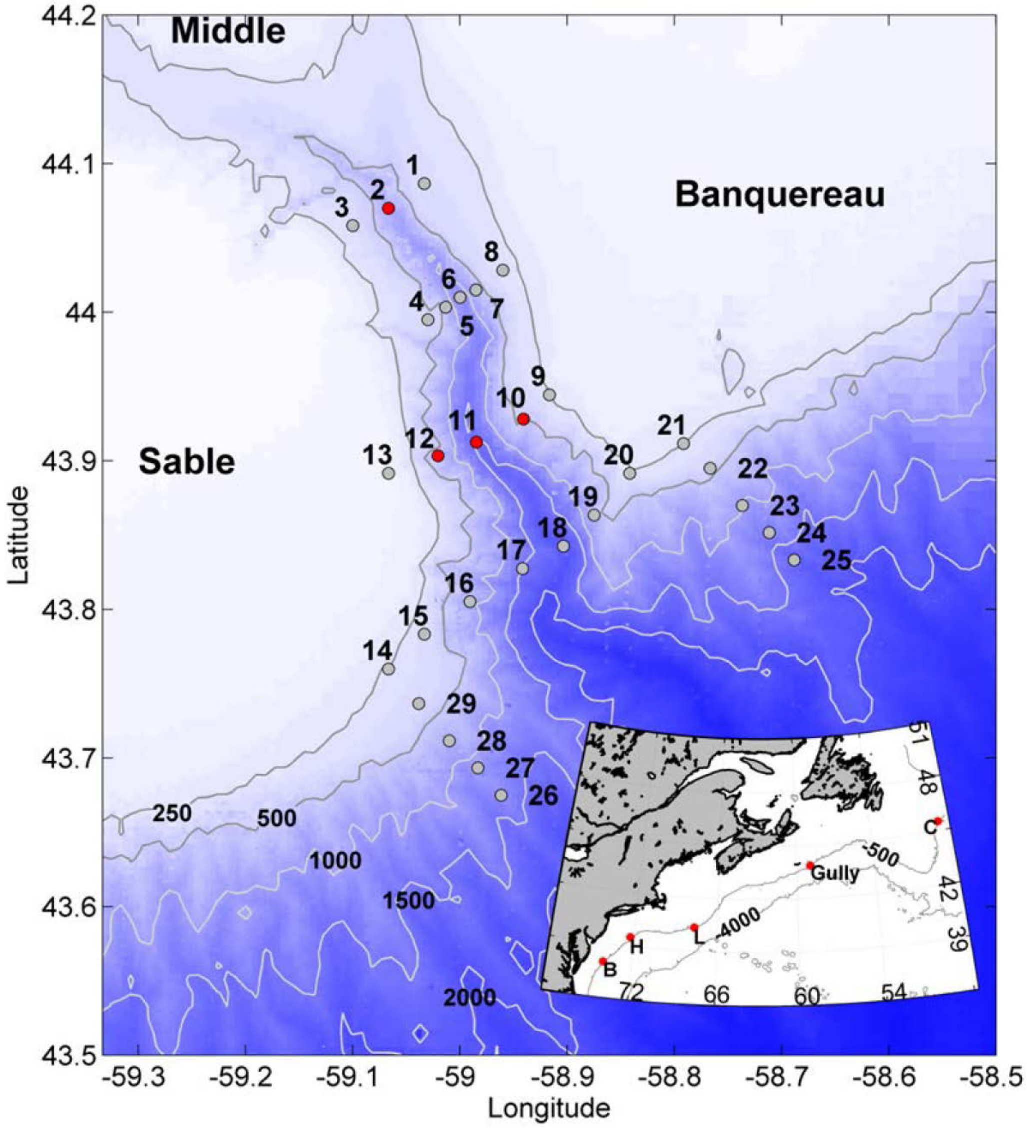


Figure 25-1: Schematic of the Gully field program with CTD stations (grey dots) and mooring sites (red dots) indicated. The inset shows the eastern North America shelf break region with other canyons which have been studied: Carson (C), Lydonia (L), Hudson (H) and Baltimore (B).

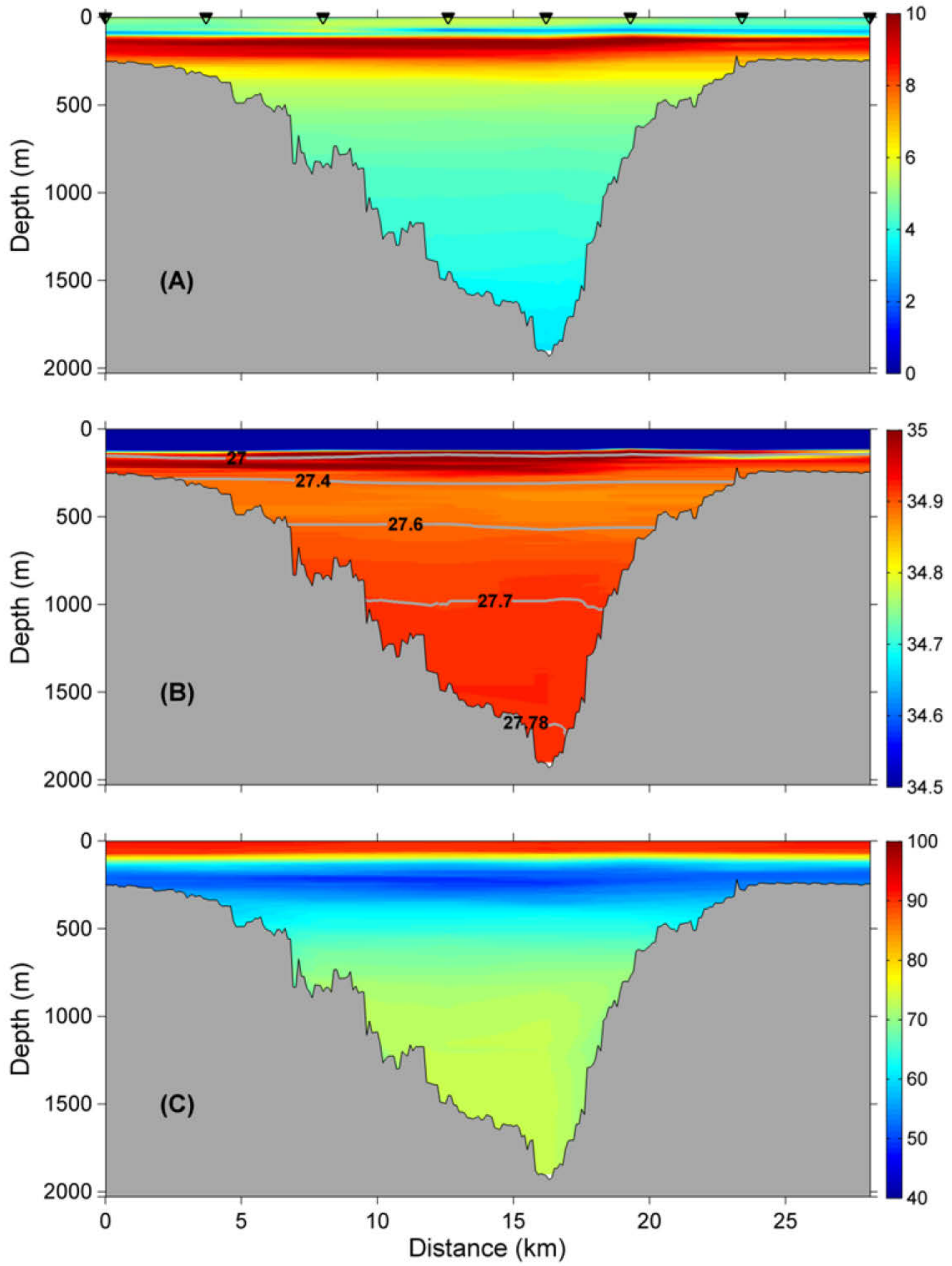


Figure 25-2: April 2006 CTD section (stations 14–21) across the mouth of the Gully showing: A) temperature (°C), B) salinity (with σ_T density contours, kg/m^3), and C) dissolved oxygen (% saturation).

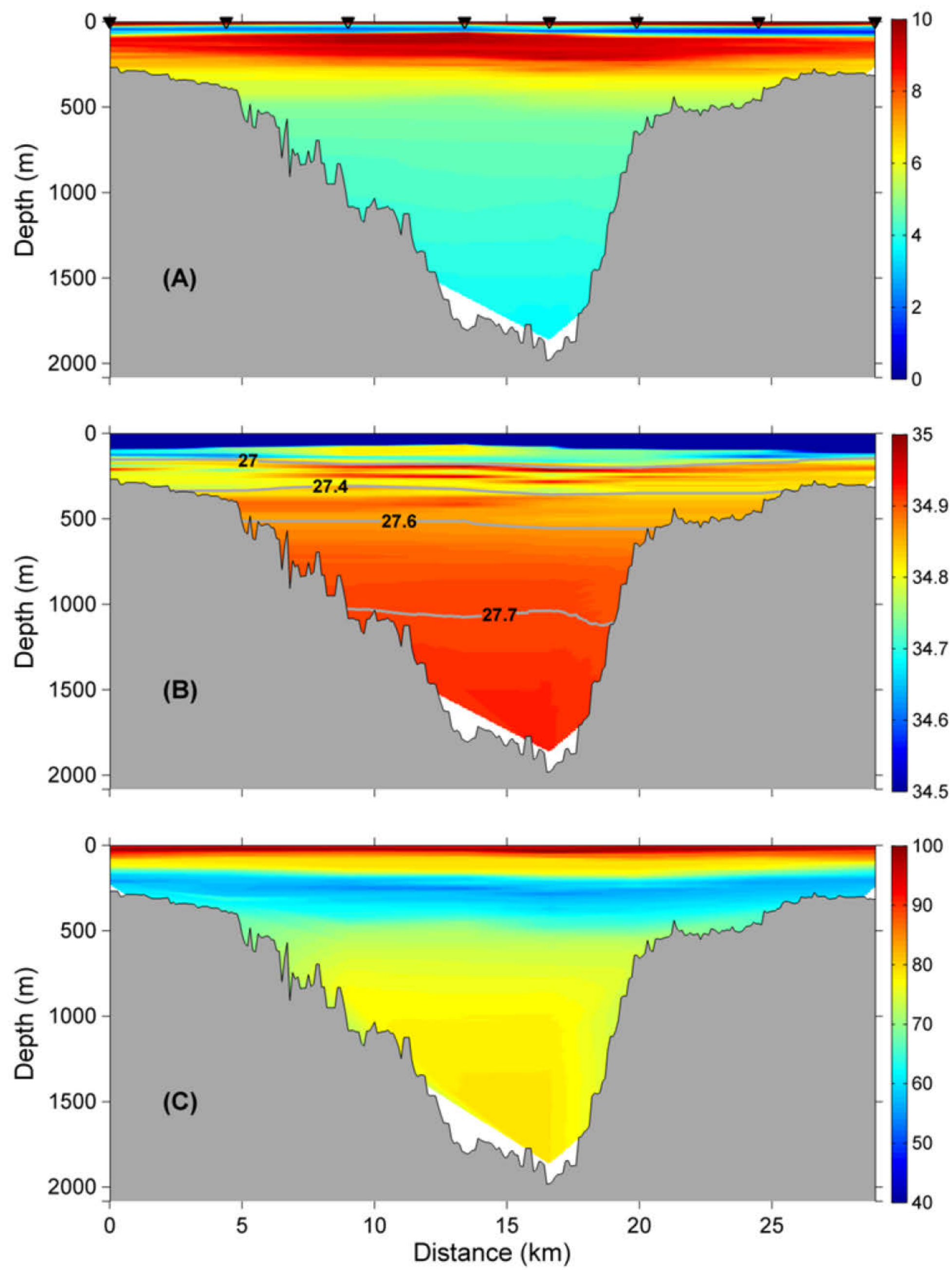


Figure 25-3: August 2007 CTD section (stations 14–21) across the mouth of the Gully showing: A) temperature (°C), (B) salinity (with σ_T density contours kg m^{-3}), and (C) dissolved oxygen (% saturation).

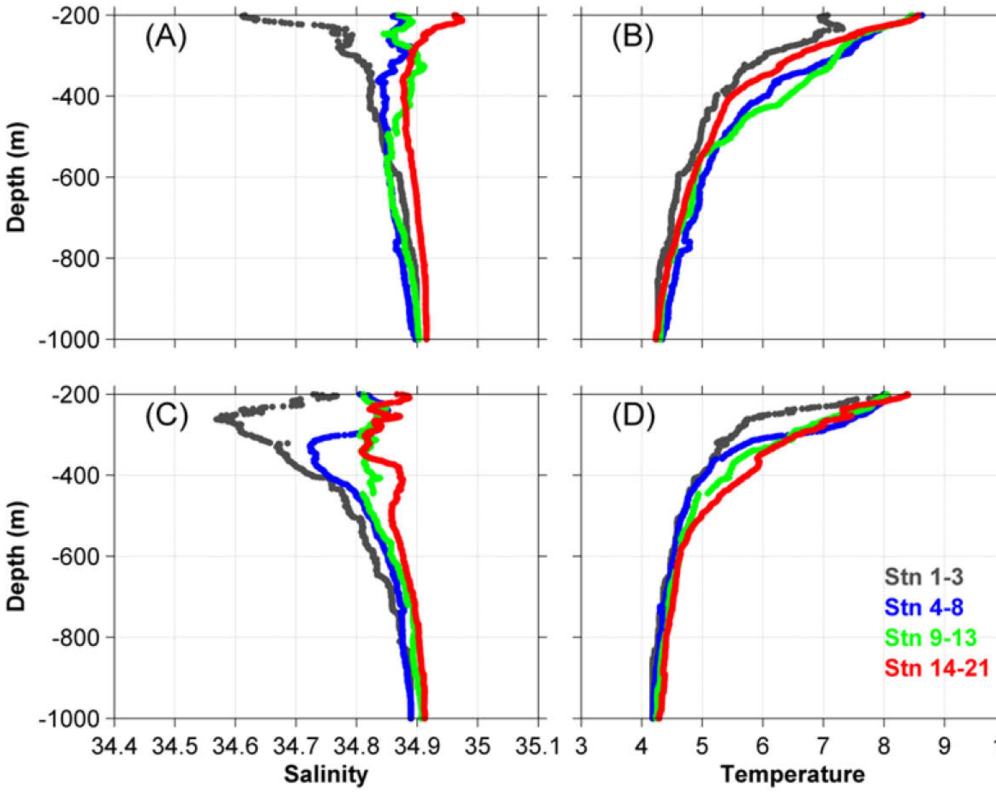


Figure 25-4: Section-averaged salinity and temperature (°C) profiles for the 2006 (A and B) and 2007 (C and D) CTD surveys. The vertical range has been limited to depths below the canyon rim (200 m) and above 1000 m.

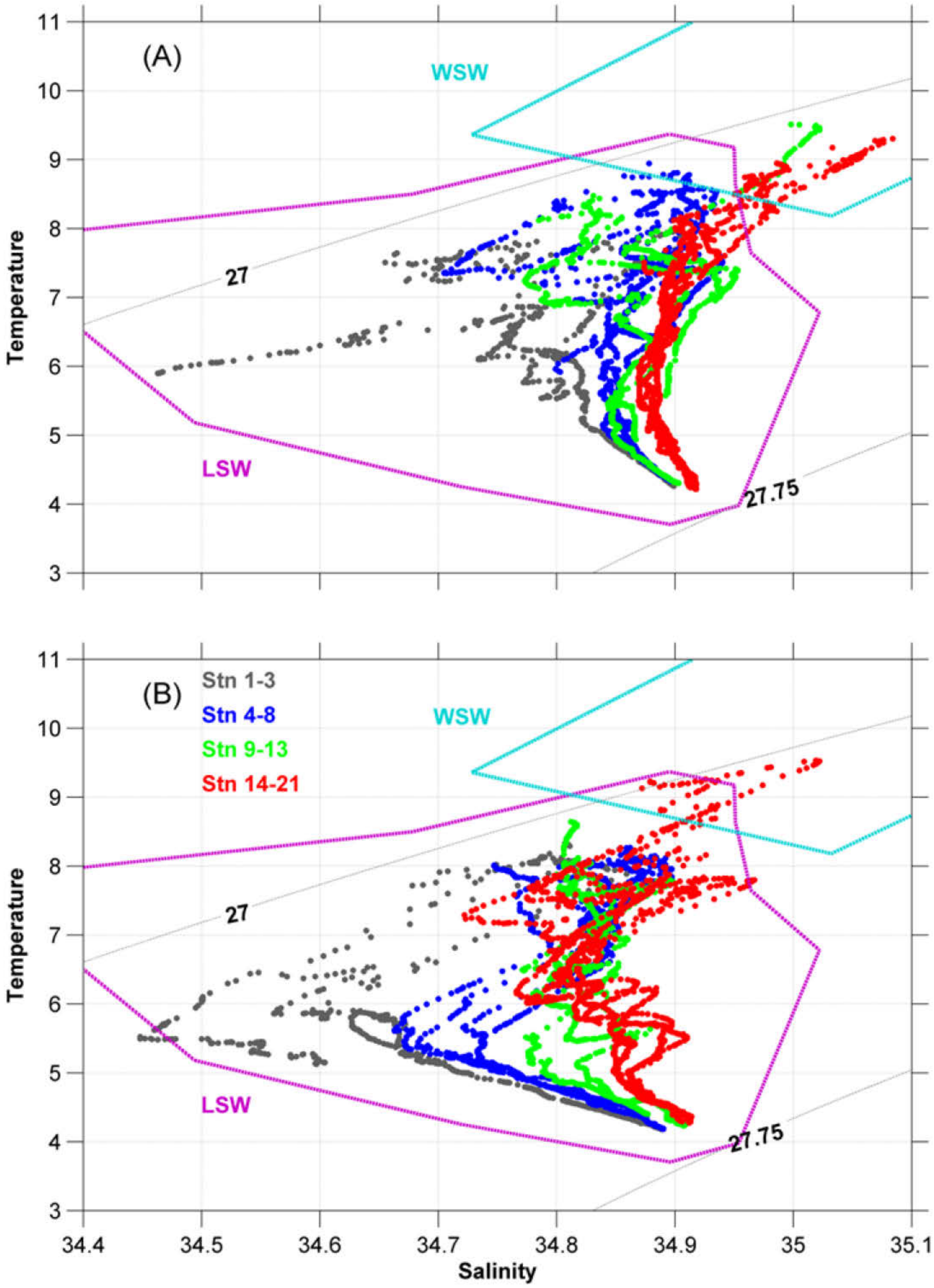


Figure 25-5: T–S plots based on the CTD surveys in 2006 (A) and 2007 (B) for 200–1000 m. Profiles for each section are colour-coded. Isopycnals are shown as sloping, grey shaded lines. T–S envelopes, based on Gatien (1976), are presented for LSW (magenta) and WSW (cyan).

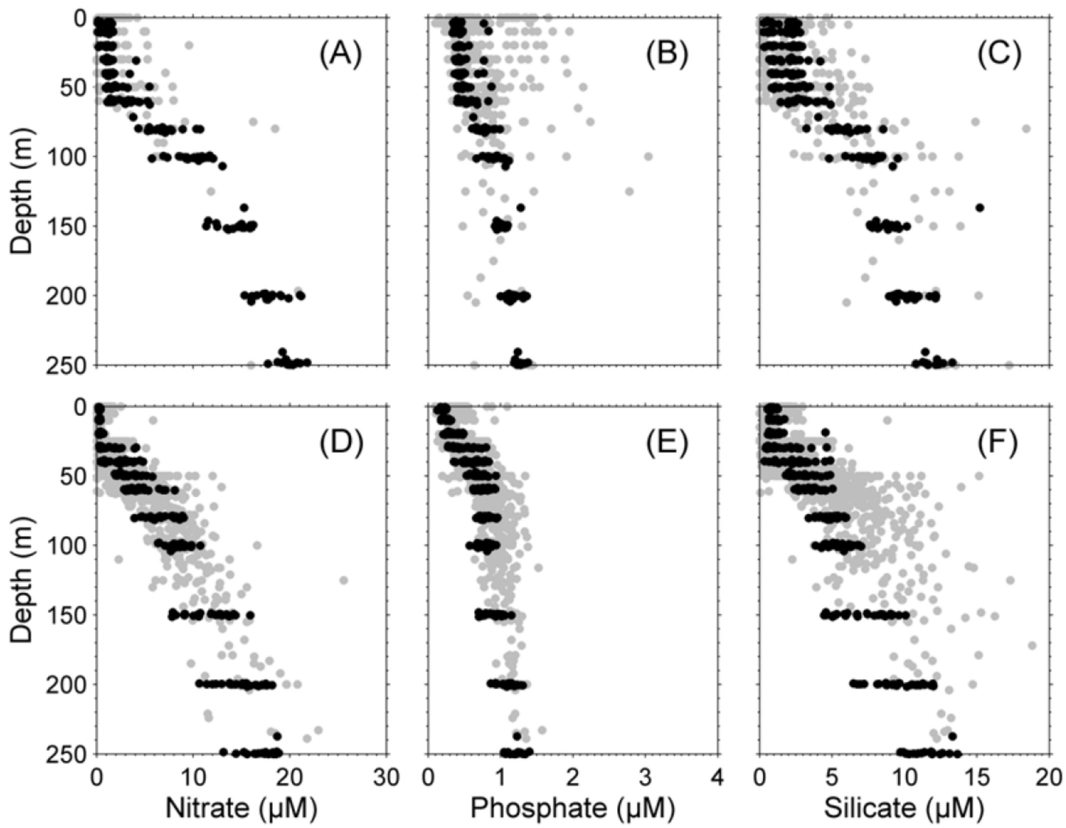


Figure 25-6: Nitrate, phosphate and silicate concentrations for the Gully (black) for April 2006 (upper panels) and August 2007 (lower panels) and for three adjacent areas (Banquereau, Middle and Sable Island Banks, grey) in April–May (upper panels) and July–August (lower panels).

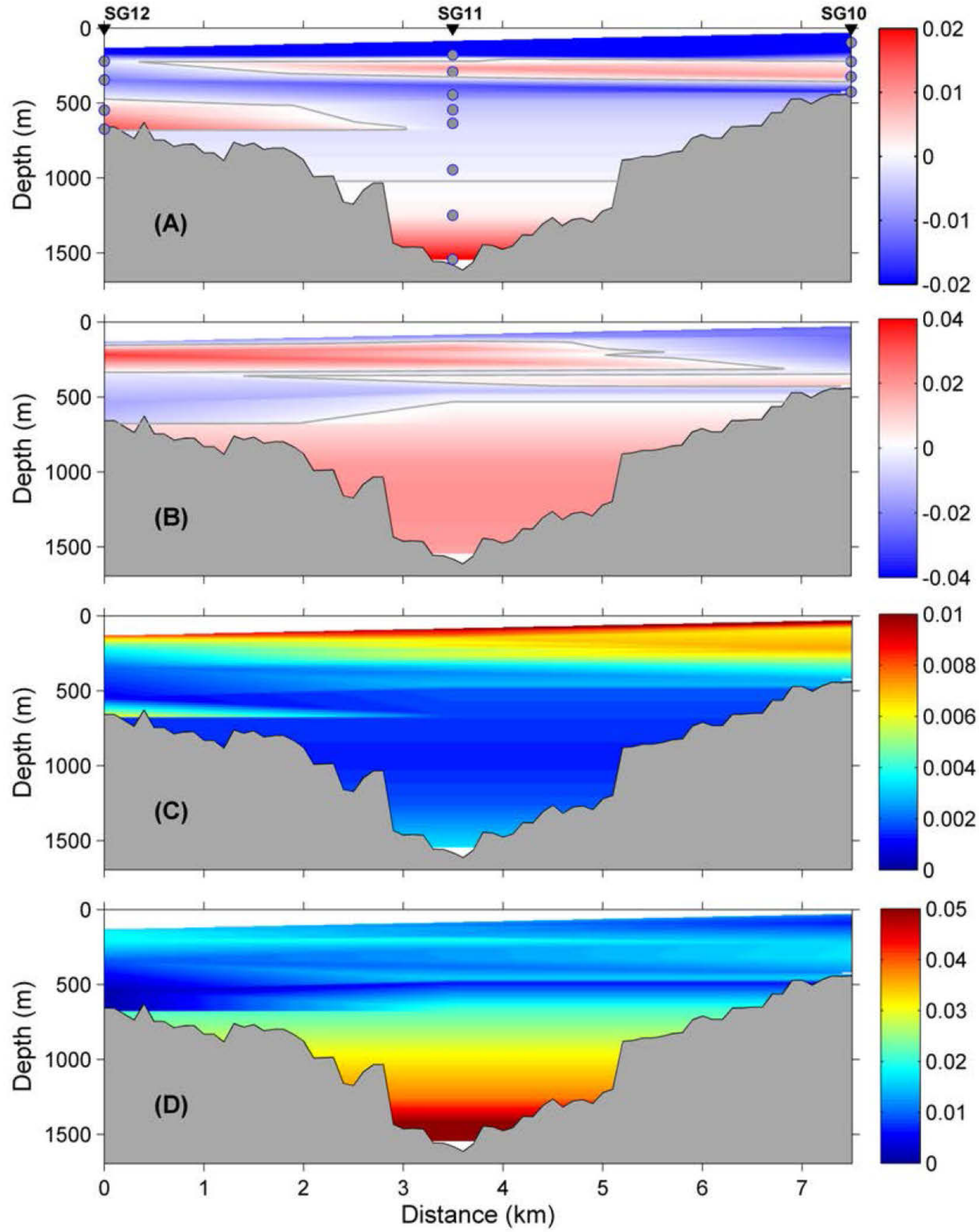


Figure 25-7: Average estimates from SG10, SG11 and SG12 moorings for: A) across-canyon speed (m/s, positive northeast), B) along-canyon speed (m/s, positive northwest), C) across-canyon variance of speed (m^2/s^2) and D) along-canyon variance (m^2/s^2). Grey lines in the top two panels represent the 0 m/s contour.

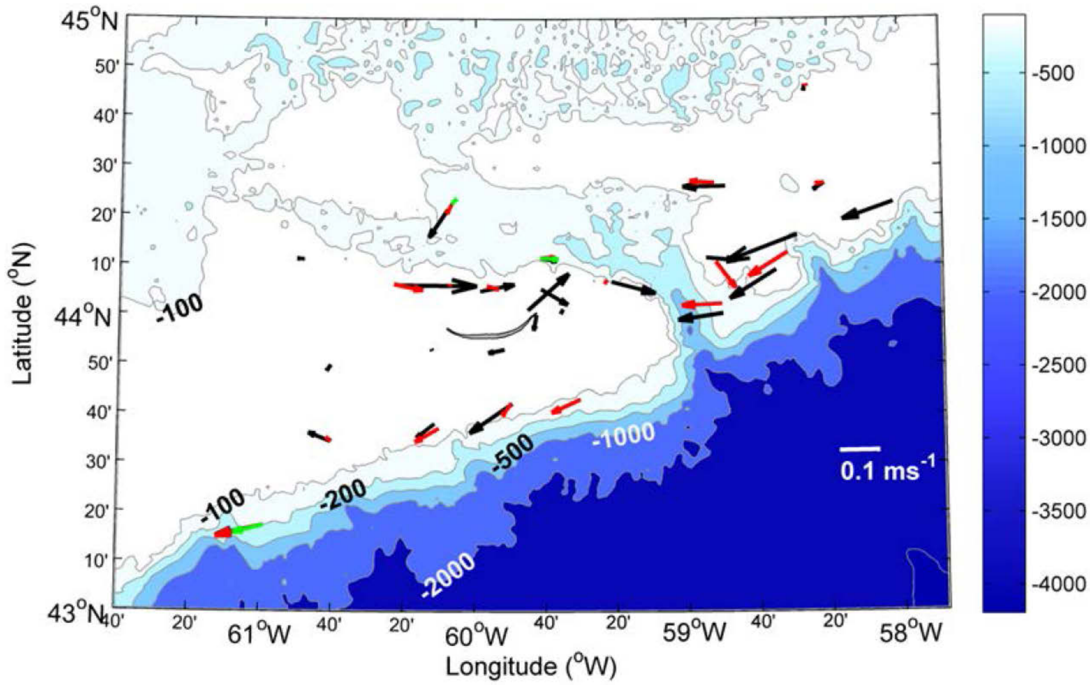


Figure 25-8: Mean currents averaged in three layers in the Sable Gully region from BIO archived data. The three layers presented are 0–50 m (black), 50–100 m (red) and 100–150 m (green).

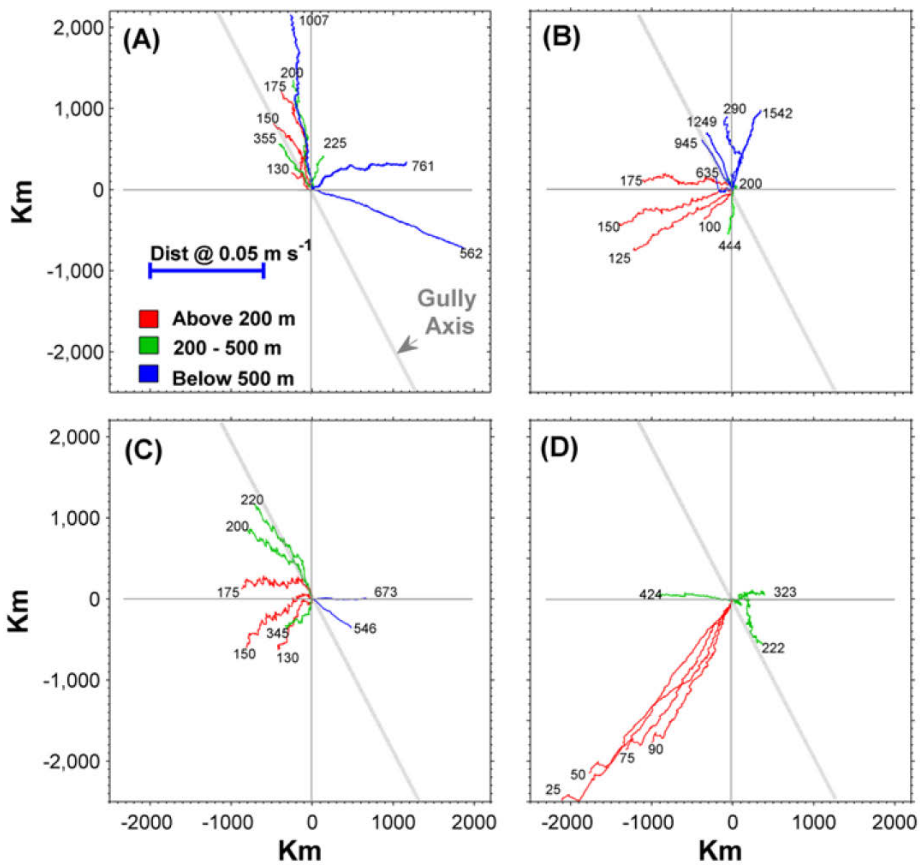


Figure 25-9: Progressive vector diagrams for: A) SG2, B) SG11, C) SG12 and D) SG10 moorings. The approximate direction of the Gully axis is shown as a light grey line. The scale in A) shows the distance travelled over the entire observation period for an average speed of 0.05 m/s. Lines are colour-coded based on instrument depth: red (<200 m, shallower than the canyon rim), green (mid-depth) and blue (deep). The number at the end of each line denotes the nominal instrument depth in metres.

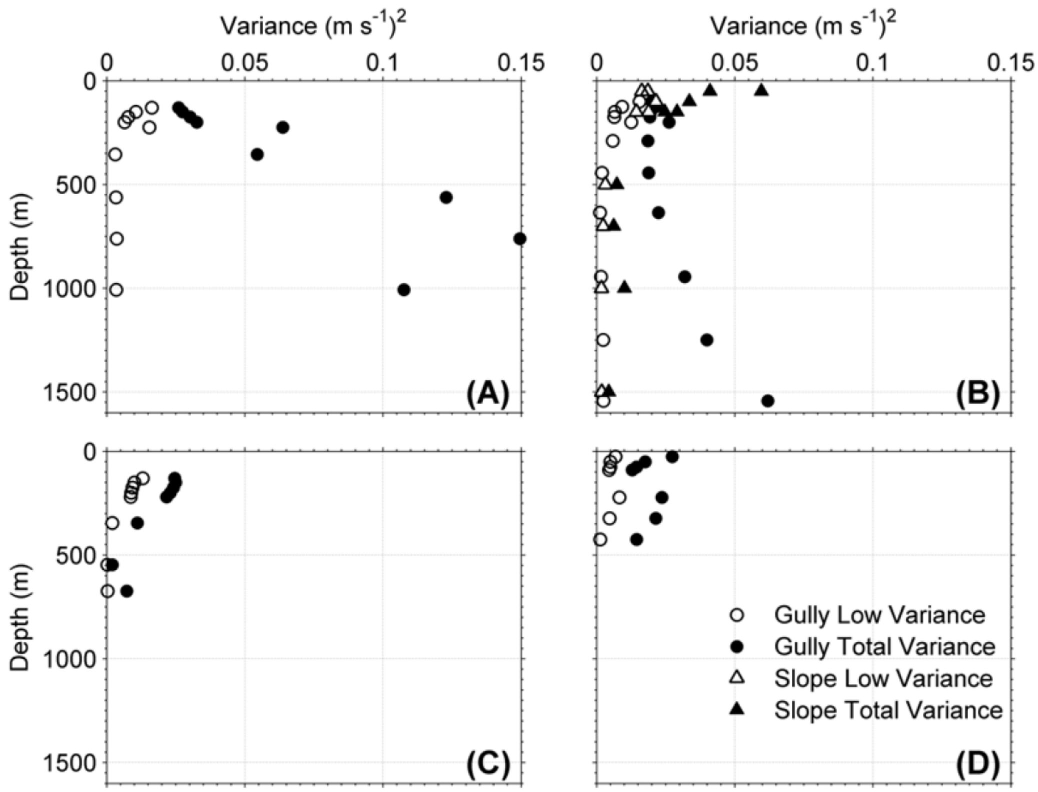


Figure 25-10: Variances derived from instruments at mooring sites A) SG2, B) SG11, C) SG12 and D) SG10. Variances from Scotian Slope moorings at comparable bottom depths are shown for comparison. Variance is presented as low frequency (subtidal) and total components.

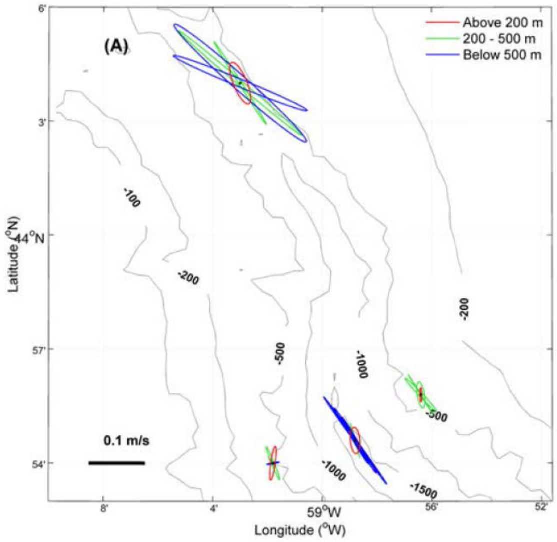


Figure 25-11: Tidal ellipses for the A) K1 and B) M2 tidal constituents. The ellipses have been plotted such that tidal excursions correspond to map geometry. Record depths are colour-coded.

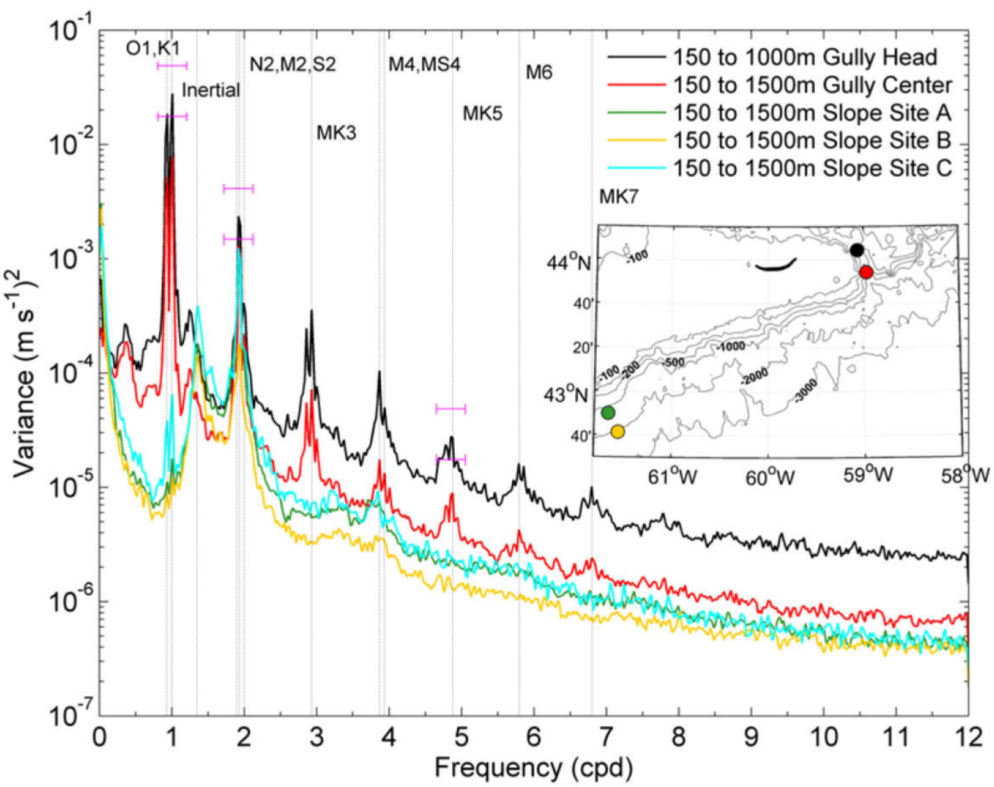


Figure 25-12: Spectra of depth-averaged currents for two locations within the Gully (black and red dots) and three locations on the Scotian Slope. Site C, not shown on the inset, is located at approximately 42.67°N and 63.5°W. Observations from sites A and B are from 2000 to 2004 (Loder and Geshelin 2009); observations from site C are from 1975 to 1978 (Smith and Petrie 1982). Vertical grey lines correspond to tidal and inertial frequencies. Ninety-five percent confidence levels are shown for the Gully Head record at diurnal, semi-diurnal and 5 cpd frequencies.

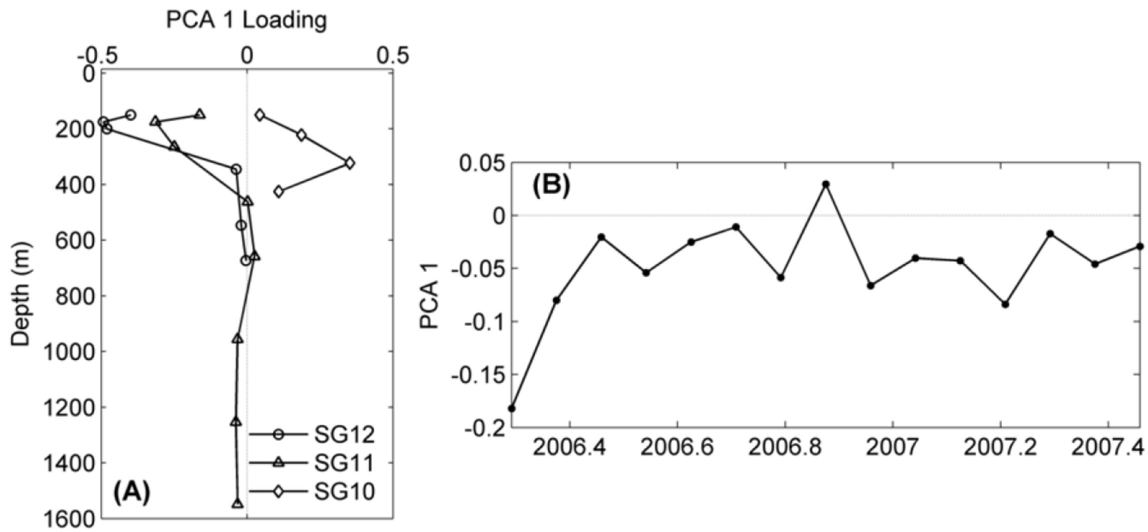


Figure 25-13: A) Loadings for the first mode of a principal component analysis based on the covariance matrix of the along-Gully monthly currents for depths ≥150 m, moorings SG10–12. B) Time series of PCA1 for the period of the mooring deployment.

Indicator 26: Phytoplankton production, community composition and the timing of the spring bloom in the MPA and the surrounding region

Indicator 27: Zooplankton biomass, community composition, and the biomass of selected species (e.g., Calanus spp. and carbonate-forming) within the MPA

E. Head

Available data

Biological data from AZMP-dedicated cruises have been collected each spring and fall since 1999 (with some gaps due to operational problems). There is sampling at one station within the Gully MPA and three across the mouth of the Gully on most missions and at fixed stations along the Louisbourg and Halifax Lines on every mission (see: Figure 21-1).

Biological data are also collected at a subset of the trawl stations occupied during groundfish survey missions on the Scotian Shelf in March and July. Stations are assigned according to a ‘random stratified survey’ design; none are located within the Gully. Sampling started in 1999.

Biological data are collected at stations of the Extended Halifax Line, generally during the fall AZMP missions (late-September to early-October) and on annual AZOMP sampling missions to the Labrador Sea (late-May to early-June) (see: Figure 21-1). The Extended Halifax Line has been sampled regularly since 2008.

Biological data were collected within the Gully in April 2006 and August 2007 in conjunction with work for Indicator 25. Biological data were also collected during SSIP survey missions between 1978 and 1982, on missions made by Dalhousie University scientists in July 1993 and by DFO scientists in July 1995, June and November 1996 and April, October and November 1997.

Phytoplankton

Between 1978 and 1986. and almost continuously since 1998, data have been collected by various satellites carrying sensors that measure ocean colour. These data, along with historical measurements of the parameters that describe the relationship between photosynthesis and irradiance, characteristics of chlorophyll profiles and modelled underwater light fields can be used to make estimates of primary production. However, the methodology for making these calculations is still under development. Parameters describing relationships between photosynthesis and irradiance (P-I parameters), in relation to temperature in the northwest Atlantic, were determined in experiments run at stations on the Scotian Shelf during DFO missions between 1976 and 2004.

Samples were collected for the microscopic identification of phytoplankton species between depths of 0 and 50 m during spring and fall AZMP missions to the Scotian Shelf since 1999 and sporadically in the Labrador Sea sporadically since 1996.

Zooplankton

Vertically-stratified net tows are made using the BIO Net Environmental Sampling System (BIONESS) at stations in the Gully, Roseway Basin and Emerald Basin and in Cabot Strait during spring and fall AZMP missions. The BIONESS is the only system deployed in the AZMP that captures euphausiids quantitatively.

Data collection

During AZMP missions, profiles of temperature, salinity, oxygen, underwater light intensity and fluorescence are taken, and water samples are collected at fixed depths for the determination of nutrient and chlorophyll concentrations. Water samples are collected at the surface to measure the concentration of POM, phytoplankton pigment composition and absorption spectra.

During AZOMP missions, profiles of temperature, salinity, oxygen and fluorescence are taken and water samples are collected at fixed depths for the determination of nutrient and chlorophyll concentrations.

Phytoplankton

Satellite measurements of ocean colour were made from 1978 to1986 using the Coastal Zone Color Scanner (CZCS). Thereafter, remote sensing of ocean colour did not occur until the fall of 1997 when the SeaWiFS came on line; it ceased functioning in 2010. In 2002 MODIS Aqua and MERIS colour sensors came on line (the latter currently non-functioning).

Samples have also been collected in the AZMP and the AZOMP for the detailed analysis of pigment composition using HPLC, to obtain some taxonomic information. Techniques have also been developed that allow for limited taxonomic information to be derived from remotely-sensed ocean colour but, as for the HPLC sampling, observations are only at the surface.

Zooplankton

Vertically-stratified tows (200 μm mesh) were made using the BIONESS, towed obliquely at a variety of stations, including a series of six tows (three day and three night) in the Gully in the fall of 1989; several in Emerald Basin in spring and fall over several years; and some in other Scotian Shelf basins. Similar tows are performed at stations in the Gully, Roseway Basin and Emerald Basin and in Cabot Strait during spring and fall AZMP missions.

Mesozooplankton samples are collected by means of vertical net (200 μm mesh) hauls at all standard stations during AZMP missions. Tows are from the bottom to surface, or from 1000 m to surface if the water depth is greater than 1000 m. Vertical ring-net tows (200 μm mesh, 0–100 m) were carried out on some trips prior to AZMP. Oblique Bongo net tows (333 μm mesh) were made during the SSIP. Note the larger mesh size, use of Bongo nets (not ring nets) and the different tow direction (obliquely not vertically) in SSIP tows.

Vertically-stratified vertical (ship-stationary) zooplankton net tows (200 μm mesh) are made using the MultiNet system at one or more of the stations along the Gully mouth and at stations on the Louisbourg, Halifax and Browns Bank Lines beyond the shelf break in fall only. These tows are to examine the overwintering depth distribution and abundance of *Calanus* copepod species. Tows are to a maximum depth of 1000 m, with sampling restricted to five strata.

Analysis

Phytoplankton

A method for the calculation of primary production from remotely sensed measurements of SSC and a series of other variables is currently under development. The other required variables include SST, measured (or modelled) sea surface and underwater light intensity, empirically derived values for P-I parameters and the shapes of chlorophyll profiles (related to SST).

The algorithms for the conversion of remotely-sensed ocean colour to chlorophyll concentration are constantly being updated by NASA. They vary among sensors and during the lifetimes of the sensors, which may change orbit affecting sensitivity. Re-processing of existing data occurs on a regular basis. The Remote Sensing Group at BIO, headed by Carla Caverhill, can provide information as to the state of operations at any particular time. SST conversion algorithms are more robust, but a description of the satellite data processing routines is beyond the scope of this document.

Satellite data are compiled by the Remote Sensing Group at BIO. The SST record complements that for SSC. In the AZMP, data are averaged over two-week periods throughout the year and maps of SSC and SST are created for the northwest Atlantic. These are available on the DFO Operational Remote Sensing website. The timing of the spring bloom is determined for standard 'boxes' of the Scotian Shelf from the time series of SSC (see: Figure 23-1). The results of these analyses are reported annually at AZMP meetings and in government research documents. The standard AZMP boxes do not include one optimized for the Gully.

Although broad taxonomic characterisation of the phytoplankton, based on pigment composition, is possible in theory, it has not been applied to the data for the Scotian Shelf, for which there are data from around 1999.

Zooplankton

Samples from BIONESS vertical ring-net tows are analyzed according to AZMP protocols, but only when funding is available. The AZMP sample analysis protocol includes identification and enumeration of the most abundant species/stages. Bulk wet and dry weight measurements are also routinely made.

Zooplankton biomass and *Calanus finmarchicus* abundance are measured over the entire water column and are also reported as station average values for the AZMP standard sections (Figure 26-1). In samples from the vertically stratified net tows made using the MultiNet system, generally only *Calanus* species and stages are identified and enumerated.

Results

Baseline values exist for the variables reported in AZMP, although only for the standard boxes for satellite measurements of SST and SSC, and only for the Louisbourg and Halifax line for field observations of nitrate and chlorophyll concentrations and zooplankton biomass and *C. finmarchicus* abundance. In general, they are the mean values over the duration of AZMP. Phytoplankton and zooplankton species compositions are not generally reported in AZMP and neither are euphausiid biomass and abundance values.

Time series for zooplankton biomass and *C. finmarchicus* abundance (Figure 26-1) are available for the Louisbourg and Halifax lines and for nitrate and chlorophyll concentration (Figure 26-2). There have been no obvious long-term trends in physical, chemical and biological variables since 1999 for AZMP sampling along the standard sections. In contrast, there is generally a high level of inter-annual variability for some variables, such as the concentrations of chlorophyll and zooplankton in April, due to the ephemeral nature of spring blooms and changes in the seasonal cycles of phytoplankton and zooplankton production.

It should also be noted that sampling in the near-surface layers (0–100 m) at stations within the Gully showed relatively little spatial variability in the distribution of phytoplankton (chlorophyll concentration) or zooplankton (biomass) during the dedicated Gully study carried out in April 2006 and August 2007 (Figure 26-3), although this program would not have sampled euphausiids quantitatively.

Phytoplankton

There was a weak ($p<0.05$) upward trend in the annual average concentration of SSC on the Eastern Scotian Shelf between 2004 and 2011 and there was considerable inter-annual variability in the timing and intensity of the spring bloom during those years (see: Figure 23-3). Annual average SSTs have not changed consistently over the same period, although they have shown a general slight upward trend, with highest values in 2006 and 2010. There are, as yet, no time series for primary production for any regions of the Scotian Shelf. Time series of SST for several of the standard satellite boxes on the Scotian Shelf and in the Gulf of Maine, including the Eastern Scotian Shelf, have shown upward trends since 1985, although with considerable inter-annual variability (see: Figure 23-4).

The one time series that has been constructed for the Gully specifically is for SSC, remotely-sensed by the MERIS ocean colour sensor from 2009 to 2011. This sensor had greater spatial resolution than any of the others, which made it especially suitable for use the relatively small area chosen to represent the Gully (see: Figure 23-2). Interestingly, the bloom characteristics seen for the Gully box between 2009 and 2011 (see: Figure 23-2) do not closely resemble those seen for the Eastern Scotian Shelf box (see: Figure 23-3).

The time series demonstrates the problems that arise when applying satellite technology to small areas: the time series are ‘spiky’ because only a relatively small number of pixels contribute to each data point. This satellite has now failed, so high resolution ocean colour data are not currently available, although another sensor is being developed for a launch in 2013.

Zooplankton

There are systematic time series observations for the Louisbourg and Halifax Lines, although only data for selected categories (*e.g.,* total biomass, total *C. finmarchicus* abundance) are routinely reported in AZMP (Figure 26-1). There are, however, data on the abundances of all of the most abundant species at individual stations in the BioChem database. Biomass and species abundance data for samples taken using the BIONESS, and for ring net tows other than those on standard sections (including some from the Gully), are also held in BioChem, for the samples that have been analyzed. For the MultiNet tows there are generally only abundances and stage distributions of *Calanus* species.

The vertical distribution of euphausiids showed peaks in the near surface layers and at depths of between 300 and 500 m, and a high level of spatial variability (range 162–3696 individuals/m^2), with the highest abundance at a station well inside the Gully, having a bottom depth of 240 m (at about 44.2°N and 59.2°W). *C. finmarchicus* were mainly at their overwintering depths of >200 m and overall abundance increased with increasing bottom depth.

Evaluation of existing protocols for meeting indicator monitoring requirements

Remotely sensed SSC and SST data are available for the entire northwest Atlantic, including the Scotian Shelf and Gully regions on an ongoing basis. Maps of satellite measurements of SSC and SST have been made for two-week periods since fall 1997 and between 1978 and 1986, but data have not been put together to give long-term time series for the Gully region specifically (although this could and should be done to fulfill Gully MPA Monitoring needs). Baseline values could also be calculated for the time series of measurements for satellite observations in the Gully box or for field observations made at the one fixed station that has been sampled bi-annually in the Gully.

Primary production estimates based on remotely-sensed variables are not currently available, although methods for their calculation are under development. In part this is because the spatial resolution of some of the satellite sensors has been inadequate, and in part (for SSC) because of problems cross-calibrating between the different sensors. Thus, for example, while the patterns of seasonal variations in chlorophyll may be comparable, so that there could be a complete times series of the timing of the spring bloom, the actual concentrations achieved may not be comparable among sensors. Nevertheless, an effort aimed at optimizing the methodology could be undertaken, which would allow construction of time series to data and reporting of ongoing satellite measurements in support of Gully MPA monitoring.

Only one station within the Gully is sampled on AZMP missions. BIONESS sampling at multiple stations in October and November 1989 suggests that the current single AZMP ‘add-on’ station probably does not give a good representation of the overall abundance of euphausiids in the Gully. Equally, the abundance of *C. finmarchicus* at depth in fall may also be poorly represented by this single sampling station, which is at approximately 500 m depth, near the western edge of the canyon. Abundances are probably greater in areas with greater bottom depths. Monitoring efforts in the Gully would be substantially enhanced by making the current station the westernmost of a three-station transect across the canyon. There should be BIONESS sampling at all three stations along with the collection of temperature, salinity, pH and oxygen profiles, as well as water samples for the determination of chlorophyll and nutrient concentrations. This enhancement of Gully monitoring would require extra funding for zooplankton sample analysis plus the commitment of an extra half day for the sampling time plus the time needed to compile and report the data. It is also possible that the issue of spatial variability in euphausiid distribution could be better addressed by using acoustics or by the sampling undertaken in the mesopelagic monitoring component of the Gully monitoring program (see Indicator 20).

The data collected in the Gully since 1999 during AZMP missions are largely unexamined. It is clear that there is a need to analyze these time series measurements and to put them in the context of the AZMP standard reporting of data from the Louisbourg and Halifax lines. This will 1) capitalize on the sampling that has been carried out to date, 2) help define baseline levels for variables particular to the Gully (e.g., for euphausiids) and 3) assist in refining the Gully monitoring program (e.g., by identifying whether there is a need for more sampling stations). There is a great deal of overlap between the information required for monitoring in the Gully and that already reported to AZMP and it seems logical that the reporting be combined. One suggestion is that the additional Gully data from satellites and the field be included in the AZMP research documents in the form of an appendix, so that the current form of the AZMP research documents is conserved.

Threats to ongoing monitoring

AZMP has carried out a minimal Gully monitoring sampling effort over the last 12 years, but it cannot be guaranteed that this will continue, without dedicated funding. With ever increasing financial constraints being put on programs non-core elements from AZMP sampling missions, such as sampling in the Gully, could be eliminated.

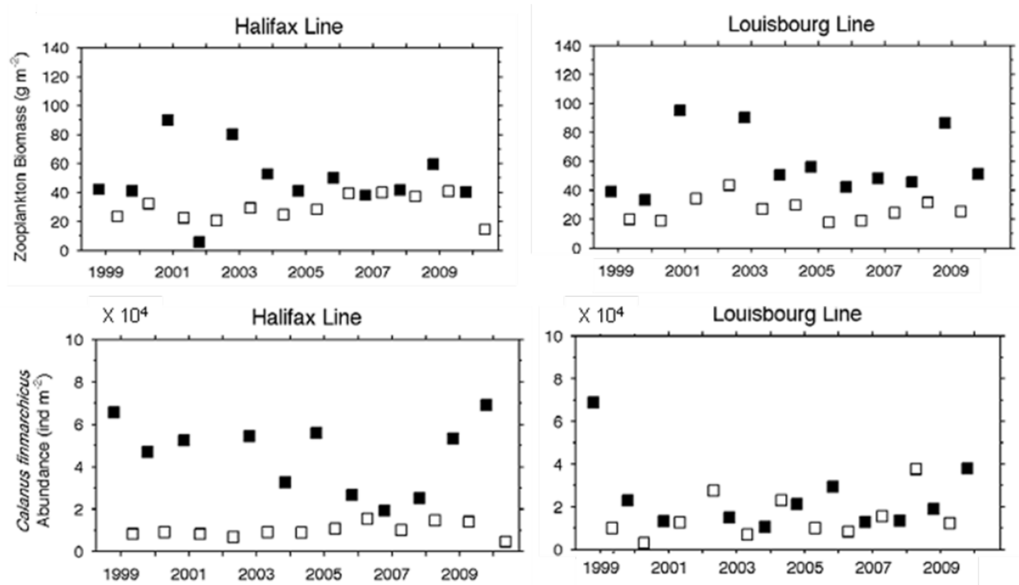


Figure 26-1: Total zooplankton biomass (g/m^2 wet weight) and total C. finmarchicus abundance (all stages) averaged for stations on the Halifax and Louisbourg Lines for spring (black square) and fall (white square) 1999–2010.

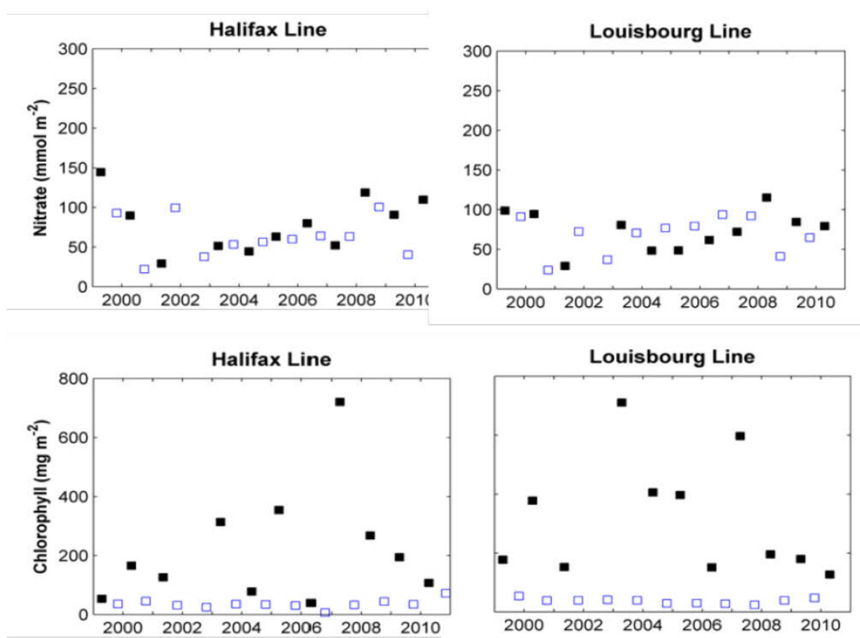


Figure 26-2: Time series for 0–50 m nitrate concentrations (upper panels) and 0–100 m integrated chlorophyll concentrations (lower panels) averaged over all stations along AZMP sections in spring (black squares) and fall (open blue squares). From Johnson et al. (2012).

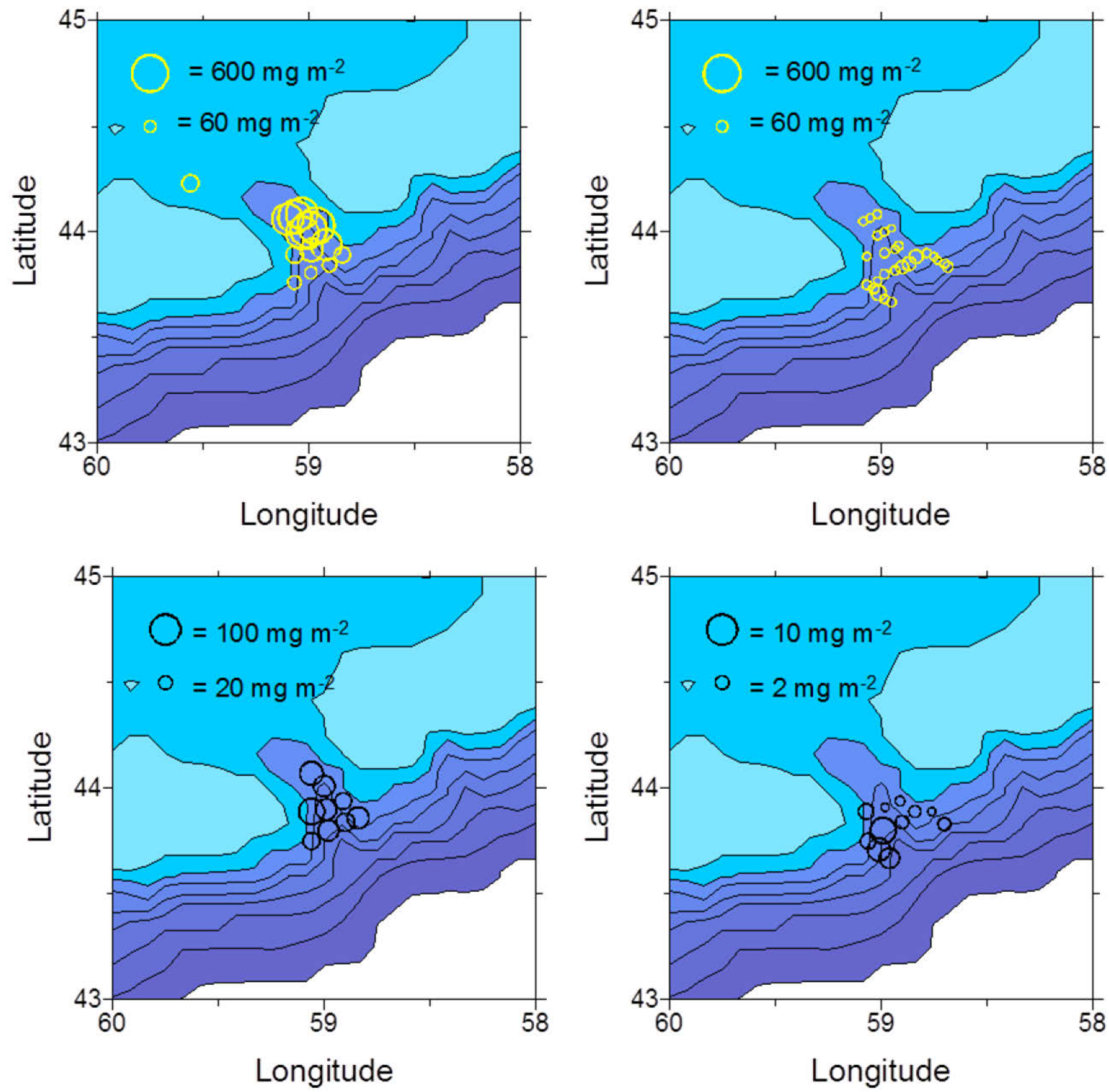


Figure 26-3: Integrated chlorophyll concentration (0–100 m, upper panels) and zooplankton wet weight biomass (0–100 m, lower panels) in the Gully in April 2006 and August 2007.

Indicator 28: Acoustic scattering in the water column within the MPA (as a measure of mesopelagic and zooplankton densities and distribution)

N. Cochrane

Suggested improvements to indicator wording

"Acoustic backscattering in the water column within the MPA (as a measure of mesopelagic and zooplankton densities and distribution)."

'Backscattering' as opposed to 'scattering' is a more precise term for the type of acoustics employed and carries a meaning immediately obvious to others in the discipline.

Available data

Two acoustic backscatter datasets are available for the Gully MPA:

- The Sable Gully Mesopelagic Survey program (in conjunction with trawl sampling).
- Data collected using DataSonics sounders on Scotian Shelf AZMP surveys and on a number of earlier scientific cruises.

The Sable Gully Mesopelagic Survey data was gathered on four cruises between 2007 and 2010 inclusive (Table 28-1). DataSonics sounder data was gathered on 31 cruises visiting the Gully MPA between 1984 and 2011 inclusive (Table 28-2).

Data collection

All reported Gully MPA backscatter data collections were ship-based using either hull transducers (pre-1992 DataSonics data) or a combination of hull and shallow-towed transducers. Many datasets included use of two or more frequencies chosen to distinguish fish from macrozooplankton backscattering (Tables 28-1 and 28-2). Gully MPA Mesopelagic Survey collections were continuous in time, consisting largely of multiple acquisitions (both day and night) along four standard trawl sampling transects labelled ‘Head’, ‘Main’, ‘Wall’ and ‘Deep’ (Figure 28-1). Sampling rates varied during acquisitions but were generally between 0.15 and 0.25 pings per second. Detailed descriptions are contained in Kenchington et al. (2009) and T. Kenchington (BIO, unpublished data). DataSonics acquisitions were mainly opportunistic and after initiation of the AZMP program, included sampling at some or all of Gully stations GULD2–GULD4 and SG23 and SG28 (Figure 28-1). Prior to 1999, DataSonics data collections were mainly event-driven; later collections have been mainly continuous. Inter-station transect lines were determined by cruise contingencies. More extensive DataSonics-based Gully surveys were undertaken in November 1999, and in April and October 2000. Both the spring and fall year 2000 surveys employed a saw-tooth pattern survey grid which covered portions of the upper MPA region and extended into the shallow Gully feeder area north of the MPA (Sameoto et al. 2002).

Analysis

Digital acoustic data from both the Mesopelagic Survey and the DataSonics-based studies have been gathered in or converted to HAC standardized hydroacoustic format, and along with navigation data, integrated into the acoustic database. Up to and including 1992, navigation data was interpolated from cruise logs or other sources; this resulted in survey tracks being somewhat less accurate than those characterizing later periods.

Results

Quantitative Mesopelagic Survey data spans an insufficient time to establish reliable trends and currently lacks analysis in the required manner. The longer DataSonics dataset is, for the most part, unsuitable for trend analysis due to lack of standardized sampling protocols, lack of absolute calibration on the low frequency channel (the most valuable for pelagic fish quantification) and other hardware limitations. The DataSonics datasets do contain valuable qualitative spatial and temporal data on biological distributions and behaviours within the Gully MPA. These are potentially of value in establishing future monitoring programs and protocols.

Evaluation of existing protocols for meeting indicator monitoring requirements

Both studies were exploratory in nature and the protocols employed were not specifically designed to constitute a long-term monitoring program. However, they have provided essential qualitative and limited quantitative information to advance more science-based monitoring protocols. Limitations of existing protocols for long-term monitoring can be summarized under the following four headings:

Planning

All studies related to backscatter in the Gully were highly variable (both spatially and temporally) with regards to inferred biological distributions. DataSonics survey lines were inconsistent in time and location which precludes inter-cruise comparisons. The standardized Mesopelagic Survey data collections are superior in this regard.

Hardware

The Gully Mesopelagic Surveys were conducted with Simrad echo sounders with capabilities approaching the theoretical performance limits of these instruments. Effective profiling depths on the mesopelagic surveys ranged from about 300 to 350 m at 120 kHz to 800 to 1000 m at 38 kHz. DataSonics surveys, in contrast, used more primitive technology which, while providing a common hardware platform over several decades, lacked the sensitivity, stability, extraneous noise rejection and dynamic range possible with modern sounding systems. For example, the restricted dynamic range of the DataSonics system was optimized to quantify daytime krill layers at depth (the main application in Emerald Basin) with the result that strong near-surface echoes from biological distributions at night are potentially clipped, preventing reliable quantification. Effective profiling depths at the most common operational frequencies of 200 and 12 kHz ranged from about 250 m to 500–600 m, respectively. Data at depths exceeding 310 m were recorded only infrequently. The limited 200 kHz DataSonics profiling range precludes quantitative assessment of krill layers by acoustic backscatter techniques at their anticipated daytime equilibrium depths of 300–400 m in the Gully mouth and southern Gully central channel. Some DataSonics data, especially at 12 kHz, is also compromised by false bottom echoes which occur as a result of pinging sounders at a rate exceeding the nominal backscatter logging rate in order to furnish high time resolution bathymetric data to other scientific systems.

A serious limitation of the mesopelagic dataset was that, except in 2009, only a single acoustic frequency was recorded. This prevents separation of fish from krill or similar-sized macrozooplankton on the basis of backscatter frequency response (see: Interpretation section below).

Calibration

The low frequency DataSonics channel (usually 12 kHz) was not absolutely calibrated (an attempt was made in the first decade to maintain a rough calibration) which precludes any inter-survey quantitative comparisons of fish backscatter at the preferred lowest frequency. Higher frequency channels (preferred for assessing macrozooplankton) with their associated transducers were tank calibrated. These channels, particularly at 200 kHz, are believed to have reliable calibrations for inter-survey and longer-term variability and trend studies.

The Simrad echo sounders used on the Mesopelagic Survey were calibrated in the DFO Newfoundland and Labrador Region prior to specific surveys. There is some uncertainty, perhaps yet resolvable, in the accuracy of these calibrations at survey time and whether calibrations were properly applied during the field acquisition and subsequent analysis. Most analysis to date has been qualitative.

Interpretation

Very limited quantitative interpretation has been performed on collected Gully backscatter acoustic datasets, and detailed interpretative protocols are yet to be defined. Nevertheless, some general comments regarding interpretational approaches may be useful. A measured acoustic backscatter level at a single acoustic frequency originating from an unidentified water column biological scatterer cannot yield a direct measure of biomass density or column-integrated biomass. Considering zooplankton alone, the relation between backscattering level and biomass density can span orders of magnitude depending on species (Stanton et al. 1996). To achieve a reliable inversion of backscatter to biomass, the nature of the acoustic scatterer(s) must be known and the proper organism-specific physical or empirical acoustic scattering model(s) must be employed. In practice, by observing simultaneous acoustic backscatter levels at two appropriately chosen acoustic frequencies, it is often possible to correctly surmise from the comparative levels whether an observed layer is dominated by fish or macrozooplankton. In the case of macrozooplankton, current or historical direct sampling may help to characterize the population by size or by species with reasonable confidence. If so, an appropriate scattering model, if available, could yield a successful inversion of acoustic levels to biomass. If there is no detailed compositional information or if reliable scattering models do not exist, the comparative backscatter frequency responses alone could be used to characterize a specific biological layer and map its spatial extent, perhaps delineating the characteristics of its diel vertical migration. This is the extent to which acoustic analysis in the Gully has been performed to date.

If, however, the species composition of distinct and separable, acoustically-delineated biological layers were to remain relatively constant over seasonal and multi-year time scales, testable to a degree using independent direct spot sampling, the comparative backscattering levels between properly designed repeat acoustic surveys might serve as proxies for actual biomass variations. This would enable valid spatial–temporal abundance studies of contrasting biological classes (e.g., macrozooplankton or mesopelagic fish) even in the absence of the full compositional data or detailed acoustic models required to rigorously reduce backscatter measures to biomass. Clearly, acoustic techniques constitute a rather ‘blunt’ instrument for inferring population changes at the species level. However, if backscatter techniques permit broad classes of aggregating organisms to be consistently identified and separated at long-term fixed sites or on periodically repeated steamed lines or grids, the quantitative variability of backscatter levels might well be directly employed for spatial–temporal monitoring purposes offering the distinct possibility of discerning gross fluctuations in the Gully ecosystem.

Two fundamental recommendations are made: 1) all future acoustic observations must be carefully calibrated; and 2) all future acoustic observations should be made at two or more frequencies optimized to separate fish from macrozooplankton. Frequencies of 38 kHz and 120 kHz are commonly used. Matched, or approximately matched, beamwidths are also advantageous.

The degree of temporal aliasing in the existing Gully MPA acoustic datasets is a major unknown considering the dynamic nature of oceanographic and biological processes in the area. Knowledge of both the character and degree of temporal variability would allow critical assessment of the utility of infrequent future ship surveys. The required knowledge of time domain variability might be obtainable from long duration deployments of continuously sampling, moored echo sounders. Critical areas, central and southern areas of the Gully MPA and especially those areas subject to mesopelagic fish population incursions, lie in deep waters (>500 m) with surface layers out of convenient range of higher-frequency bottom-mounted sounders; however, upward-looking moored sounders could sample continuously at a very low rate (also precluding adverse effects on marine mammals) over multi-month deployments. Within DFO Maritimes Region, the St. Andrews Biological Station (SABS) has procured and is currently evaluating the use of ASL Ltd. self-contained, programmable echo sounders suitable for long-duration moored (or bottom-mounted) deployment. These units are available in a nearly optimal dual-frequency configuration of 38 kHz and 125 kHz at an approximate cost of $45,000 per unit, depending on configuration.

On the basis of qualitative study of both the existing Mesopelagic Survey and DataSonics based data, two tentative locations in the Gully MPA are suggested. The first is a deepwater site at the Gully mouth in the vicinity of GULD4, reasonably close to the north end of the ‘Deep’ mesopelagic sampling line (Figure 28-1). The specific site would probably be displaced to one side of the channel, limiting mooring deployment depths to 1500 m. The main target would be migrating mesopelagics (the myctophid *Benthosema glaciale* and other species) in the upper 200 m at night. Use of 38 kHz would minimize contributions from inter-mixed krill. In favourable circumstances, krill layers may vertically segregate during portions of their diel migration cycle allowing their detection and elimination (using 125 kHz for reference). The second is a shallower site in the upper Gully central channel near GULD3 (about 500 m deep) or near the southern end of the Mesopelagic 'Head' line. Krill (*Meganyctiphanes norvegica*) most probably constitute the major quantifiable scatter at 125 kHz. Again, dual-frequencies should allow separating residual fish from macrozooplankton populations.

Moored echo sounders could further inform us of the utility of future ship-based monitoring and, at best, could serve as the primary instrumentation for long-term studies of fish and krill populations. It is unlikely that specific pelagic species can be quantified; rather, vertically integrated backscatter at 38 kHz would serve directly as a lumped pelagic fish abundance indicator. A similar situation exists for macrozooplankton detected at 120 kHz or 125 kHz, although *M. norvegica* is likely dominant and, in principle, backscatter could be reduced to krill columnar biomass. Moored echo sounders would, however, present several challenges. Instrumentation moored near the surface in deep waters characteristically experiences marked vertical excursions resulting from fluctuating currents. Preliminary modelling shows that a practical unfaired mooring of 1500 m total length would experience vertical excursions on the order of 50 m for vertically uniform tidal currents of 0.5 m/s (for 500 m length or shorter, analogous excursions should only be a few metres). In addition, currently available ASL units have more limited profiling ranges than higher-powered ship-mounted sounders. Indications are that 38 kHz units would have effective profiling ranges for mesopelagic fish aggregations of 300 m or so while 125 kHz units would have effective detection ranges for krill layers of around 150 m. Vertical placement of the instruments in the water column, especially for krill detection at GULD3, would, therefore, be challenging. Last, ASL units, while of high technical quality, present difficulties for precise calibration because of their single beam construction and self-contained nature. Specialized calibration methodologies and support infrastructures would be required, particularly if moored sounders were to constitute the primary quantitative instruments for multi-year trend monitoring. Biofouling of transducers could create calibration drifts on long deployments if instruments were moored too shallow. Battery life and storage should be sufficient for 5–6 month deployments at low ping rates.

Future ship-based backscatter measurements need not await resolution of the aliasing question. Ship-based sampling (even without trawling) would allow quantitative tie-ins with moored sampling, allow a greater vertical depth range to be explored, add to our knowledge of backscatter spatial distributions unobtainable from a small number of moored systems, and allow temperature–salinity profiles to be collected for better control of acoustic absorption. Any resumption of mesopelagic trawl sampling within the MPA should be accompanied by at least dual-frequency backscatter profiling. AZMP surveys should also incorporate at least dual-frequency acoustics. While other AZMP cruise constraints may well prevent long duration ship-based sampling within the MPA, profiling the 'Deep' and 'Head' lines at night should be considered the minimal program. It should be noted that past attempts to mount modern dual beam–dual frequency survey transducers on the CCGS *Hudson*'s RAM were not successful. The successor vessel to DFO's CCGS *Hudson* should have capabilities for advanced acoustic survey, as well as the facility to readily mount and remove transducers between surveys and to deploy acoustic calibration targets as required.

The fundamental need exists to establish the degree of seasonal and inter-annual variability in both pelagic fish and krill concentrations. This might be accomplished with moored acoustic sounders and if so, would be foundational to determining the degree of temporal aliasing potentially present in existing datasets and the utility of future ship-based acoustic backscatter monitoring. A detailed exploration of the practicality and utility of using moored systems would constitute a basic research problem; it should not be viewed as a ready-made monitoring solution. In general, the identification of discrete acoustic scattering layers with specific fish species is still uncertain in spite of excellent trawl–acoustic correlation work from the mesopelagic surveys. The species identity of deep non-migrating acoustic horizons is especially uncertain.

Potential may exist for quantitative (integrated backscatter) analysis of the digital mesopelagic datasets from 2008, 2009 and 2010, in particular along the ‘Deep’ line in the Gully mouth where high night concentrations of mesopelagic fish appear to be present fairly consistently and concentrated near the surface. Some limited potential may exist within the DataSonics database for the quantitative vertical integration of 200 kHz krill backscatter at upper Gully station GULD3. This station has been frequently visited and is characterized by interfering backscatter from fish tending to be both minimal (compared to stations closer to the Gully mouth) and identifiable in the dual-frequency data.

Threats to ongoing monitoring

Both the Sable Gully Mesopelagic Survey and the DataSonics based backscatter data collections were terminated. There are currently no programs performing quantitative backscatter monitoring in the Gully MPA on an ongoing basis. The DataSonics sounders are currently inoperable and are not recommended for repair. The above-suggested moored echo sounder technology for long-term fish and macrozooplankton monitoring is still experimental and may or may not be applicable to monitoring in the Gully. The current AZMP survey vessel, the CCGS *Hudson* presents major difficulties for the hull-mounting of multiple-frequency transducer arrays. In addition, there is a need to retain scientific expertise within DFO Maritimes Region to establish and support a new marine acoustics program.

Additional comments

In addition to basic hardware costs, significant investments in calibration infrastructure (for both moored and ship-based sounders), in modern analytical software and in personnel training would be required. In regard to analysis, purchase of industry standard Myriax Echoview fisheries acoustics analytical software supporting Simrad Sounders, the HAC standardized format data and the ASL profilers is highly recommended. It is important that DFO Science plan for long-term acoustic expertise within the DFO Maritimes Region to support any future backscatter studies.

Table 28-1: Acoustic backscatter data collected within Gully MPA on Sable Gully Mesopelagic Surveys

Cruise	Month	Days	Rate	Sounder	Frequency (kHz)	Depth (m)	Comments
2007 TEM-768	Sep	9	Var.	EK500	38	1000	Paper echograms only
2008 TEM-832	Aug–Sep	7	Var.	EK500	38	1000	Digital recording
2009 NED-035	Aug–Sep	4	Var.	EK60	38 & 120	1000	Digital recording
2010 TEL-900	Mar	9	Var.	EK500	38	1000	Digital recording

Table 28-2: Acoustic backscatter data collected within the Gully MPA using DataSonics hardware during AZMP surveys and earlier opportunistic studies. A dash (-) indicates 'no comment'.

Cruise	Month	Days	Rate (per s)	Frequency (kHz)	Depth (m)	Comments
1984-009	Apr	0.01	1	50.5 & 200	310	-
1989-029	Oct	0.57	0.2 to 1	12, 50, 122 & 200	615	Malfunction, low quality graphical viewing only
1990-005	May	0.08	0.5 to 1	12, 50, 122 & 200	310	
1992-037	Oct	0.05	0.0083	12	600	CCGS *Hudson* Trans-Atlantic Transect
1996-028	Nov	0.08	0.1	12 & 105 (uncalib.)	600	-
1997-003	Apr	0.6	0.1	12 & 200	310	-
1997-063	Nov	0.4	0.1	12 & 200	310	-
1998-002	Apr	0.2	0.1 to 0.5	12 & 200	310	-
1998-050	Oct	0.14	0.1	12 & 200	310	-
1999-003	Apr	0.15	0.1	12 & 200	310	-
1999-054	Nov	2.3	0.1	12 & 200	310 or 480	Extensive observations
2000-002	Apr	1.2	0.1	15 & 105 (uncalib.)	1050	-
2000-050	Oct	1.1	0.1	12 & 200	1050	Grid steamed
2001-009	May	0.17	0.1	12 & 200	310	-
2001-061	Nov	0.3	0.1	12 & 200	310	-
2002-064	Oct	0.21	0.1	12 & 200	310	-
2003-005	Apr	0.23	0.1	12 & 200	310	-
2003-067	Oct	0.29	0.1	12 & 200	310	-
2004-009	May	0.21	0.1	12 & 200	310	-
2004-055	Oct	0.17	0.1	12 & 200	310	-
2005-055	Oct	0.25	0.1	12 & 200	310	-
2006-008	Apr	3.5	0.1	12 & 200	310	-
2006-052	Oct	0.46	0.1	12 & 200	310	-
2007-001	Apr	0.34	0.1	12 & 200	310	-
2007-045	Oct	0.18	0.1	12 & 200	310	-
2008-004	Apr	0.58	0.1	12 & 200	310	-
2009-005	Apr	0.51	0.1	12 & 200	615	-
2009-048	Oct	0.63	0.1	12 & 200	615	-
2010-006	Apr	0.71	0.1	12 & 200	615	-
2011-004	Apr	0.60	0.1	12 & 200	615	-
2011-043	Oct	0.77	0.1	12 & 200	615	-

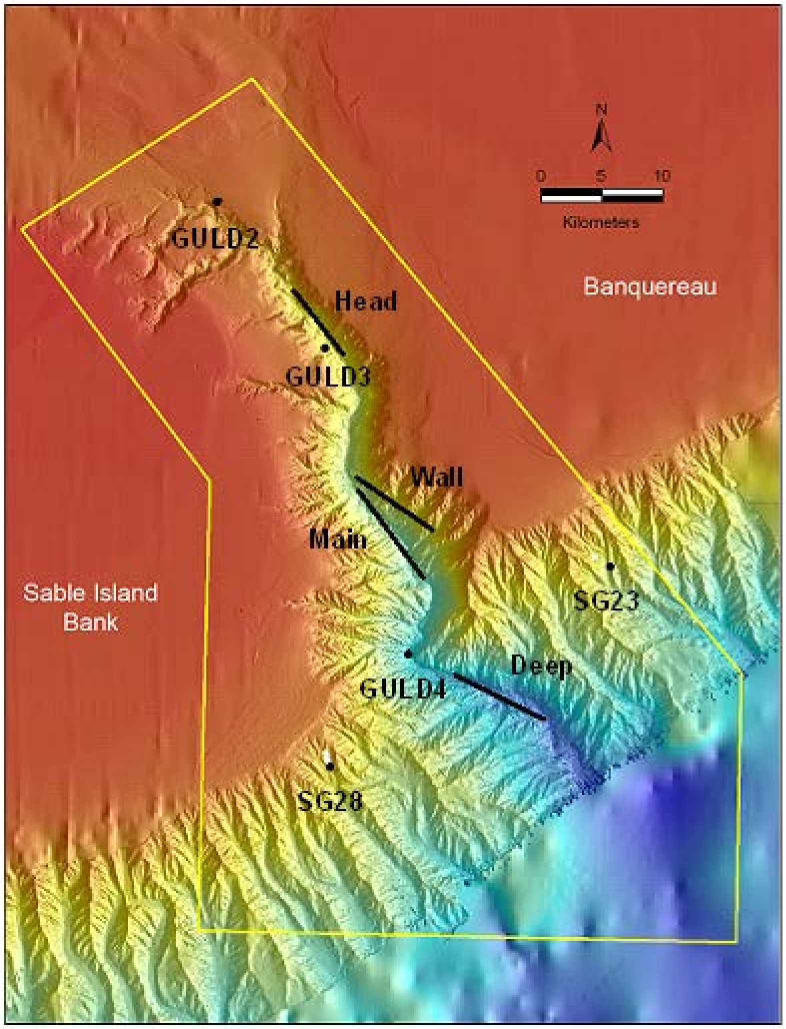


Figure 28-1: Sable Gully Mesopelagic Survey lines and Gully AZMP sampling stations.

Indicator 29: Distribution and abundance of seabird species within the MPA, including an index of planktivorous seabird species

C. Gjerdrum and K. Allard

Available data

Pelagic seabird data have been collected in the northwest Atlantic under two major programs: the *Programme intégré des recherches sur les oiseaux pélagiques (PIROP)* and Eastern Canada Seabirds at Sea (ECSAS), both coordinated by the Canadian Wildlife Service (CWS) of Environment Canada. PIROP took place from 1966 to 1992. ECSAS began in 2006 and is ongoing, with data being collected regularly but opportunistically.

Data collection

Early PIROP surveys were based on 10-minute observation periods during which all birds observed were recorded, regardless of their distance from the moving vessel. These surveys were designed to gather information on the relative abundance and distribution of seabirds; the short recording periods allowed observations to be related to the variable oceanographic conditions of the area (Brown et al. 1975). Following a review of survey methods by Tasker et al. (1984), PIROP surveys after 1984 recorded birds observed within a 300 m transect band, scanning a 90 degree arc to one side of the ship. This protocol change allowed the estimation of densities (birds per square kilometer) but the protocol did not adopt the recommended snapshot approach for flying birds, which often move faster than the ship and thus inflate estimates of local density (Tasker et al. 1984; Gaston et al. 1987).

ECSAS surveys follow the standardized protocol for pelagic seabird surveys from moving platforms (Gjerdrum et al. 2012). The main objective of the protocol is to ensure that observers conducting surveys at sea from a moving platform are recording data in a consistent, unbiased fashion which permits subsequent conversion into seabird areal densities. This protocol is consistent with methods used elsewhere in the world, which makes these data comparable to other geographic areas.

Surveys are conducted while looking forward from the bridge, scanning ahead to a 90 degree angle from either the port or starboard side, limiting observations to a transect band 300 m wide from the side of the platform. A survey consists of a series of five-minute observation periods, which are primarily dedicated to detecting birds at sea (i.e., detections of other marine taxa including marine mammals, sea turtles and large pelagic fish are also recorded, as well as marine debris). As many consecutive five-minute observation periods as possible are conducted consistently throughout the day, regardless if birds are present (i.e., resulting in presence/absence data). Observations can only be conducted when the platform is travelling at a minimum speed of 4 knots (7.4 km/h) and a maximum of 19 knots (35.2 km/h). The transect is scanned continuously by eye, and birds in the air or on the sea surface are counted and identified. Binoculars are used to confirm species identifications and to obtain any other relevant information such as age, moult or behaviour (e.g., carrying fish). Birds observed on the sea surface during the observation period are recorded continuously and their distance from the platform is estimated. Flying birds are not recorded continuously throughout the observation period, as this would overestimate bird density. Instead, flying birds are recorded using instantaneous counts, or ‘snapshots’, at regular intervals throughout the observation period. The number of snapshots conducted depends on the speed of the platform. Distances to birds are recorded to determine detection probabilities and ultimately for estimating true areal bird densities.

Results

Pre–MPA establishment data collected through PIROP could have been considered baseline, but there are not enough data from within the Gully MPA during that program for comparisons to current survey data (Figure 29-1). There is insufficient data to evaluate temporal, spatial or environmental sources of variability in seabirds within the Gully. However, using data from beyond the limits of the MPA, large-scale patterns of variation can be described.

Evaluation of existing protocols for meeting indicator monitoring requirements

Though the seasonal patterns of occurrence, abundance, and distribution are largely known across species, data resolution is insufficient to describe these temporal patterns at the scale of the Gully. Whether these seasonal patterns change across years remains to be determined. Further, it is not known how many surveys of the area would be required to detect such changes, nor is it known what level of change would be considered significant. More sampling is required to understand sources of variation in seabird densities within the Gully.

The current protocol can measure avian biodiversity and quantify seabird abundance and distribution within an area by generating ‘true’ areal density estimates that account for variability in detection probabilities. These density estimates include confidence intervals that describe the uncertainty associated with each estimate. The degree of uncertainty can be reduced by accounting for sources of variation such as year, season, biological and physical oceanographic features and environmental conditions. Reducing the uncertainty associated with density estimates by increasing the frequency of surveys, both seasonally and annually, and accounting for other sources of variation will improve our ability to detect temporal trends.

Although the current protocol can generate estimates of seabird densities, the Gully area is not surveyed frequently enough to detect temporal changes. Seasonal use patterns need to be quantified, which means systematic surveys of the Gully must occur throughout the year and over multiple years. To meet Gully monitoring objectives, ECSAS observers will need to survey from more vessels entering the Gully. At present, the ECSAS program relies on ships of opportunity and surveys of the Gully occur only when ships carrying ECSAS observers travel to the area (Figure 29-2).

In addition, the actual survey area (i.e. transect locations) should be systematic and standardized from one survey to the next. Surveys are currently conducted from the moving platform when travelling between oceanographic sampling points. For the seabird community to be adequately characterized and tracked over time, there should be standardized survey locations within the Gully for seabirds, such as transect lines that run through multiple oceanographic sampling points within the MPA.

Additional information on seabird behaviour, associations and flight direction could also be emphasized to quantify seabird activity within the Gully (Camphuysen and Garthe 2004). These detailed data are collected by ECSAS observers, but as they are secondary in priority to measures of abundance, gaps are common. Such data could be used to determine how birds are using the area (e.g., foraging, resting, in transit, and/or associating with marine mammals).

The CWS is interested in identifying methods for estimating distributions and trends from the 2006–2012 data. As part of that, limitations of the current survey design for monitoring trends in seabird abundance and distribution could be assessed and suggestions for improvement made. Such efforts will contribute to ensure evaluation of the status of seabirds in the Gully, and achievement of desired efficiency of monitoring efforts. These analyses are a priority for the ECSAS monitoring program throughout the Atlantic region, and CWS is currently working toward meeting this objective.

Better understanding of the role seabirds play in marine ecosystems such as the Gully is required. More specifically, important physical and biological oceanographic features that underlie observed seabird distribution patterns need to be identified. Many of these oceanographic data are already collected under various DFO monitoring programs, but integrating them in such a way that would allow analysis is warranted.

Threats to ongoing monitoring

The CWS ECSAS pelagic seabird monitoring program recently underwent a rigorous internal review (Avian Monitoring Review) with favourable results. The program will continue to collect data on seabirds in Eastern Canada for management and conservation purposes for the foreseeable future, but there are no specific funds to target surveys within the Gully MPA.

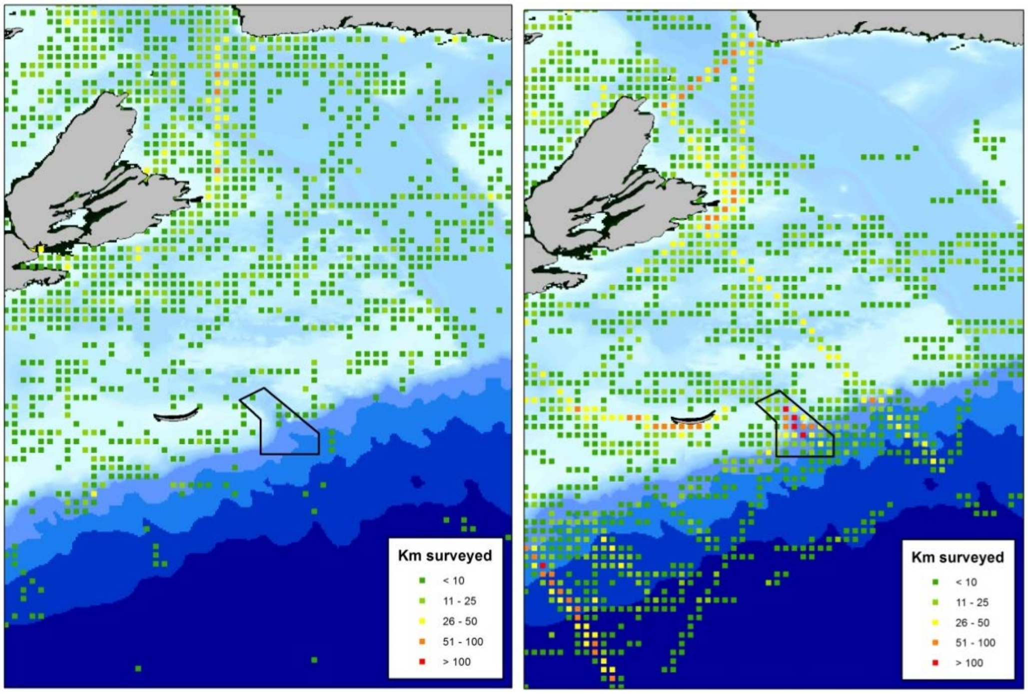


Figure 29-1: Distribution of survey effort for PIROP collected between 1966 and 1992 (left panel) and ECSAS monitoring program collected between 2006 and 2012 (right panel). For PIROP and ECSAS, a total of 26 km and 1393 km, respectively, have been surveyed for seabirds within the boundaries of the Gully MPA.

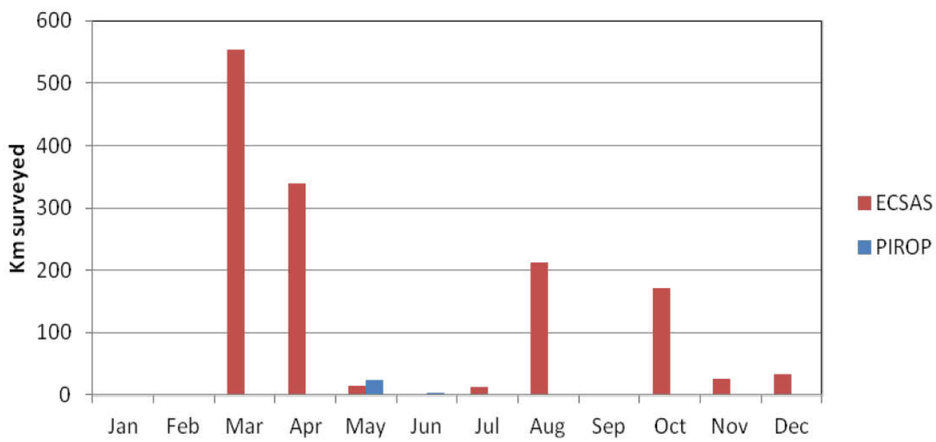


Figure 29-2: Seasonal survey coverage for PIROP and ECSAS monitoring programs.

MONITORING PRESSURES

Indicators 30 through 47 relate to the threats or pressures on the Gully ecosystem. They focus on pressures related to vessel traffic (both generally and specifically for commercial fishing and research); offshore petroleum (installations, discharges); anthropogenic debris; invasive species; and anthropogenic sound.

Indicator 30: Number of transits through the MPA by vessels other than pleasure craft, such as mercantile vessels, surface naval vessels, and fishing vessels not fishing in the area

T. Koropatnick

Suggested improvements to indicator wording

"Number and average speed of transits through the MPA by vessels other than pleasure craft, such as commercial vessels and fishing vessels not fishing in the area."

While the Canadian navy does conduct surveillance and enforcement patrols of the Gully MPA and surrounding area, records on vessel routing are not kept in a manner that is easily accessed for monitoring purposes. As such, 'surface naval vessels' was removed from the indicator.

'Average speed' was added to better capture the intent of this indicator to monitor the potential for vessel strikes and anthropogenic noise, as described in Kenchington (2010).

Available data

Commercial vessel transits

Commercial vessels subject to the International Convention for the Safety of Life at Sea (SOLAS), such as mobile offshore drilling rigs and passenger and cargo ships of over 300 gross tonnage on international voyages (International Maritime Organization 2006) are required to transmit their identity and location every six hours via the satellite based Long-Range Identification and Tracking (LRIT) system (Maritime Safety Committee 2008). While six-hourly reports are the default, reports may be transmitted as frequently as every 15 minutes as requested by entitled governments.

The Canadian LRIT program began in 2009 with the development of the Long-Range Identification and Tracking of Vessels Regulations (Minister of Justice 2010) under the *Canada Shipping Act*, 2001 and the establishment of the Canadian Coast Guard's LRIT National Data Centre. This data centre collects, manages and archives LRIT data for all vessels travelling within 1000 NM of a Canadian coast, Canadian-flagged vessels located worldwide and foreign vessels bound for a Canadian port.

Thirteen months (February 2010 to February 2011) of LRIT data was acquired from the Maritime Security Branch of the Canadian Coast Guard. Each six-hourly vessel report included vessel position (latitude and longitude), a date and time stamp, a unique vessel identifier code and vessel type (e.g., cargo, tanker, cruise ship). LRIT data were collected and analyzed as part of a larger study of commercial vessel traffic in Atlantic Canadian waters (Koropatnick et al. 2012).

Fishing vessel transits

DFO's satellite-based Vessel Monitoring System (VMS) is an important surveillance and compliance monitoring tool for Canadian fisheries. Many Atlantic fleets are now required to carry VMS transmitters, which report the vessel's position and the date and time at regular intervals (generally hourly). Vessel monitoring became a requirement for certain Atlantic Canadian fisheries starting in 2005, and the requirement to carry VMS transmitters has been added to licence conditions for specific fleets at different times since then. With the exception of vessels licensed exclusively for harpoon and trolling gear and the bluefin tuna fishery, most fleets active in the vicinity of the Gully MPA were required to provide hourly position reports via VMS by 2010. While VMS data does not include information about gear type or whether a vessel is fishing or steaming, track patterns and vessel speeds can be used to infer vessel behaviour.

Furthermore, a retrospective analysis can be performed to spatially and temporally correlate VMS tracks with archival fisheries logbook data (which includes VRN, catch date, location, gear type and species landed) to help further characterize vessel tracks in terms of fishing behaviour.

The VMS data for Canadian vessels are archived at DFO's VMS Centre of Expertise (COE) in Newfoundland. VMS data from January 1, 2005 to December 31, 2010 for an area encompassing the Gully MPA was obtained by request to the VMS COE. Given uncertainties about VMS coverage for various fleets operating near the Gully MPA in earlier years, the analysis for 2010 should be considered the most reliable. Fisheries logbook data for the same geographic location and time period were acquired by request to DFO's Commercial Data Division.

Analysis

Commercial vessel transits

Using a geographic information system (ArcGIS 9.3), the LRIT dataset of six-hourly commercial vessel position reports was first separated into calendar months (Koropatnick et al. 2012). Vessel-specific track lines were created by connecting successive position reports. A spatial join was performed to produce a count of vessel tracks within each cell of 2 x 2 arc minute grid overlay. The data were mapped as track line counts per 2 x 2 minute grid cell. Tracks crossing through the Gully MPA were also counted and reported in tabular form.

Fishing vessel transits

Fishing vessel transit analyses were done using MapInfo and subsequently exported into ArcGIS. For each vessel in the VMS dataset, straight line segments were created by joining each successive VMS report location. For cases when more than six hours elapsed between VMS reports, a new track line was created in order to break the tracks when the vessel left the study area or stopped reporting for an extended period. Logbook data were linked to VMS tracks in cases where catches were reported in the vicinity (within 10 NM of the MPA's outer boundary, see Figure 30-1) of the corresponding vessel's track within an appropriate time frame (±24 h). Vessel tracks that crossed into the Gully MPA, but had no associated log entry, were counted as transiting vessels.

It should be noted that track lines generated for both the commercial and fishing vessel transit analyses indicate an inferred path of the vessel rather than the true vessel track, since they are simply straight lines connecting known vessel positions.

Results

Commercial vessel transits

The Gully MPA Regulations permit the exercise of international navigational rights in the MPA throughout the year. However, vessels are asked to either reduce speed or avoid passage through the area to minimize acoustic disturbance and the risk of collisions with marine mammals (Canadian Coast Guard 2012). Using commercial vessel tracks generated from the six-hourly position reports from the LRIT dataset, 497 commercial vessel tracks passed through the Gully MPA between February 2010 to February 2011, which equates to an average of 38 transits per month (Table 30-1; see Figure 30-1 for an example month). Transits through the MPA were highest in August 2010 and lowest in February 2011. Vessel transits each month were variable with no obvious seasonal trends (Koropatnick et al. 2012).

Fishing vessel transits

The method for separating transiting vessel tracks from tracks for vessels fishing in or nearby the Gully MPA was somewhat successful. While it is expected that vessels transiting through the MPA without stopping to fish would follow a relatively straight path through the MPA, some tracks identified as 'transiting' are clearly suggestive of fishing activity. For example, a plot of tracks for vessels transiting without fishing in the Gully MPA in 2010 shows many straight or slightly curved paths, but also includes a patch of tightly looping tracks overlapping the southwest boundary of the MPA, and another tangle of tracks along the northern boundary (Figure 30-2). Further refinement of the method is required to filter out these misclassified tracks.

While current VMS coverage for fleets active in and around the Gully MPA is fairly comprehensive, the adequacy of VMS coverage for years prior to 2010 is unclear, and requires clarification through discussions with fisheries managers. Even so, the total number of VMS-derived tracks for vessels crossing into the Gully MPA has remained relatively constant since 2005 (Table 30-2). From 2008 to 2010, more vessel tracks were associated with fishing than with transiting through the MPA without fishing. Between 2005 and 2010, approximately 47 vessels per year transited the Gully MPA without fishing.

Evaluation of existing protocols to meet indicator monitoring requirements

Commercial vessel transits

For the commercial vessel traffic analysis, track lines were generated by connecting known vessel positions reported at six-hour time intervals with straight lines. Because of this, subtle adjustments to vessel trajectory, such as those required to avoid the Gully MPA, will not likely be captured in the dataset. As such, the adequacy of the LRIT data for monitoring commercial vessel traffic at a geographic scale suitable for the Gully MPA must be questioned. However, if vessel positions were reported at a higher frequency (e.g., hourly), the analysis would be improved. Options for increasing LRIT reporting intervals for areas such as the Gully MPA are being explored in partnership with the Maritime Security Branch of the Canadian Coast Guard.

Alternatively, access to Automatic Identification System (AIS) data for the Gully MPA is also being investigated. Like LRIT, all vessels of 300 gross tonnage or more on international voyages are required to carry an AIS transponder (International Maritime Organization 2003). Passenger vessels, regardless of size, are also required to carry AIS. In contrast to LRIT, vessel identification and positional information can be transmitted via AIS at a very high frequency – up to 2 second intervals (Eide et al. 2007). While the Gully MPA is too remote to allow for the monitoring of vessel traffic using available VHF radio-based terrestrial AIS receiver towers, the recent advent of satellite-based AIS receiver technology provides an appealing alternative to the lower resolution LRIT data stream. Current coverage for the Gully allows for the capture of AIS signals from vessels transiting in the area once per hour on average (Peter Dorcas, Exact Earth Ltd., pers. comm.).

Further improvements to the commercial vessel transit analysis might include the assessment of commercial vessel transits by type and the calculation of an average transit speed by vessel type to further characterize the risk presented by commercial vessel transits to cetaceans in the MPA.

Fishing vessel transits

The intent of this indicator is to monitor vessels travelling at speeds that could pose a vessel strike risk to cetaceans. As such, another logical approach to this analysis would be to calculate the speed between each successive position report and then apply a speed filter to select for line segments associated with faster-moving vessels. While the results using this approach would be similar, since vessels transiting through the MPA without fishing generally travel at faster speeds than vessels engaging in fishing activities, the addition of short, higher speed line segments associated with vessels travelling between fishing locations within the MPA would make data interpretation more difficult. Alternatively, if the 10 NM buffer area around the MPA, used to associate logbook records with VMS, were extended to 15 or 20 NM, tracks suggestive of fishing activity in Figure 30-2 would likely be successfully linked with a nearby catch and reclassified accordingly.

Additionally, for vessels identified as ‘transiting without fishing’, an analysis of average speed for line segments falling within the MPA could be done to further characterize the risk of vessel strikes presented by transiting fishing vessels.

Threats to ongoing monitoring

Technologies such as LRIT, AIS, and VMS are important surveillance and compliance monitoring tools relied upon by many federal government departments for monitoring Atlantic Canada’s waters. Current data for all three data streams is accessible in near-real time using online viewers; data are archived in centralized databases that can be accessed for retrospective analyses such as the ones presented here. However, a considerable amount of time and advanced GIS expertise was required to perform these analyses. For regular, ongoing ecosystem monitoring of the Gully MPA, it would be useful to investigate options for automation and alternative software and data processing methods (e.g., R, Matlab).

Table 30-1: Commercial vessel track lines that passed through the Gully MPA during the period of February 2010 to February 2011 as generated from LRIT data.

Date	Number of Track lines
February, 2010	24
March, 2010	34
April, 2010	44
May, 2010	42
June, 2010	42
July, 2010	28
August, 2010	61
September, 2010	41
October, 2010	32
November, 2010	41
December, 2010	52
January , 2011	36
February, 2011	20
13-Month total	497

Table 30-2: Fishing vessel track lines that crossed into the Gully MPA (2005–2010) as generated from VMS data.

Year	Tracks for vessels transiting without fishing (#)	Tracks for vessels fishing in or nearby the MPA (#)	Total Tracks in the MPA (#)
2005	54	38	92
2006	54	20	74
2007	65	35	100
2008	35	69	104
2009	44	53	97
2010	28	67	95

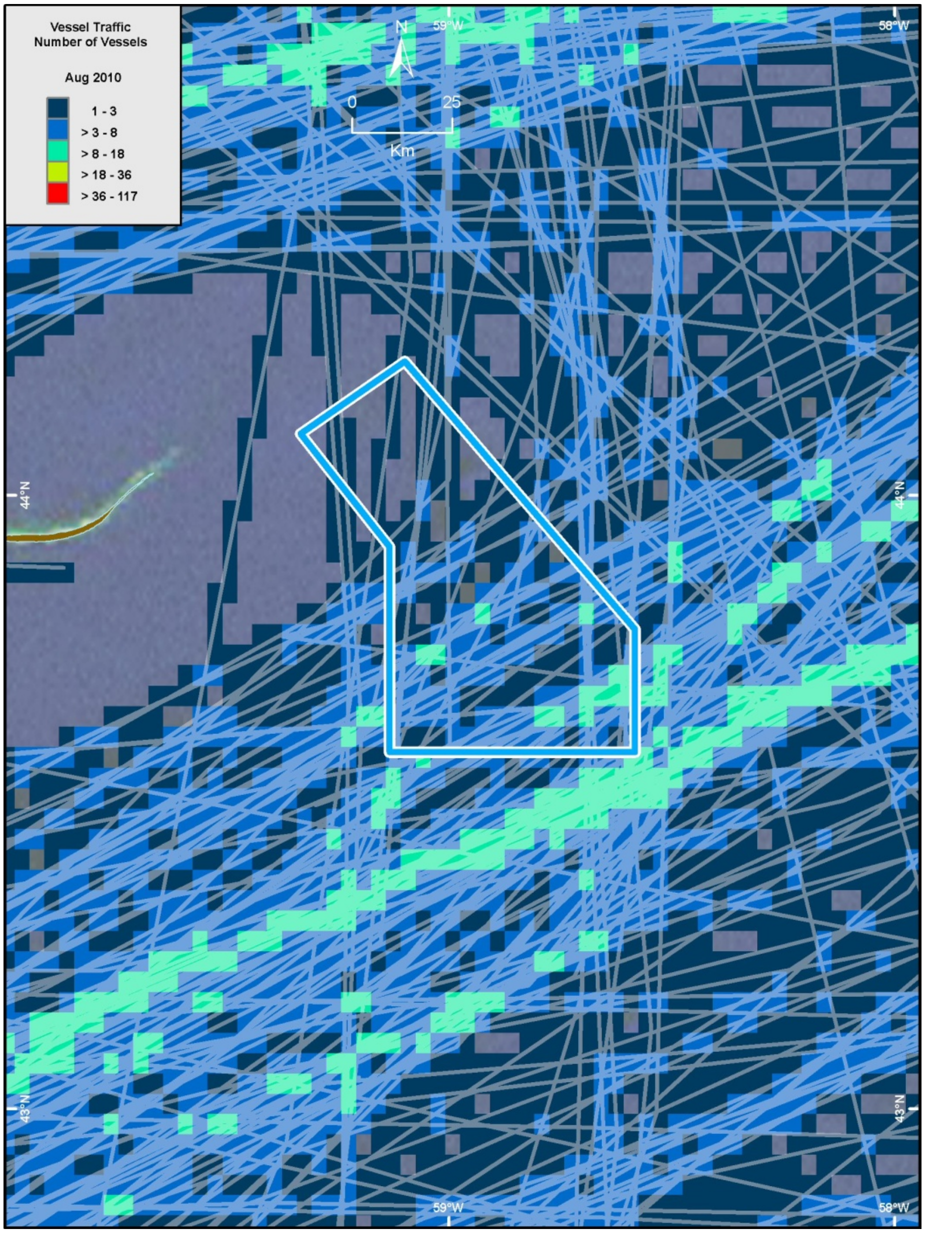


Figure 30-1: Commercial vessel track counts per 2 x 2 arc-minute grid cell generated from the August 2010 LRIT dataset. Tracks crossing the Gully MPA (blue polygon) were highest in this month. Vessel tracks are represented by grey lines. From Koropatnick et al. (2012).

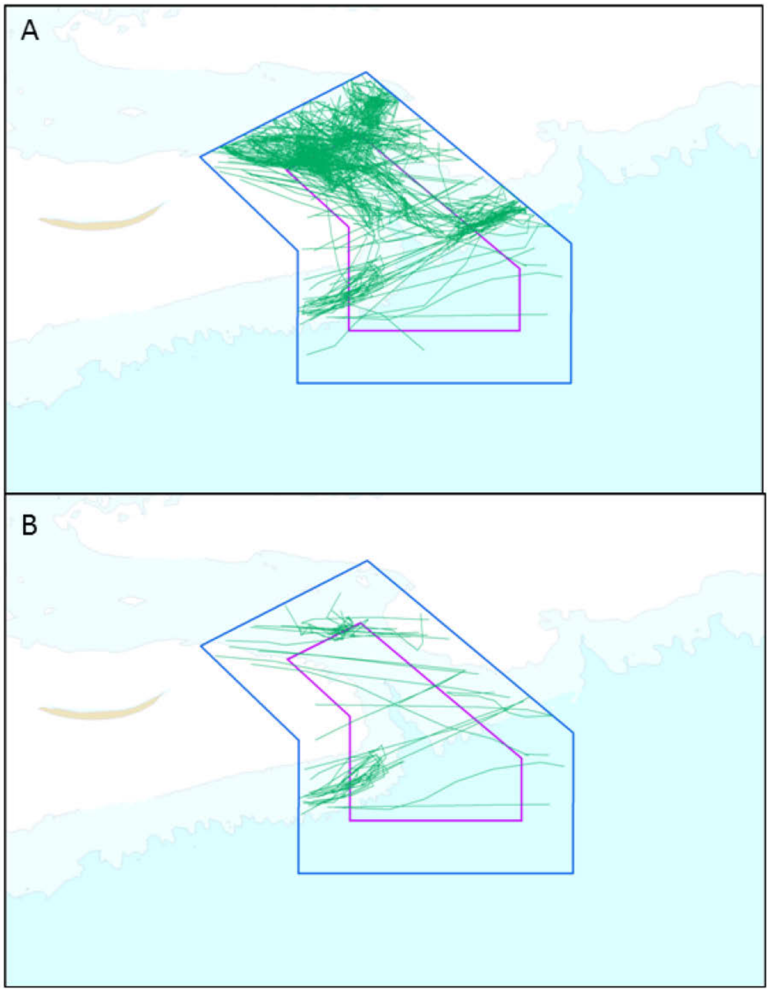


Figure 30-2: Track lines of fishing vessels passing into the Gully MPA (purple polygon) generated from VMS data from 2010: A) all vessel tracks that crossed into the MPA; and B) tracks from vessels that transited without fishing in the MPA. A 10 NM buffer zone around the Gully MPA outer boundary was used to delineate the geographic extent of the VMS study (blue polygon).

Indicator 31: Hours of operation within the MPA by vessels other than commercial fishing vessels or pleasure craft, such as research and monitoring vessels, other government vessels, and ecotourism vessels

Indicator 37: Quantities of organisms (other than corals) removed from or discarded within the MPA by research activities

P. Macnab

Suggested improvements to indicator wording

"Hours of operation within the MPA by vessels other than commercial fishing vessels or pleasure craft, such as research and monitoring vessels, other government vessels, and ecotourism vessels AND Quantities of organisms (other than corals) removed from or discarded within the MPA by research activities."

Indicator 30 above examines mariners travelling through the MPA without stopping as they exercise international navigation rights. In contrast, Indicators 31 and 37 examine vessels that spend time in the MPA for purposes other than navigation or fishing. For indicator 31, "operation within the MPA" implies some targeted activity besides transiting whereby the vessel slows down, stops, keeps station, deploys some kind of sampling equipment, or navigates along transect lines for the purpose data collection (e.g., fisheries sonar or sub-bottom profiling). Indicator 37 is directly tied to the research performed on the vessels reflected in Indicator 31.

Further, rewording may be warranted to indicate operations as something different from overall MPA residency or occupancy. Specifically, total hours spent in the MPA does not alone capture the nature of the threat or the scope for disturbance. For example, a passive acoustics program differs greatly from an active acoustics program.

Available data

For the purposes of this review, data compilation and analysis focused on the three primary documents associated with Ministerial Approvals: 1) Activity Plans submitted under Section 5 of the Gully Marine Protected Area (MPA) Regulations; 2) MPA Approvals issued under Section 6 of the Gully MPA Regulations; and 3) cruise reports submitted post-activity that provide temporal, spatial and biological details of the operations conducted.

Records associated with MPA Approvals extend from MPA designation in May 2004 to present day. Results were compiled for operations conducted through fall 2011.

Data collection

With the exception of certain fisheries, innocent passage, national defence and emergency response, the Gully MPA Regulations stipulate that any person proposing to carry out an activity in the MPA must submit a plan to the Minister for approval. Regulations lay out the plan components, including the proposed period or periods of operation within the MPA. An application form and guidelines have been developed to assist operators with plan preparation. In practice, applicants are advised to indicate how many days will be spent in the MPA. The guidelines further request that applicants provide: an estimate in hours for the duration of planned activities (e.g., dive times for ROVs, periods of transducer usage); the number of samples to be collected (e.g., coral colonies); and estimated biomass removals (e.g., weight of fish to be sampled by survey trawl). When submitted plans are approved, the Minister generally authorizes the periods of time and quantities of organisms requested but limits may be and have been imposed. Applicants are also asked to provide a report on their activities. To facilitate activity reporting, a report form was recently developed that includes space to provide MPA entry and exit times, as well as temporal, spatial and biological details pertaining to the operations conducted (e.g., start and stop of net tows, biomass weights, etc.). The DFO Oceans and Coastal Management Division (OCMD) maintains a spreadsheet to track, log and summarize the entire Approval process for all submitted applications.

Analysis

Despite the longstanding approval request to file cruise reports containing details of operations conducted, only a limited number of these documents have been submitted to the MPA management team, although compliance has improved in recent seasons with the creation of a standard report form. Analysis in the current exercise was thus limited to proposed rather than actual durations and removals. In principle, this indicator involves some simple calculations to derive time spent and organisms collected in the MPA. Further binning would provide useful operational summaries according to typical classes of activity (e.g., oceanographic sampling, echo sounders, ecotourism); vessel type (e.g., government, academic, charter) and removal summaries (e.g., number and weight of organisms sampled).

Results

Vessel residency times while in the MPA were determined according to approved activity plans. A preliminary review of available data indicates that domestic research vessels dominate. Canadian Coast Guard vessels on DFO scientific missions account for the majority of the MPA trips and almost all of the biological removals. Dalhousie University researchers have conducted non-invasive research at regular intervals. Miscellaneous and largely unpredictable trips have been made by foreign research vessels and chartered hydrographic ships. Two ecotourism vessels have been granted approval to visit the MPA; the first for a one-time visit, the second for repeat visits in 2010 and 2011. With the exception of mesopelagic and mammal surveys, most trips are of short duration (1 to 2 days).

Evaluation of existing protocols for meeting indicator monitoring requirements

With testing, refinement and full adoption, the existing protocols for approved operations should be adequate to meet indicator requirements.

Threats to ongoing monitoring

Few trip reports have been provided thus far, as formal follow-up with applicants has been eschewed in favour of informal exchanges, tracking of data analysis, joint learning and continued collaboration in Gully research and monitoring. The data and trip logs are not in jeopardy, but unless reports are filed, there is considerable risk that there will not be ready access to the required information.

Indicator 32: Commercial fishing effort within the MPA

D. Fenton, A. Serdynska, T. Koropatnick

Suggested improvements to indicator wording

“Commercial demersal and pelagic longline fishing effort within and in close proximity to the MPA.”

Within the Gully MPA, the only fishing allowed is demersal longline directing for halibut and pelagic longline for swordfish, tuna and shark. As such, the indicator can be more specific. As part of the same indicator, it is a simple addition to compare effort within the MPA to effort in close proximity to the MPA for the same gear types. As such, this indicator could serve to combine the analysis for Indicators 32 and 33 as they are written in Kenchington (2010).

Available data

Fish harvesters are required by licence to submit data on fishing activity to DFO using fishery-specific monitoring documents (logbooks). An example of licence conditions which describe what is to be submitted is as follows:

> 28. The licence holder/operator is required to make entries into the log section of the fixed gear monitoring document 2011 in accordance with the following requirements:
>
> a) the entries in the fixed gear monitoring document 2011 shall always be an accurate record of all fish on board the vessel.
>
> b) the licence holder/operator shall make an entry immediately following each set, and at a minimum, once within every twelve-hour period, from the time the vessel leaves port until the vessel returns to port.
>
> c) each such entry must set forth the time of the entry, what, if any, fish were caught since the last entry, the location where the fish were caught, the species of fish caught, the accurate round weight of the fish caught, and the species and weight of any fish discarded. If no fish are caught during any twelve-hour period, an entry still must be made confirming this fact.
>
> (d) any licence holder/operator, regardless of the length of the fishing trip, is required to make a final entry in the log section of the fixed gear monitoring document 2011 immediately after hauling all gear that will be fished on that trip.

Fisheries data captured in fishing logbooks are stored in the Maritime Fishery Information System (MARFIS), a regional repository for licensing, vessel, participant, quota, catch and effort information.

Logbooks have been used consistently to track fishing activity in various fixed gear groundfish fleets since the mid-1990s. Data from 2005 to 2011 were extracted from the logbooks for the current analysis.

Analysis

MARFIS data from 2005 to 2011 were extracted from DFO's Virtual Data Centre (VDC) for a study area including the Gully MPA and an external assessment area extending 10 NM beyond the MPA outer boundary. The number of unique fishing sets (i.e., where a set is a single deployment of gear) were counted using the SETID field (i.e., a unique number assigned to each set). Sets were further divided and counted by gear type using the GEAR field. Fisheries allowed within the Gully MPA (Zones 2 and 3) are demersal longline directing for halibut and pelagic longline for swordfish, tuna and shark. MARFIS does not distinguish between demersal and pelagic longline gear so the longline gear type was classified into demersal or pelagic based on the species caught in the set. For example, if the set reported mostly groundfish (e.g., halibut, cusk, cod, etc.), the gear type for the set was classified as demersal longline. Conversely, if the set reported mostly pelagic fishes (e.g., swordfish, tuna, sharks, etc.), the gear type was classified as pelagic longline.

A one-minute grid encompassing the Gully study area was created using ArcGIS 10.0, and a spatial join was performed to derive the total number of sets reported per year within each grid cell. Cumulative (2005-2011) effort maps were created for demersal and pelagic longline.

Results

For each year of the study period, the number of demersal and pelagic longline sets reported within Zones 2 and 3 of the Gully MPA were tallied (Table 32-1). The number of demersal longline sets was variable over the time period and there was a marked drop in 2006. This may be because no commercial index sets occurred in the Gully as part of the annual halibut survey from 2005 to 2006. The final year of the analysis (2011) had the greatest level of effort. For pelagic gear, the number of sets recorded within the MPA remained low throughout the study period.

The number of demersal and pelagic longline sets within 10 NM of the Gully MPA was tallied for each year of the study period (Table 32-2). Similar to trends noted within the MPA, demersal longline activity outside the MPA was lowest in 2006 and highest in the last two years of the study period (2010 and 2011). This is likely a result of overall changes in the directed halibut fishery, with an increase in the available quotas in the region in the latter half of the time series (DFO 2011). Pelagic longline effort in close proximity to the Gully remained low and relatively constant throughout the study period.

The cumulative spatial distribution of demersal and pelagic longline sets are shown in Figures 32-1 and 32-2, respectively. Most demersal longline activity occurred in the northwest portion of the MPA and extended outside of the northwest MPA boundary. Pelagic longline activity was sparse within the MPA but some significant effort was concentrated in a narrow band outside the eastern boundary and along the shelf edge.

Evaluation of existing protocols for meeting indicator monitoring requirements

An annual calculation of the number of sets is a simple indicator of overall fishing effort in the MPA for pelagic and demersal longline fisheries; however more complex analyses could be conducted to further examine fishing effort in the MPA. For example, the number of sets per grid square could be analyzed by month or by season to monitor changes to fishing at finer time scales. Additional calculations that take into account the number of hooks per set could also be incorporated using available datasets (MARFIS, Commercial Index of Halibut Survey, and At-Sea Observer Program reports).

A comparison of effort within and in close proximity to the Gully MPA is the logical and straightforward next step to the above analysis. A comparison of the number of sets per unit area for each gear type within the MPA to the number of sets per unit area in the assessment area outside the MPA would have been done if time permitted. Effort for fisheries that are active in the vicinity, but not permitted to occur within the MPA (snow crab or hagfish), should also be analyzed to fully address the intention of Indicator 33 as described by Kenchington (2010).

Establishing reference points for catch/landings (Indicator 36/Indicator 18) may be more appropriate to consider than number of sets. Likewise, Indicator 39 provides a spatial representation of effort, which may be a more useful reference point (percentage of MPA with effort).

Threats to ongoing monitoring

Logbook data will be provided by industry for the foreseeable future as a condition of licence. Plans for implementing a nationwide licensing, quota, and catch and effort system may have data access implications that could prevent ongoing commercial fisheries data analysis required for this indicator.

Table 32-1: Number of fishing sets per year within the Gully MPA by gear type. A dash (-) indicates that data could not be published to protect confidentiality. 'ND' indicates no data in MARIS.

Gear Type	2005	2006	2007	2008	2009	2010	2011
Demersal Longline	24	12	30	32	42	27	47
Pelagic Longline	-	ND	ND	-	-	-	-

Table 32-2. Number of fishing sets per year in the area surrounding the MPA (10 NM buffer). A dash (-) indicates that data could not be published to protect confidentiality. 'ND' indicates no data in MARIS.

Gear Type	2005	2006	2007	2008	2009	2010	2011
Demersal Longline	34	24	31	27	35	64	57
Pelagic Longline	13	ND	-	17	7	-	21

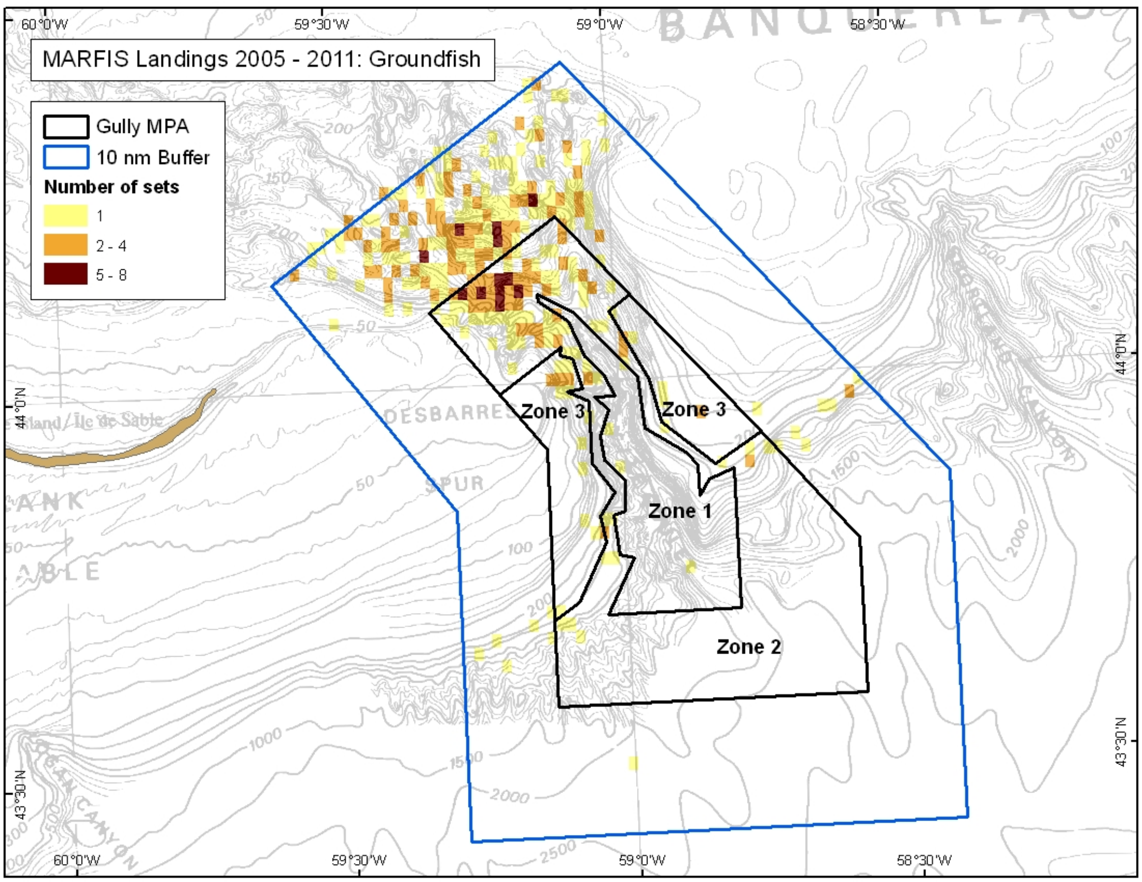


Figure 32-1: Cumulative density (2005–2011) of demersal longline sets per 1 x 1 minute grid within and nearby the Gully MPA (blue polygon indicates the extent of the Gully assessment area).

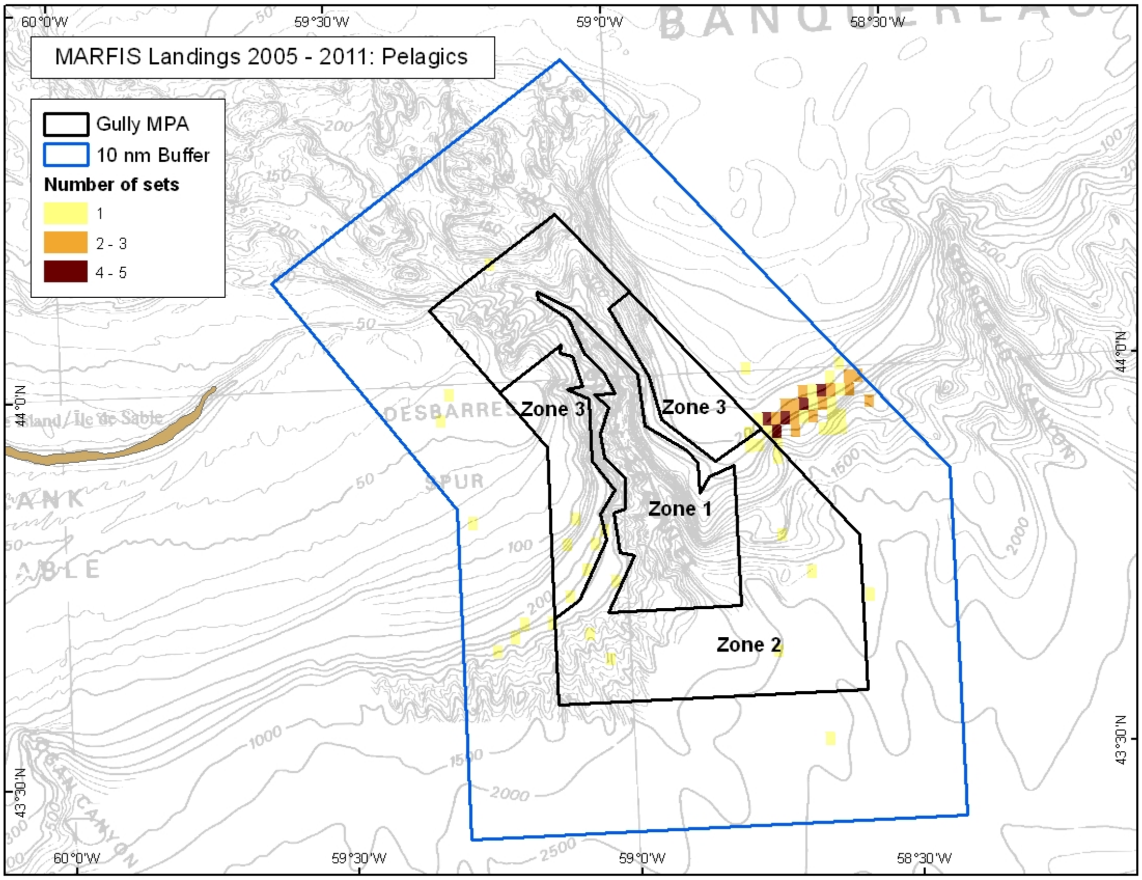


Figure 32-2: Cumulative density (2005–2011) of pelagic longline sets per 1 x 1 minute grid within and nearby the Gully MPA (blue polygon indicates the extent of the Gully assessment area).

Indicator 33: Commercial fishing effort in close proximity to the MPA boundary

D. Fenton, A. Serdynska, T. Koropatnick

Suggested improvements to indicator wording

"Quantities of organisms removed by commercial fishing activities in close proximity to the MPA."

Commercial fishing effort in close proximity to the MPA boundary was addressed as part of the proposed modification to Indicator 32.

As Kenchington (2010) explains, this indicator is intended to assess the effects of the MPA on biomass densities nearby. Thus, an alternative to an analysis of fishing effort for relevant gear types in proximity to the MPA is proposed. Instead, this indicator has been used to assess catch data (i.e., biomass removed) in proximity to the MPA.

Available data

Logbooks have been used consistently to track fishing activity in various fixed gear groundfish fleets since the mid-1990s. Logbook data is submitted by industry as a condition of license and stored in the MARFIS. Data from 2005 to 2011 were extracted from MARFIS for the current analysis.

Data collection

MARFIS data from 2005 to 2011 were extracted from DFO's VDC for a study area including the Gully MPA and an external assessment area extending 10 NM beyond the MPA outer boundary. Catches (by weight) from within the MPA were not included in the analysis (see Indicator 36 for catches within the MPA). Catches within the assessment area were summed for each species using the RPT_WEIGHT field (reported weight in metric tonnes) for each year and in total.

Results

Catches for the top five species by total weight in the assessment area are provided in Table 33-1. The highest catches by weight were snow crab, followed by sea cucumber, halibut and swordfish. Catches for snow crab were highly variable over the study period, while catch levels for halibut and swordfish were more consistent. The increase in total catches in the last several years of the time series can be attributed primarily to the sea cucumber fishery.

Evaluation of existing protocols for meeting indicator monitoring requirements

The original indicator wording asks for an analysis of fishing effort in close proximity to the MPA. An alternative analysis, presented here, looks at catch weights by species as a measure of biomass removed in proximity to the MPA, while effort (number of logbook records) in close proximity to the MPA was addressed in Indicator 32. Both approaches provide a measure of effects of the MPA on nearby fishing activity. Science advice on the best approach to address this indicator would be useful.

Focused research on potential spillover effects as a result of the MPA could be further examined, as suggested by Kenchington (2010). Interesting candidates for study would include snow crab and sea cucumber (fishing for these species is not permitted in MPA) and halibut (fishing for halibut is not permitted in Zone 1).

Threats to ongoing monitoring

Logbook data will be provided by industry for the foreseeable future as a condition of licence. Plans for implementing a nationwide licensing, quota, and catch and effort system may have data access implications that could prevent ongoing commercial fisheries data analysis required for this indicator.

Table 33-1: Total catches (metric tonnes) by species by year (within 10 NM of the MPA). A dash (-) indicates that data could not be published to protect confidentiality. 'ND' indicates no data in MARIS.

Species	2005	2006	2007	2008	2009	2010	2011
Snow crab	-*	-	-	-	116.01	85.00	-
Sea cucumber	ND	ND	ND	ND	ND	-	-
Halibut	10.91	10.06	10.42	11.67	15.76	23.84	16.05
Swordfish	11.19	ND	-	16.08	3.63	-	17.58

Indicator 34: Suspected and confirmed unauthorized fishing activity within or in close proximity to the MPA

T. Koropatnick

Suggested improvements to indicator wording

"Unauthorized fishing activity within the MPA."

Suspected unauthorized fishing activity includes many false alarms, such as logbook entry errors that indicate catches that have occurred within a closed area. These errors are often resolved by cross-referencing the vessel's location at the time of the log entry by using hourly vessel position reports provided via the satellite-based Vessel Monitoring System (VMS) or by checking the hard-copy monitoring document to determine if a key-punch error occurred when the logbook data was entered into the MARFIS database. Tracking and reporting on suspected unauthorized fishing incidents would be onerous and would not provide useful information about real pressures on the Gully ecosystem.

Unauthorized fishing activity outside the MPA boundaries but in close proximity to the MPA is not routinely tracked by the OCMD. Such activity is also not easily identified through the DFO Conservation and Protection's (C&P's) Department Violations System (DVS) database because incident reports are not indexed using geographic coordinates in the current system.

Available data

Information collected for this indicator was taken from the DVS database and through ongoing communication between OCMD and C&P. Data is available from MPA establishment in May 2004 to September 2012.

Data collection

Upon request from OCMD, C&P staff conducted a keyword search of the DVS to identify entries relevant to specific management areas.

Results

Since Gully MPA establishment, there have been very few reports of illegal fishing in the MPA, and there have been no prosecutions attempted for violations in the Gully MPA. Since May 2004, the following fisheries-related incidents have been entered into the DVS:

- 2004: A fishing vessel's pelagic longline gear drifted inside the Gully Zone 1 at night. No charges were laid after further investigation.
- 2008: Pelagic longline drifted into the Gully Zone 1. The gear was removed quickly, and the section that had been in the MPA did not catch anything. The vessel moved on and no further violations occurred. No charges were laid.
- 2011: Two sections of pelagic longline gear drifted into Gully Zone 1. An observer was aboard, but there was no reference to distance within prohibited zone or catch in the report. VMS indicated vessel was approximately 0.3 NM inside Zone 1 at one point. Observer stated situation was not intentional and captain acknowledged error. No further action taken.
- 2011: Questioned VMS plots for a groundfish longline vessel. Some questions whether plots were suggestive of fishing activity. No observer aboard nor other sighting to confirm if vessel was actually fishing. No further action taken.
- 2012: One section of pelagic longline gear drifted into Gully Zone 1. Observer noted that one section of gear became tangled, broke free of the main line and drifted approximately 0.25 NM over the Zone 1 boundary. VMS confirms that the gear was set 0.67 NM outside of the closure. The gear was removed promptly upon detection, and

nothing was entangled and no fish were caught from within the closure. No further action was taken.

While only a few fisheries-related incidences have been entered in the DVS system since MPA establishment, OCMD's recent efforts to engage with C&P partners in surveillance and compliance monitoring may have prompted an apparent increase in the number of DVS entries from 2011 to present. More time is needed to see if a real trend exists.

Evaluation of existing protocols for meeting indicator monitoring requirements

Given inevitable limitations on the ability to detect unauthorized fishing within the MPA, this protocol is adequate to meet the requirements of the indicator provided the new wording is acceptable. Improvements to the DVS interface that would permit queries for specific geographic areas would increase search efficiency for this type of query.

Threats to ongoing monitoring

The Gully MPA's remote location presents the biggest challenge for surveillance and enforcement activities because of the expense of manned surveillance patrols in the offshore. Although recent advances (e.g., VMS) have made the detection of unauthorized activities in the Gully MPA more practical, in general, detections via technological means must still be corroborated by other surveillance intelligence (e.g., logbook entries, At-Sea Observer Program reports and aerial surveillance reports) before enforcement can take place. While surveillance flights can be tasked for further investigations if necessary, resources for aerial surveillance are limited.

Indicator 35: Quantities of corals removed from or discarded within the MPA by commercial fishing and by research activities.

D. Fenton, A. Serdynska, T. Koropatnick

Suggested improvements to indicator wording

"Quantities of corals removed, discarded or damaged by commercial fishing and research activities within the MPA."

'Damaged by' was added to more comprehensively track impacts from sampling of corals or other unintended contact by research efforts.

Available data

In general, five percent of each fishery active in and around the Gully is monitored by the At-Sea Observer Program, but coverage may be increased by resource managers as needed. Fishing vessels are generally randomly selected for observer coverage, but targeted coverage can also occur. Observers watch and record activities on the vessel to ensure compliance with licence conditions, and data from their reports are entered into an At-Sea Observer Program database. Further, DFO Research Vessel (RV) Survey data, science cruise reports and Gully MPA approval reports and correspondence provide descriptions of coral interactions that occur as part of research activities within the MPA.

The At-Sea Observer Program database records between 2005 and 2011 were queried. Results from approved research programs within the Gully MPA since 2004 were also reviewed.

Data collection

The At-Sea Observer Program database and the RV survey database were queried for coral records using DFO's VDC for 2005 to 2011. The SPECCD_ID field was used in the Observer database and the CODE field was used in the RV survey database to search for coral species.

Results

Coral interactions from commercial fishing activities

The Gully has a high diversity of coral species with known concentrations of species susceptible to longline interactions such as *Primnoa* or *Paragorgia* (Cogswell et al. 2009). Fishery interactions with corals have occurred in the Gully prior to MPA establishment (Breeze 1998); however, no coral bycatch was reported in the At-Sea Observer Program database within the MPA during the period of this study (observer records from 2005-2011 included 12 trips and 104 sets).

Coral interactions from research activities

Within the study period, there were several bottom-contacting events that impacted or may have impacted corals during research cruises within the MPA:

- The RV trawl survey occurred in the summer of 2004. No corals were recorded.
- Mooring systems for oceanographic and acoustic studies include bottom-contacting ballast, which could impact corals.
- In 2006, 2010 and 2011 directed research on corals took place with benthic sampling and survey programs, which included the use of remotely operated vehicles. The survey gear (e.g. Campod) may have unintentionally impacted corals upon bottom contact, although quantification of these impacts is not available. The anticipated number of coral colonies or segments to be sampled was provided in MPA activity applications(e.g., in 2007, three to five complete colonies of coral of the species *Primnoa resedaeformis* and *Paragorgia arborea* were expected to be sampled). The actual number sampled can be determined through discussion with the principal investigator.
- A mesopelagic trawl survey took place in 2007 that made contact with the canyon wall. This interaction with the seafloor resulted in the unintended removal of 2.5 kg of coral, including small quantities of *Keratoisis*, *Paragorgia* and *Primnoa*. The full extent of the damage from this event is unknown, but the gear was hauled in as soon as contact occurred to minimize impacts.

Evaluation of existing protocols for meeting indicator monitoring requirements

An analysis of the spatial depth overlap of observed sets in the Gully with known coral concentrations was not conducted, which might help explain the lack of At-Sea Observer Program reports that mention coral bycatch in the MPA. In general, it is expected that vulnerable coral species occur primarily in Zone 1, where research can occur but no commercial fishing is permitted. However, continued efforts to understand the distribution of corals in the area of possible interaction (Zone 2) would be useful to determine possible areas of greater interaction.

The At-Sea Observer Program in the DFO Maritimes Region has coral identification sheets and protocols for encounters with coral. There is an ongoing need for regular training to ensure observers know how to adequately document these encounters.

As part of MPA approval requirements, potential coral interactions must be considered, and proponents are asked to document unexpected incidents such as accidental damage to coral. It is important that MPA practitioners engage in follow-up and ensure documentation of coral encounters are obtained to better track these interactions in the MPA.

Threats to ongoing monitoring

The At-Sea Observer Program provides a useful indicator of commercial fisheries interactions with some coral species. Adequate observer coverage within the Gully is required to monitor coral interactions with fisheries in the MPA. Reductions in observer coverage for the area could strongly impact available data.

Indicator 36: Quantities of target organisms removed from or discarded within the MPA, and bycatch organisms (other than corals) removed from the MPA by commercial fishing

D. Fenton, A. Serdynska, T. Koropatnick

Available data

The data source used for this indicator is logbook data submitted by industry as a condition of licence and stored in MARFIS, as well as observer report data submitted to the At-Sea Observer Program database. Data from 2005 to 2011 were used for the current analysis.

Indicator 18 provides a catch and bycatch profile using other relevant datasets (i.e., Commercial Index as part of the Halibut Survey).

Data collection

MARFIS landings data and At-Sea Observer Program data for 2005 to 2011 were extracted from DFO's VDC for the area encompassed by the outer boundaries of the Gully MPA. Catches within the MPA were summed for each targeted, bycatch and discard species for each year of the study period.

Targeted organisms

Fisheries allowed in the Gully MPA (Zones 2 and 3) are demersal longline directed for halibut and pelagic longline for swordfish, tuna and shark. MARFIS landings within the MPA were summed for each of these species using the RPT_WEIGHT field (reported weight in metric tonnes). Landings from observed trips within the MPA were summed for each species using the CATCH_MT field (catch in metric tonnes).

Bycatch organisms

Species other than the targeted species listed above that have been reported in the MARFIS landings for the area were assumed to be bycatch.

Discarded organisms

To identify potentially discarded organisms from observed trips to the MPA, MARFIS catch data and observer catch data from within the MPA were compared. Species reported in the At-Sea Observer Program dataset that did not appear in the MARFIS landings were presumed to be discards.

Results

Targeted organisms

The landed weights for target species (i.e., halibut, swordfish, tunas and sharks) caught within the MPA are provided in Table 36-1. The bulk of landings come from directed halibut trips.

Bycatch organisms

Table 36-2 summarizes the total bycatch of all species reported in MARFIS landings during the study period. Cusk, white hake and cod make up the bulk of the bycatch profile from demersal longline activity in the MPA.

Discarded organisms

Available data on discarded organisms within the MPA are restricted to information provided by observer records for trips that include the MPA. The total number of observed trips to the Gully during the study period was limited, with only 12 trips in total, and no coverage occurred from 2006 to 2008 (Table 36-3). With the exception of one pelagic trip in 2009, all observed trips to the Gully were for groundfish longline. The catch weights for the potential discards identified from observer reports are listed in Table 36-4. The species identified as caught but discarded were primarily sharks, skates and wolffishes.

Evaluation of existing protocols for meeting indicator monitoring requirements

In the DFO Maritimes Region, harvesters are not required to distinguish between "targeted" and "bycatch" species as part of the catch data recorded in their monitoring documents. However, given that only specific species may by targeted within Zone 2 and 3 of the Gully MPA under the regulations, an assessment of targeted and bycatch biomass can be done using MARFIS data. Comparing catch data in observer reports with landed catches from MARFIS is the only method of characterizing discarded organisms. However, observer coverage for the Gully MPA has been limited and should be increased to satisfy the requirements of this indicator.

Threats to ongoing monitoring

The limited observer coverage in the MPA continues to be a risk, as observer data are imperative for assessing this indicator. Plans for implementing a nationwide licensing, quota, and catch and effort system may have data access implications that could prevent ongoing commercial fisheries data analysis required for this indicator.

Table 36-1: Catch weights in metric tonnes (mt) for target species within the MPA (2005–2011).

Species	Catch weights (mt)
Halibut	83.38
Swordfish	16.11
Tuna (bigeye, albacore, yellowfin)	1.14
Tuna, bluefin	0.50
Total	101.12

Table 36-2: Catch weights in metric tonnes (mt) for bycatch species in the MPA (2005–2011).

Species	Catch Weights (mt)
Cusk	11.01
White hake	4.94
Cod	3.90
Redfish	1.78
Shark, mako	0.58
Crab, snow	0.42
Greenland halibut/turbot	0.41
Shark, porbeagle/mackerel	0.28
Scallop, sea	0.18
Groundfish, unspecified	0.11
Haddock	0.10
Roundnose grenadier	0.04
Shark, unspecified	0.03
Dogfish	0.03
Marlin white	0.02
American plaice	0.02
Mahi mahi, dolphin	0.02
Monkfish	0.01
Pollock	0.004
Catfish	0.002
Fins, fish unspecified	0.001
Total	23.88

Table 36-3: Number of observed trips to the Gully MPA and the number of sets observed within the MPA (2005–2011). A dash (-) indicates no value.

Year	2005	2006	2007	2008	2009	2010	2011	All Years
Trips	1	-	-	-	7	3	1	12
Sets	7	-	-	-	47	15	35	104

Table 36-4: Catch weights in metric tonnes (mt) reported within the Gully for all observed trips to the MPA (2005–2011). Discarded species were listed as caught in observer reports, but not landed as indicated by MARFIS records.

Status	Species	Catch weights (mt)
Suspected discards	Blue shark	0.705
	Black dogfish	0.328
	Thorny skate	0.302
	Winter skate	0.133
	Northern wolffish	0.073
	Little skate	0.063
	Spotted wolffish	0.011
	Skates (ns)	0.009
	Conger eel	0.002
	Atlantic rock crab	0.001
Landed species	Halibut (Atlantic)	16.440
	White hake	1.149
	Cod (Atlantic)	0.637
	Swordfish	0.580
	Cusk	0.445
	Bluefin tuna	0.428
	Porbeagle, mackerel shark	0.186
	Redfish unseparated	0.078
	Spiny dogfish	0.035
	Haddock	0.017
	Turbot, Greenland halibut	0.012
Total		21.657

Indicator 37: Quantities of organisms (other than corals) removed from or discarded within the MPA by research activities

See Indicator 31 above.

Indicator 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

Indicator 39: Length of lines of, and seabed area occupied by, bottomset fixed commercial fishing, research and monitoring gear set within the MPA, both as a total and subdivided by seabed habitat type

D. Fenton, A. Serdynska, T. Koropatnick

Suggested improvements to indicator wording

"Potential seabed area impacted by bottom-tending gear from commercial fishing and scientific research and monitoring within the MPA."

It is proposed that Indicators 38 and 39 be combined, and to conduct a more simple approach for characterizing the area within the Gully MPA that is impacted by bottom-tending gear.

Available data

Bottom contact from research and monitoring

MPA activity approval documents and RV Survey data were reviewed.

Bottom contact from commercial fisheries

Fish harvesters are required by licence to submit data on fishing activity to DFO using fishery-specific monitoring documents (logbooks). As part of the reporting requirements for groundfish longline, one set of geographic coordinates must be provided for each set fished. Geographic coordinates provided in these reports are generally rounded to the nearest arc minute. Logbook data is submitted by industry as a condition of licence and stored in MARFIS.

Fisheries data from 2005 to 2011 were extracted from the MARFIS database for the current analysis. Available documents on research and monitoring activities that have occurred in the Gully MPA since its establishment in 2004 were also reviewed.

Data collection

MARFIS data from 2005 to 2011 were extracted from DFO's VDC for an area encompassed by the Gully MPA outer boundary. The number of unique fishing sets for demersal longline gear was counted as described in Indicator 32.

Data analysis

A one-minute grid encompassing the Gully MPA was created using ArcGIS 10.0, and a spatial join was performed to count the 'fishable' cells within which sets had been reported for each year. At the latitude of the Gully MPA, each grid cell is approximately 2.5 km^2. Note that fishable cells were defined as cells located within Zones 2 and 3 because fishing is not permitted in Zone 1.

Results

Bottom contact from research and monitoring

One RV trawl survey station set that was 1.78 NM in length occurred in the MPA in 2005. Other research activities with benthic interactions were described in Indicator 35.

Although there are uncertainties regarding the amount of total area research activities occupied, it is expected to be very low due to the expected length and area of the intended interaction and the low levels of unintended interactions.

Bottom contact from commercial fisheries

Zones 2 and 3 contain 767 'fishable' 1 x 1 minute grid cells. During the study period, 128 of these cells included at least one demersal longline set (Table 38-1). This equates to approximately 17% of the 'fishable' cells in the MPA having been fished by bottom-contacting fixed gear. Most of the fished cells were located in the northwestern corner of the MPA (Figure 38-1).

As noted in Indicator 32, the effort in the Gully increased in the latter half of the time period coinciding with increases in available quotas for directed species in the region.

Evaluation of existing protocols for meeting indicator monitoring requirements

At this time, a benthic classification scheme is not available to assess seabed area impacted by fishing and research activities subdivided by seabed habitat type. Once such a data layer is available, the analysis of activity per 'fishable cell' could be further broken down by habitat type. Draft benthic maps and geological maps for the MPA are available (e.g. Cameron and King

2008), but further work is required to develop a benthic classification scheme that could be used to evaluate this indicator.

Bottom contact from research and monitoring

More work is needed to monitor bottom contact by research activities in the MPA. Current efforts to improve data holdings from research and monitoring activities include personal follow-ups to obtain information from researchers who have conducted bottom-contacting activities. A new post-activity report form has also recently been developed and is now distributed to researchers along with their Gully MPA research approval. Researchers are asked to use the report form to provide details about the activities conducted in the MPA within 60 days of completion of the activity. Information, such as the estimated biomass removed and the estimated location and area impacted from bottom contact activities can be used for assessing this indicator in a manner described for commercial fishery footprint analysis.

Bottom contact from commercial fisheries

Estimates of fishery presence using this gridded mapping approach will ultimately over-estimate the geographic coverage of gear interactions with the sea floor. However, the requirements for groundfish monitoring documents in terms of geographic accuracy and reporting are not expected to change. Thus, the grid cell size is considered adequate for the purposes of understanding spatial patterns and potential changes to the bottom contact fishing footprint over time.

The At-Sea Observer database provides set locations and retrievals for fixed gear groundfish. As such, this database would provide a better estimate of the spatial extent of bottom contact associated with demersal longline fishing in the MPA. Using the limited records available for observed trips to the Gully, an average area of impact could be estimated for a single deployment of demersal longline. This estimate could then be used to inform appropriate adjustments to the grid cell size used in the analysis.

Using a gridded approach of set locations is the most efficient way of determining overall fishing presence. However, more work is required to address the actual contact of fishing gear on the seafloor, subsequent movements and related seafloor impacts. This would help determine if an indicator directed at estimating seabed area is appropriate for this gear.

Threats to ongoing monitoring

Plans for implementing a nationwide licensing, quota, and catch and effort system may have data access implications that could prevent ongoing commercial fisheries data analysis required for this indicator.

Table 38-1: Total number and percentage of 1 x 1 minute cells fished by bottom-contacting gear (demersal longline) in the MPA (2005–2011).

Cells Fished	2005	2006	2007	2008	2009	2010	2011	All years
Total cells fished	21	10	24	31	35	28	41	128
% of fishable cells	2.7	1.3	3.1	4.0	4.6	3.7	5.3	16.7

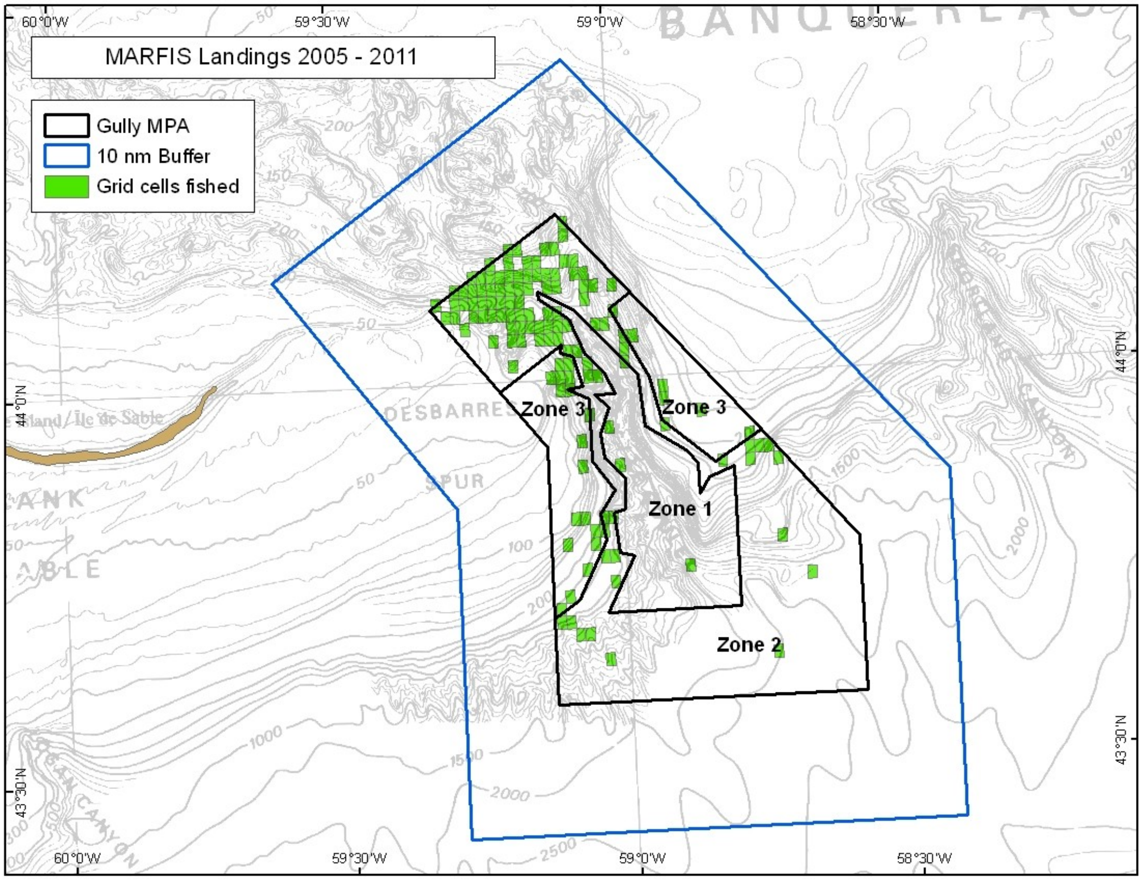


Figure 38-1: Total 1 x 1 minute cells fished by bottom-contacting gear (demersal longline) in the Gully MPA (2005–2011).

Indicator 40: Number and types of offshore petroleum exploration and development activities (e.g., number of wells, platforms, etc.) on the Eastern Scotian Shelf.

K. Curran T. Koropatnick and P. Macnab

Background

Seismic surveys are used by the oil and gas industry to identify areas of petroleum resource potential (Breeze and Horsman 2005). Offshore petroleum exploration typically begins with 2-Dimensional (2-D) seismic surveying to acquire a broad scale, low-resolution survey of the area of interest. If the 2-D survey identifies general areas of resource potential, a high resolution 3-Dimensional (3-D) survey typically follows, which targets particular areas of interest. Exploratory drilling typically follows if 3-D seismic surveys identify areas of resource potential. These exploratory wells are needed to confirm the presence, type and volume of hydrocarbons present at a site (Breeze and Horsman 2005). If an exploratory well reveals a significant discovery of oil or gas, a significant discovery licence may be granted, which allows the licence holder to maintain rights granted by an exploratory licence until they are ready to start production. If a commercially-viable oil or gas reserve is identified, a production licence may be issued to permit extraction to market. In Nova Scotia, offshore petroleum activities are primarily regulated by the Canada-Nova Scotia Offshore Petroleum Board (CNSOPB), although other regulatory authorities such as DFO may play a role.

The CNSOPB imposes an exclusion zone over all offshore petroleum activities within 1-nautical mile from the low tide mark around Sable Island. In addition, oil and gas exploration and development are not permitted within the Gully MPA.

Available data

All data used in this analysis were provided courtesy of the CNSOPB Data Management Centre. Geo-spatial data available from the CNSOPB includes offshore petroleum exploratory seismic program locations; exploratory drilling locations; production drilling and infrastructure locations and associated exclusion zones; leases, licences, Calls for Bids and Strategic Environmental Assessment boundaries; and applicable management boundaries (e.g., CNSOPB jurisdiction, Georges Bank moratorium boundary, Sable Island 1 NM exclusion zone, etc.).

Where available, data includes all offshore petroleum activities from 1967 to present, provided the data is verifiable, abides by quality assurance and quality control standards suitable for reporting purposes, and conforms with the proprietary information provisions outlined in the *Accord Acts*.

Analysis

The data allows for proximity mapping within 10 km and 50 km of the Gully to determine the nature and intensity of various offshore petroleum activities that have occurred in close proximity to the canyon pre–MPA establishment (1967 to May 2004) and post–MPA establishment (May 2004 to present).

For seismic surveys conducted between 1999 and 2003, available data on 2-D seismic activities conducted by industry near the Gully were mapped as the sum of the estimated track line kilometres shot per 10 km x 10 km grid cell. Areas where 3-D seismic surveys were conducted have been depicted as hatched polygons on top of the 2-D survey data.

Data on drilled wells, production centres, licensed parcels and parcels for bid located within 50 km of the Gully MPA were mapped by location.

Results

Seismic surveys

Seismic programs within 50 km of the Gully that occurred during a period prior to MPA establishment (1999 to 2003) are mapped in Figure 40-1. DFO is currently working with the CNSOPB to update its offshore petroleum geo-spatial data holdings, including any new seismic survey data.

Drilled wells (1972–2012)

Since 1972, 37 wells have been drilled within 50 km of the present-day Gully MPA boundaries (Table 40-1, Figure 40-2). Three of these, drilled in the early 1970s, are located within the current MPA. Post–MPA establishment, three gas wells have been drilled within 50 km of the MPA; the last of these was drilled in 2005.

Development and significant discovery licences (2012)

The Sable Offshore Energy Project (SOEP) is the only offshore petroleum development project to date with operations located within 50 km of the Gully MPA. The SOEP project began production in 1999. The hub for the project at the Thebaud natural gas field connects processing platforms at the active fields to a submarine pipeline that brings natural gas to shore. Two of the active fields of the SOEP are within 50 km of the Gully MPA: Venture and South Venture (Figure 40-3). In 2012, there were three Call for Bids areas, one exploratory licence, and 19 significant discovery licences within 50 km of the Gully MPA (including two significant discovery licences located in the MPA).

Evaluation of existing protocols for meeting indicator monitoring requirements

Proposed projects in proximity of the Gully MPA may be subject to an environmental assessment and follow-up monitoring to evaluate potential impacts of the proposed activity on the marine environment. Results from the SOEP environmental effects monitoring program were not presented in this document, but could be considered as an additional source of data. The 50 km assessment area chosen for this review was selected arbitrarily, and scale could be changed to evaluate the indicator over a larger or smaller area depending on future need.

Table 40-1: Drilled wells located within 50 km of the Gully MPA (1972–2012).

No.	Date	Well type[1]	ID	Water Depth (m)	Well Depth (m)	Description
In the MPA:						
1	Apr 21, 1972	Exploratory	N-50	90.8	1713	Plugged oil and gas well
2	Jan 27, 1973	Delineation	A-41	109.7	3616	Plugged gas show
3	May 3, 1973	Delineation	F-41	68.6	2592	Plugged gas show
Within 10 km of the MPA:						
4	Apr 25, 1973	Exploratory	G-47	81.4	4587	Plugged gas show
5	May 9, 1983	Exploratory	2 G-47	85.3	5797	Plugged gas show
6	Aug 30, 1983	Exploratory	F-34	173.9	6309	Plugged gas show
Within 50 km of the MPA:						
7	Jul 20, 1970	Exploratory	H-54	102.1	4202	Plugged dry hole
8	Oct 7, 1971	Exploratory	A-57	60	4575	Plugged dry hole
9	Apr 22, 1972	Exploratory	D-21	51.2	4660	Plugged gas show
10	Apr 29, 1974	Exploratory	I-59	94.5	4575	Plugged gas well
11	Jun 16, 1979	Exploratory	D-23	20.1	4945	Plugged gas well
12	Aug 17, 1980	Delineation	B-13	24.7	5368	Plugged gas well
13	Jan 8, 1982	Exploratory	C-21	83	4991	Plugged gas well
14	Apr 25, 1982	Delineation	B-43	20.4	5872	Plugged gas well
15	Dec 28, 1982	Exploratory	I-13	91	5188	Plugged dry hole
16	Feb 1, 1983	Exploratory	O-59	24	6176	Plugged gas well
17	Jul 19, 1983	Exploratory	J-16	55.5	6005	Plugged gas well
18	Jul 26, 1983	Delineation	H-22	24	5944	Plugged gas well
19	Sep 5, 1983	Exploratory	G-72	152.9	5735	Plugged gas well
20	Oct 27, 1983	Delineation	B-52	19.5	5960	Plugged gas well
21	Mar 23, 1985	Exploratory	C-62	16	5522	Plugged gas well
22	May 29, 1985	Exploratory	H-52	65.3	5666	Plugged dry hole
23	Jun 13, 1985	Exploratory	A-99	62	4024	Plugged dry hole
24	Jun 30, 1985	Service Relief	N-01	40.1	3632	Plugged gas well
25	Jul 7, 1985	Exploratory	N-91	38.1	5547	Plugged gas well
26	Apr 18, 1986	Exploratory	M-41	1516	5602	Plugged dry hole
27	May 11, 1999	Development	O-32	22	5314	Gas well
28	Oct 23, 1999	Development	O-32	22	5469	Gas well
29	Oct 29, 1999	Development	O-32	22	5110	Gas well
30	Dec 4, 2000	Development	O-32	22	6029	Gas well
31	Jun 30, 2001	Development	O-32	22	5586	Gas well
32	Oct 23, 2002	Development	O-32	22.5	6025	Gas well
33	Jan 15, 2003	Development	P-60	23	4439	Gas well
34	Mar 16, 2004	Exploration	I-85	55.5	5408	Plugged gas show
35	Jun 24, 2005	Development	P-60	22.9	5315	Gas well
36	Jan 7, 2005	Development	P-60	22.9	4666	Gas well
37	24-Dec-05	Development	O-32	22	6483	Gas well

[1] Delineation wells may be drilled to confirm the extent and characteristics of hydrocarbon resources after an exploratory well reveals their presence. Development wells are drilled for extracting hydrocarbon resources.

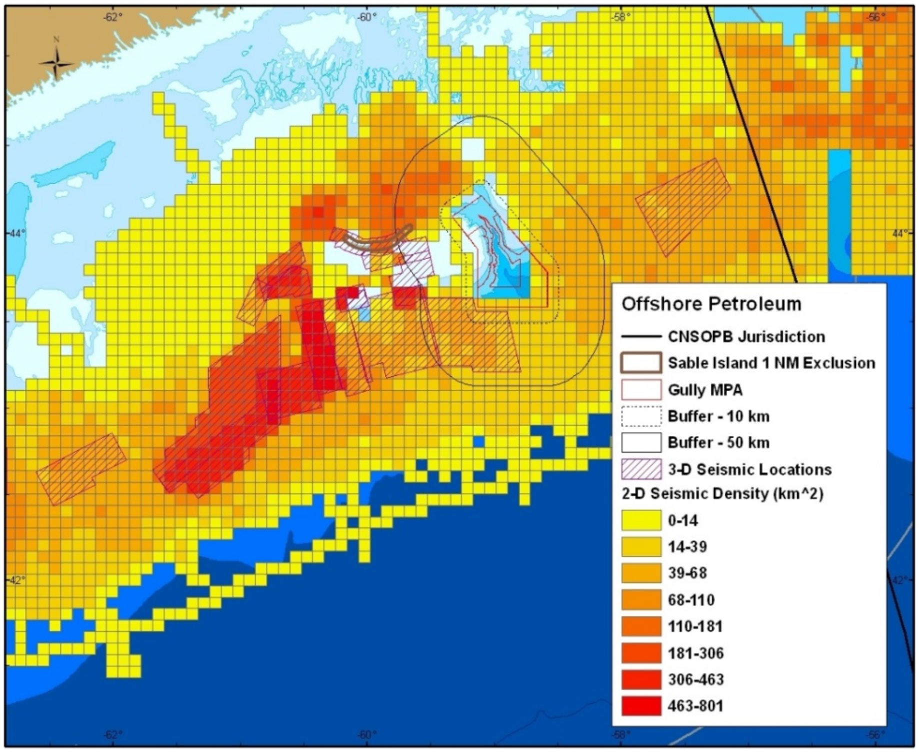


Figure 40-1: Seismic programs located within 50 km of the Gully MPA that occurred from 1999 to 2003. Modified from Breeze and Horsman (2005).

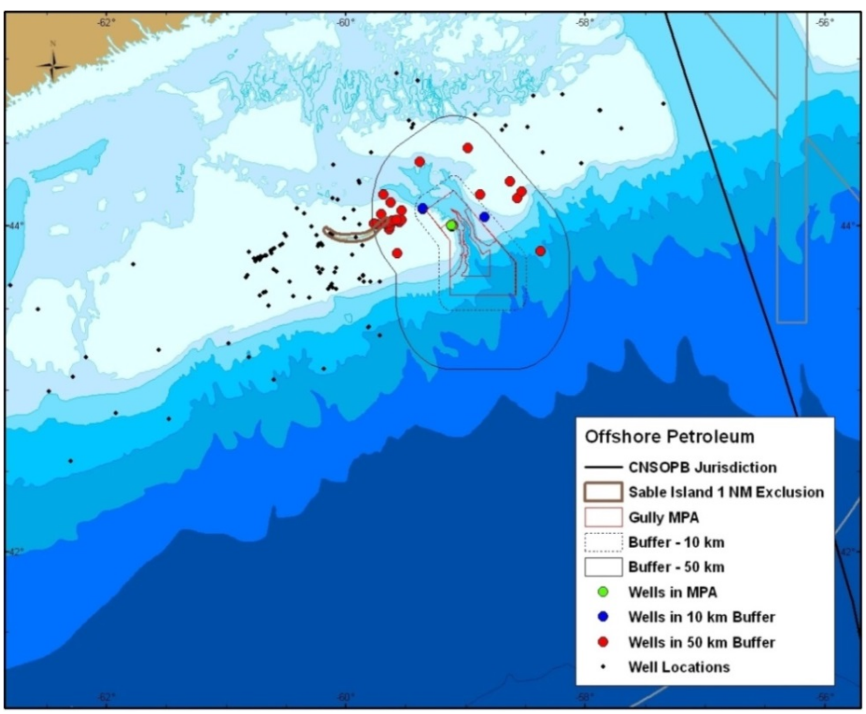


Figure 40-2: Drilled wells located within 50 km of the Gully MPA from 1972 to 2012.

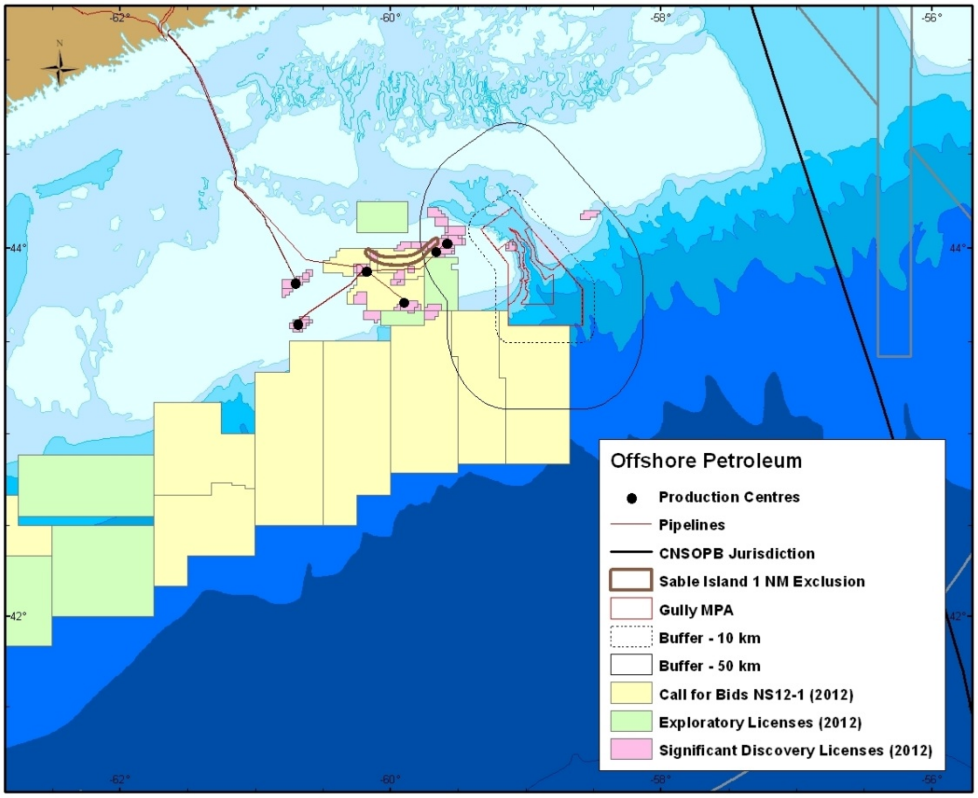


Figure 40-3: Calls for Bids, exploratory licences, significant discovery licences and production centre locations (2012). Within 50 km of the Gully MPA, the northernmost production centre is the Venture platform and the other is South Venture.

Indicator 41: Number, quantities and type of discharges from offshore petroleum installations and activities on the Eastern Scotian Shelf.

K. Curran, T. Koropatnick and P. Macnab

Available data

Quality-controlled discharge data associated with offshore petroleum activities, including date, volume, location and source, is available from the Canada-Nova Scotia Offshore Petroleum Board (CNSOPB) Data Management Centre. Data for spills located within 50 km of the Gully MPA, from January 2000 to September 2012, was used in the analysis presented here.

Analysis

Spill data within 50-km of the Gully MPA were assessed to determine the nature and intensity of spills that have occurred in close proximity to the Gully from January 2000 until MPA establishment in May 2004, and post establishment to present day (September, 2012).

Results

From January 2000 to September 2012, discharges associated with offshore petroleum activities occurring within 50 km of the Gully have included accidental releases of diesel fuel, hydraulic oil, lubricating oil, other unclassified oils, condensate and synthetic muds (Table 41-1, Table 41-2, Figure 41-1). The largest volumes released have been from diesel (385.5 L), hydraulic oil (194 L) and condensate (183 L, including one spill of 128 L in November 2011).

Spills have totaled 797 L since 2000, including 304.3 L spilled post–MPA establishment in May 2004. There have been no spills to date in 2012.

Spill volumes have primarily been characterized by a few large spill events. No discernible patterns or trends are evident when spill volumes per year are analyzed by spill type (Figure 41-1). Overall, a larger volume of material was spilled from offshore petroleum installations within 50 km of the Gully MPA prior to establishment in May 2004 as opposed to the post-establishment period.

Evaluation of existing protocols for meeting indicator monitoring requirements

While the assessment presented here is adequate to characterize spills associated with offshore petroleum activities, it did not include a review of produced water discharges, which do occur within 50 km of the Gully. Produced water discharges are regularly monitored and reports are filed with the CNSOPB on a monthly, basis or more often, if discharge levels exceed regulatory limits. These data are available through the CNSOPB website. For comprehensive monitoring of this indicator, produced water discharge levels should be included in future analyses.

The 50 km assessment area chosen for this review was selected arbitrarily and scale could be changed to evaluate the indicator over a larger or smaller area depending on future need.

Threats to ongoing monitoring

Operators are required to report environmental and health and safety incidents to the CNSOPB in accordance with criteria set out in regulation, as detailed in the Guideline for the Reporting and Investigation of Incidents (C-NLOPB and CNSOPB 2009). As such, the data sources used in this analysis can be relied upon for ongoing monitoring of the Gully MPA.

Table 41-1: Spills within 50 km of the Gully MPA (January 2000–September 2012).

Spill Substance	Spill Volume Pre-MPA 2000–May 2004 (L)	Spill Volume Post-MPA May 2004–Present (L)	Total Spills (L)
Diesel	385.0	0.5	385.5
Hydraulic oil	91	103.0	194.0
Lubricating oil	0.1	0.0	0.1
Condensate	1.9	181.1	183.0
Oil (unclassified)	12.9	0.5	13.4
Synthetic-based muds	1.8	19.2	21.0
Total spills	493.2	304.3	797.0

Table 41-2: Spills details within 50 km of the Gully MPA (January 2000- September 2012). A dash (-) indicates not applicable.

Date	Volume (L)	General Location	Spill Source
Diesel:			
Jun 30, 2000	350	Venture 5	Diesel loading hose
May 19, 2001	35	Venture	Transfer hose
May 11, 2003	0.5	Venture 1	Fuel tank-on line
Sep 2, 2010	0.0068	S. Venture	Bunkering hose
Sep 13, 2010	0.008	S. Venture	Bunkering hose
Total	385.5	-	-
Hydraulic Oil:			
Aug 30, 2000	91	Venture	Value actuator
Jun 15, 2005	4	S. Venture 2	ROV hydraulic oil system
Aug 5, 2005	55	S. Venture	Loose hydraulic fine fitting
Dec 2, 2005	5	S. Venture	Condensate level control valve
Jun 1, 2009	39	S. Venture	Valve
Total	194.0	-	-
Lubricating Oil:			
Aug 21, 2001	0.1	Venture	Vent pumps
Total	0.1	-	-
Oil (Unclassified):			
Nov 7, 2000	0.1	Venture	Deck drainage
Apr 19, 2001	0.5	Venture	Degassing drum vent
Apr 3, 2002	0.3	Venture	Test separator
Feb 9, 2003	10	Venture	Unknown
Jul 22, 2003	2	Venture	Vent drum
Feb 25, 2005	0.1	S. Venture	Not reported
May 4, 2005	0.1	S. Venture	Deck drainage
Jun 28, 2005	0.1	S. Venture	Bucket of produced water
Aug 29, 2005	0.1	Venture	Vent drum
Oct 22, 2008	0.1	S. Venture	Deck drainage
Total	13.4	-	-
Condensate:			
Feb 21, 2002	1.3	Venture	Test separator
Mar 3, 2002	0.6	Venture	Test separator
Aug 6, 2004	0.4	Venture	Drum level valve
Mar 21, 2005	0.5	Venture	Pressure safety valve
Jul 11, 2005	0.1	Venture	Pressure safety valve
Apr 1, 2006	50	S. Venture	Condensate valve
Jun 28, 2006	2	Venture	Vent drum
Aug 25, 2008	0.1	Venture	Vent drum pump
Nov 28, 2011	128	S. Venture	Crudesorb unit
Total	183.0	-	-
Synthetic-based Muds:			
May 29, 2002	1	Venture 6	Stripping tank
Jun 12, 2002	0.3	Venture 6	Mud-line jumper hose
Jul 30, 2002	0.5	Venture 6	Bulk transfer operations
Mar 10, 2005	19	S. Venture 3	Exhaust vent fan
Dec 19, 2005	0.2	Venture 7	Mixed slops

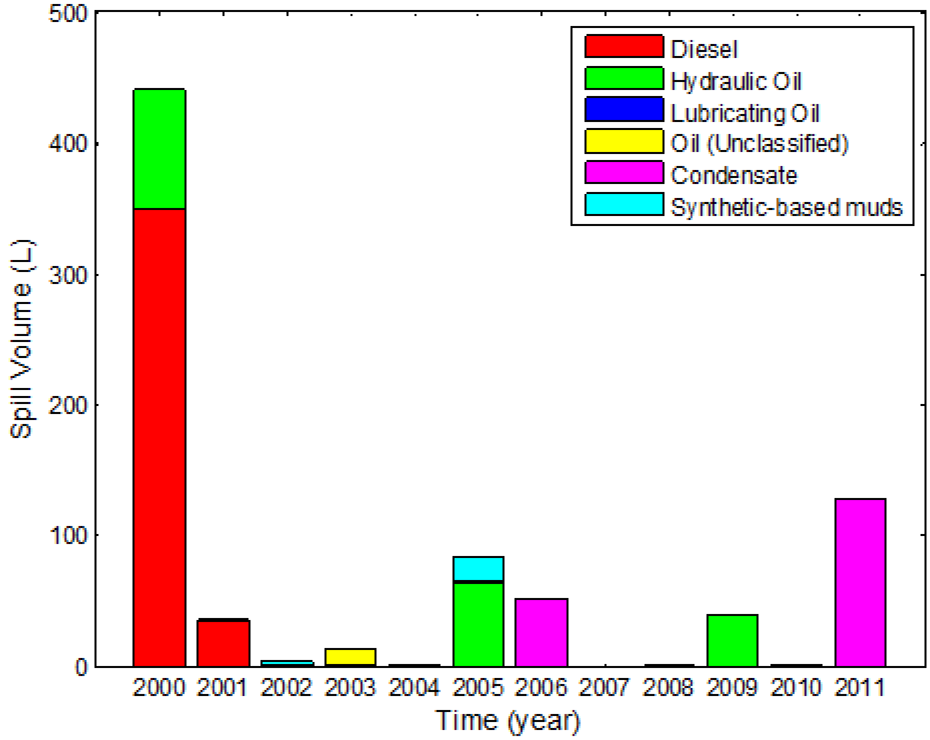


Figure 41-1: Spill volumes within 50 km of Gully MPA (2000–2011).

Indicator 42: Number of ships' ballast-water exchanges in close proximity of the MPA and the quantities of ballast exchanged

T. Koropatnick

Suggested improvements to indicator wording

"Number and quality of ships' ballast-water exchanges conducted within or in close proximity to the MPA."

The mapping method presented here serves to classify ballast exchanges as compliant or anomalous based on spatial rules outlined in the *Ballast Water Control and Management Regulations*. This classification provides some indication of the quality of water undergoing exchange (e.g., a compliant exchange within the Gully may represent an exchange of water sourced from an acceptable distance offshore, or an otherwise acceptable location within Canadian waters). The addition of the word 'quality' in the indicator reflects this nuance in the maps. As well, available data from ships' ballast water exchange reports provides volumes exchanged in each tank for the entire exchange track, which generally spans hundreds of kilometres, so quantities exchanged within or nearby the MPA cannot be determined.

Background

Ballast water is water carried in tanks on-board vessels that is taken up or discharged to ensure proper trim and stability under varying loads. Port-sourced ballast water may contain non-indigenous species, pathogens, and pollutants that pose a risk to the marine environment. By 2016, Canada and other signatories of the *International Convention for the Control and Management of Ships Ballast Water and Sediments* will require vessels to have on-board ballast water treatment systems (chemical, filtration, and/or ultra violet radiation treatment) to reduce the risk of non-indigenous species introductions from ballast water. Currently, the most commonly used ballast water management technique is ballast water exchange. Ballast water exchange involves the replacement of low salinity port-sourced water with high salinity offshore water. Since coastal species are unlikely to survive in the open ocean and vice-versa, ballast water exchange reduces the risk of non-indigenous species introductions from ships' ballast. There are two commonly used methods for ballast water exchange. The first is the flow-through method, which involves pumping water through each ballast tank until three times the volume of the tank has been exchanged. The second method is the sequential (empty/refill) method, which is faster but can affect vessel stability.

Canada's *Ballast Water Control and Management Regulations* and associated guidelines (TP13671; Transport Canada 2007) prescribe acceptable management practices, treatment standards and reporting requirements and lay out spatial rules and restrictions for ballast water exchange in Canadian waters. These include the identification of Alternative Ballast Water Exchange Zones (ABWEZ) where ballast water exchanges can be conducted in waters under Canadian jurisdiction if safety or logistical considerations preclude exchanges farther offshore. One of these exchange zones extends north to a latitude line 5 km south of the MPA boundary. This northern limit was designed with consideration for the Gully MPA and predominant tidal flows in the vicinity (Brickman et al. 2004). Vessels are also permitted to conduct exchanges within a seasonal (December 1 and May 1) ABWEZ in the Laurentian Channel.

Available data

Vessels bound for Canadian ports must report the status of their ballast tanks, the management activities that have been conducted on their ballast and tanks and their intentions for additional ballast water management to Transport Canada's Marine Safety program. Data from these reports are entered into a central database maintained by Transport Canada.

Ballast exchange reporting became mandatory when the *Ballast Water Control and Management Regulations* came into force in June 2006. When the analysis undertaken in this report was performed, comprehensive, quality-controlled data was available from 2007 to 2009.

Atlantic ballast water exchange records were accessed from Transport Canada's central ballast water exchange database. Variables in the dataset included: vessel identification; name of departure port; destination port and ballast water source port; expected arrival date; geographic coordinates of source ballast water for ballast taken up outside of port and date; volume; and start and stop coordinates of any exchange conducted for each ballast tank.

Analysis

Ballast exchange track lines (inferred path represented by a straight line connecting start and stop coordinates for each reported exchange) or points (for records that only included stop coordinates) were mapped as compliant or anomalous[1] based on spatial rules distilled from the Regulations. Briefly, vessels may discharge ballast water anywhere in Canadian waters if it is sourced from within Canadian waters. Vessels may also discharge ballast water sourced from outside Canadian jurisdiction in Canadian waters if an exchange has been conducted so that the water comes from an area at least 200 NM from shore in depths of at least 2000 m [Section 6(2)], or from 50 NM offshore in depths of at least 500 m for vessels on non-transoceanic voyages (voyages where vessels do not navigate more than 200 NM from shore where water depths are at least 2000 m) [Section 7(2)]. Alternatively, if safety or logistical considerations

[1] Anomalous exchanges could not be identified as compliant based on the spatial rules outlined in the Regulations and associated guidance document, but they may still be compliant for other reasons, such as safety.

preclude the management of ballast as described above, vessels may exchange their ballast within several designated ABWEZ. In the vicinity of the Gully MPA, vessels may conduct ballast exchange in an area south of 43°30′ N latitude where the water depth is at least 1000 m [Section 6(4a) and Section 7(3a)}. Further, vessels may conduct an exchange in the Laurentian Channel east of 63° W longitude where the water depth is at least 300 m, between December 1 and May 1.

Results

Maps were created to show compliant and anomalous ballast exchange activities on the Scotian Shelf for 2007, 2008 and 2009 (Figures 42-1 to 42-3).

A comparison of the three annual ballast exchange maps reveals some pronounced differences between 2007 and the two subsequent years. The dataset for 2007 contains substantially fewer records than 2008 and 2009 and many of the records include exchange coordinates for end points only. Before the Regulations came into force in June 2006, ballast exchange reporting was voluntary and based on the IMO report form, which only requires geographic coordinates for the end point of each exchange. Reporting requirements, such as the recording of start and end points for each exchange, were not standardized across the country until 2009. The trend towards the adoption of the more detailed reporting requirements is evident when comparing the proportion of ballast exchange tracks versus end points in each consecutive year (Figures 42-1 to 42-3).

For each year, compliant exchange activity was concentrated within the ABWEZ, and primarily in the Scotian exchange zone. Compliant tracks outside of these zones indicate exchanges of water of acceptable quality (i.e., water sourced from at least 200 NM offshore in depths of at least 2000 m).

In 2007, six vessels had exchange tracks that crossed or ended within the Gully MPA, and 11 had exchange tracks that crossed the MPA boundaries in 2008 (Table 42-1). The increase in ballast exchange tracks passing through the Gully MPA in 2008 compared to 2007 likely reflects improvements in compliance with the reporting requirements after 2007 and not an increase in activity. In 2009, 17 exchange tracks passed through the MPA, six of which were reported by the same vessel. The number of individual vessels with exchange tracks that crossed into the MPA were similar for 2008 (i.e., 11) and 2009 (i.e., 12).

Most exchange tracks that passed through the Gully MPA in each of the three years were classified as anomalous (Table 42-1). The majority of these were from vessels originating from ports along the east coast of the United States destined for ports in Nova Scotia, Newfoundland or Quebec. Because the MPA is located just north of the Scotian ABWEZ, many of the track lines passing through the MPA connect start coordinates that began within the acceptable exchange zone to stop coordinates located north and eastward along the shelf edge beyond the zone. In these cases, vessels were most likely exchanging their ballast using the flow-through method. Because the Regulations require that vessels conducting flow-through exchanges must pump enough water through each tank so that three times the volume has been exchanged, flow-through exchanges can take a considerable amount of time over long distances. As such, it may be difficult for a vessel to complete a flow-through exchange within the ABWEZ boundaries. Even so, by the time the vessel has left the designated exchange zone and is passing through the MPA, the concentration of pollutants and non-indigenous species being discharged from the ballast tanks would be low compared to concentrations released at the start of the exchange.

Evaluation of existing protocols for meeting indicator monitoring requirements

While the mapping method presented here permits the visualization of ballast exchange activities in the vicinity of the Gully MPA, the available data do not permit an adequate determination of the quality of water released within or nearby the MPA. For example, even if water from an 'anomalous' exchange is released within the MPA, ballast tanks may be in the final stages of flow-through flushing and have very low concentrations of non-indigenous species and pollutants remaining. As well, because the exchange track lines represent an inferred, straight line route, rather than the actual path of each ballast exchange, it is possible that vessels took a longer route to avoid discharging their ballast within 50 km of the MPA, in accordance with Section 5a of the Annual Notices to Mariners (Canadian Coast Guard 2012).

Threats to ongoing monitoring

The data required to perform the analyses described here are collected as part of a program led by another government department. Specifically, Transport Canada provides monitoring and oversight of ballast water management activities to ensure compliance with the ballast water reporting and management requirements in the Regulations.

Additional comments

In 2016, when the requirements for on-board ballast water treatment systems take effect, ballast exchange as a form of ballast water management may become less common and the level of threat presented by this activity to the Gully MPA may be reduced.

Furthermore, as a primarily deep- water habitat, the Gully is not highly susceptible to non-indigenous species introductions from near shore environments. While any discharge of contaminants from polluted port waters would be a contravention of the Gully MPA Regulations under the *Oceans Act*, the quantities discharged within the MPA from this vector may not be enough to warrant the inclusion of this indicator in the Gully MPA monitoring program. Either way, ballast water exchange activities in and around the Gully will continue to be monitored by Transport Canada and the OCMD, as part of ongoing regulatory compliance monitoring for the MPA.

Table 42-1: Vessels that exchanged ballast within the Gully MPA from 2007 to 2009.

Vessel # (Trip #)	Compliant (C)/ Anomalous (A)	Ballast Source (# of tanks)	Departure Port	Destination Port
2007:				
1 (1)	A	New Haven, CT (5)	New Haven, CT	Come By Chance, NL
2 (1)	C	Saint John, NB (1)	Saint John, NB	Montreal, QC
3 (1)	A/C (1 tank)	Baltimore, MD (11) Non-port water (1)	Baltimore, MD	Botwood, NL
4 (1)	A	Searsport, ME (14)	Searsport, ME	Tracy, QC
5 (1)	A	Port Reading, NJ (2)	Port Reading, NJ	Come By Chance, NL
6 (1)	A	Searsport, ME (2)	Searsport, ME	Come By Chance, NL
2008:				
1 (1)	A	NY and NJ (12)	NY and NJ	Come By Chance, NL
2 (1)	A	Carteret, NJ (1)	Carteret, NJ	Come By Chance, NL
3 (1)	A	NY and NJ (2)	Bayonne, France	Come By Chance, NL
4 (1)	A	Portland, ME (2)	Portland, ME	Come By Chance, NL
5 (1)	A	Portland, ME (2)	Portland, ME	Point Tupper, NS
6 (1)	A	Providence, RI (3)	Boston, MA	Nanticoke, ON
7 (1)	A	Searsport, ME (1)	Searsport, ME	Come By Chance, NL
8 (1)	A	Portland, ME (2)	Portland, ME	Come By Chance, NL
9 (1)	C	Non-port water (1)	Freeport, Bahamas	Montreal, QC
10 (1)	A	Non-port water (2)	Portland, ME	Come By Chance, NL
11 (1)	A	New Haven, CT (2)	Portland, ME	Come By Chance, NL
2009:				
1 (1)	A	Non-port water (1)	La Havre, France	Halifax, NS
2 (1)	A	Savannah, GA (2)	Searsport, ME	Come By Chance, NL
3 (1)	A	Bayway, NJ (5)	Bayway, NJ	Conception Bay, NL
4 (1)	A	NY and NJ (3)	NY and NJ	Come By Chance, NL
5 (1)	A	Philadelphia, PA (2)	Philadelphia, PA	Point Tupper, NS
5 (2)	A	Bayway, NJ (4)	Bayway, NJ	Point Tupper, NS
5 (3)	A	Bayway, NJ (2)	Bayway, NJ	Point Tupper, NS
5 (4)	A	Bayway, NJ (2)	Bayway, NJ	Point Tupper, NS
5 (5)	A	Bayway, NJ (2)	Bayway, NJ	Point Tupper, NS
5 (6)	A	Bayway, NJ (2)	Bayway, NJ	Point Tupper, NS
6 (1)	A	NY and NJ (2)	NY and NJ	Tracy, QC
7 (1)	A	Boston, MA (1)	Boston, MA	Trois-Rivieres, QC
8 (1)	A	Non-port water (1)	Jacksonville, FL	Hantsport, NS
9 (1)	A	Portland, ME (1) Paulsboro NJ (1)	Paulsboro, NJ	Come By Chance, NL
10 (1)	A	Bayway, NJ (4)	Bayway, NJ	Come By Chance, NL
11 (1)	A	Bayway, NJ (4)	Bayway, NJ	Come By Chance, NL
12 (1)	C	Non-port source (4)	Providence, RI	Port Alfred, QC

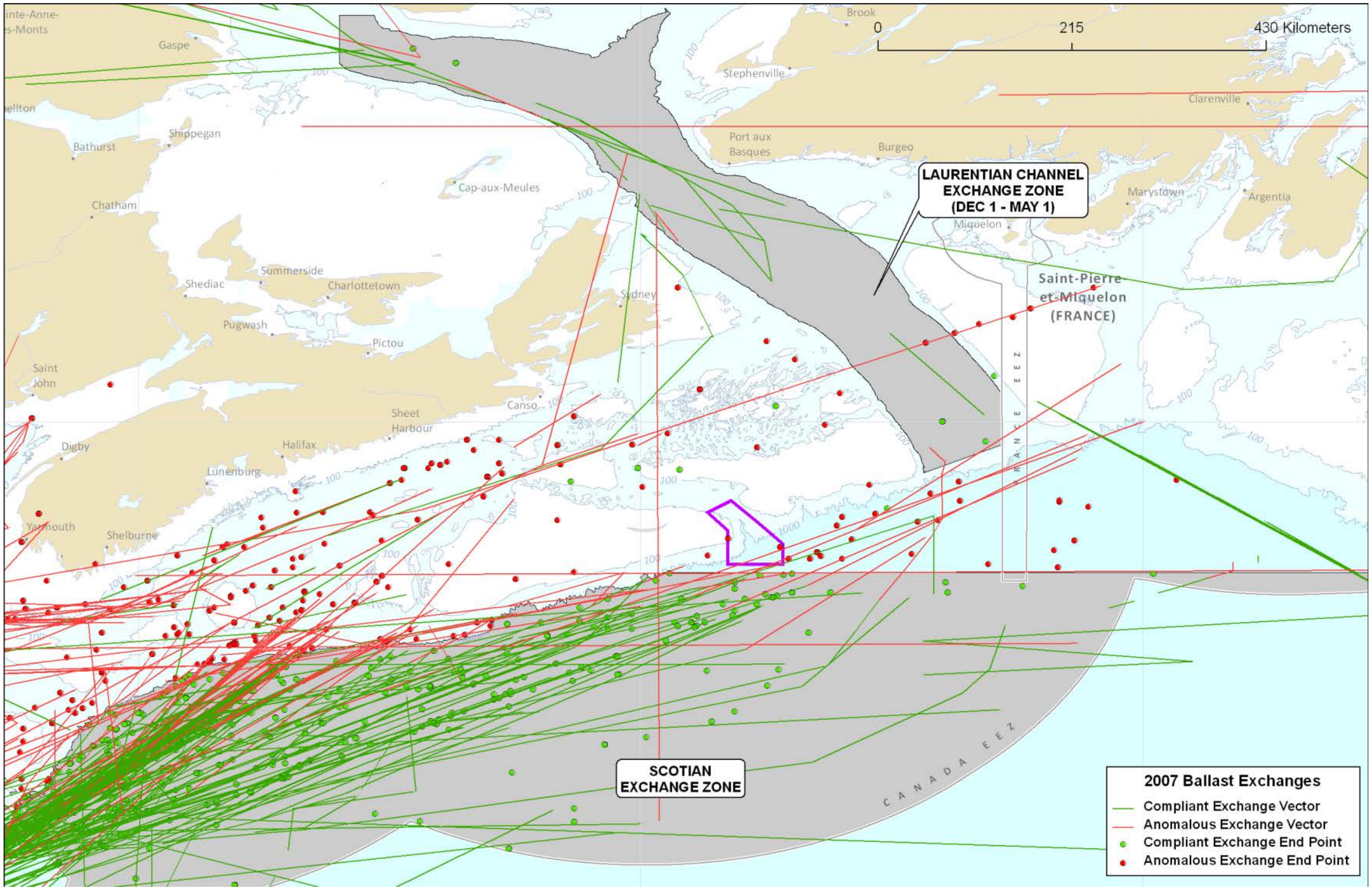


Figure 42-1: Ballast water exchange activity on the Scotian Shelf in 2007. Green track lines and end points indicate exchanges identified as compliant according to the Ballast Water Control and Management Regulations. Red track lines and end points indicate anomalous exchanges. Purple polygon: Gully MPA; dark grey polygons: Alternative Ballast Water Exchange Zones.

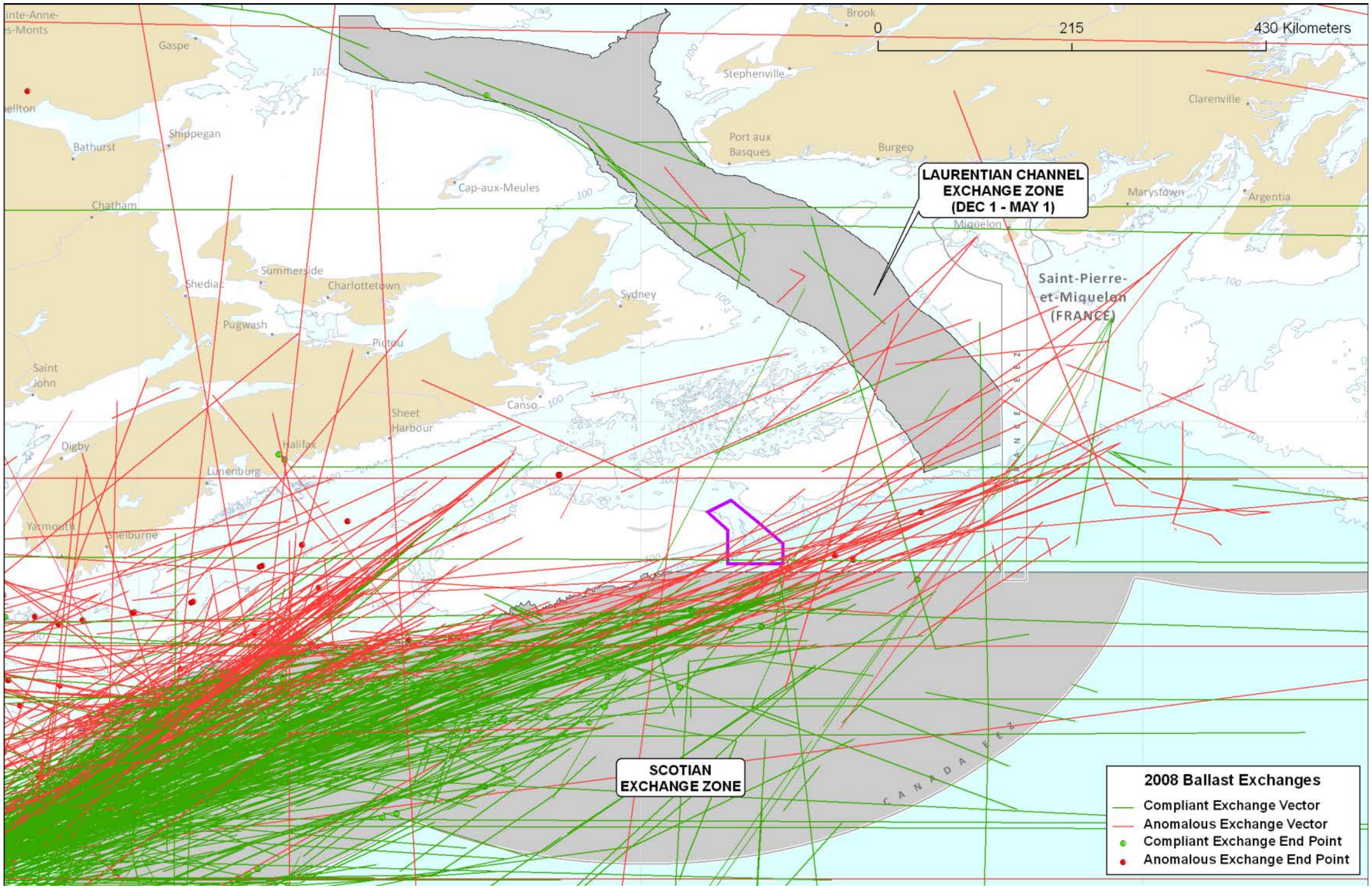


Figure 42-2: Ballast water exchange activity on the Scotian Shelf in 2008. Green track lines and end points indicate exchanges identified as compliant according to the Ballast Water Control and Management Regulations. Red track lines and end points indicate anomalous exchanges. Purple polygon: Gully MPA; dark grey polygons: Alternative Ballast Water Exchange Zones.

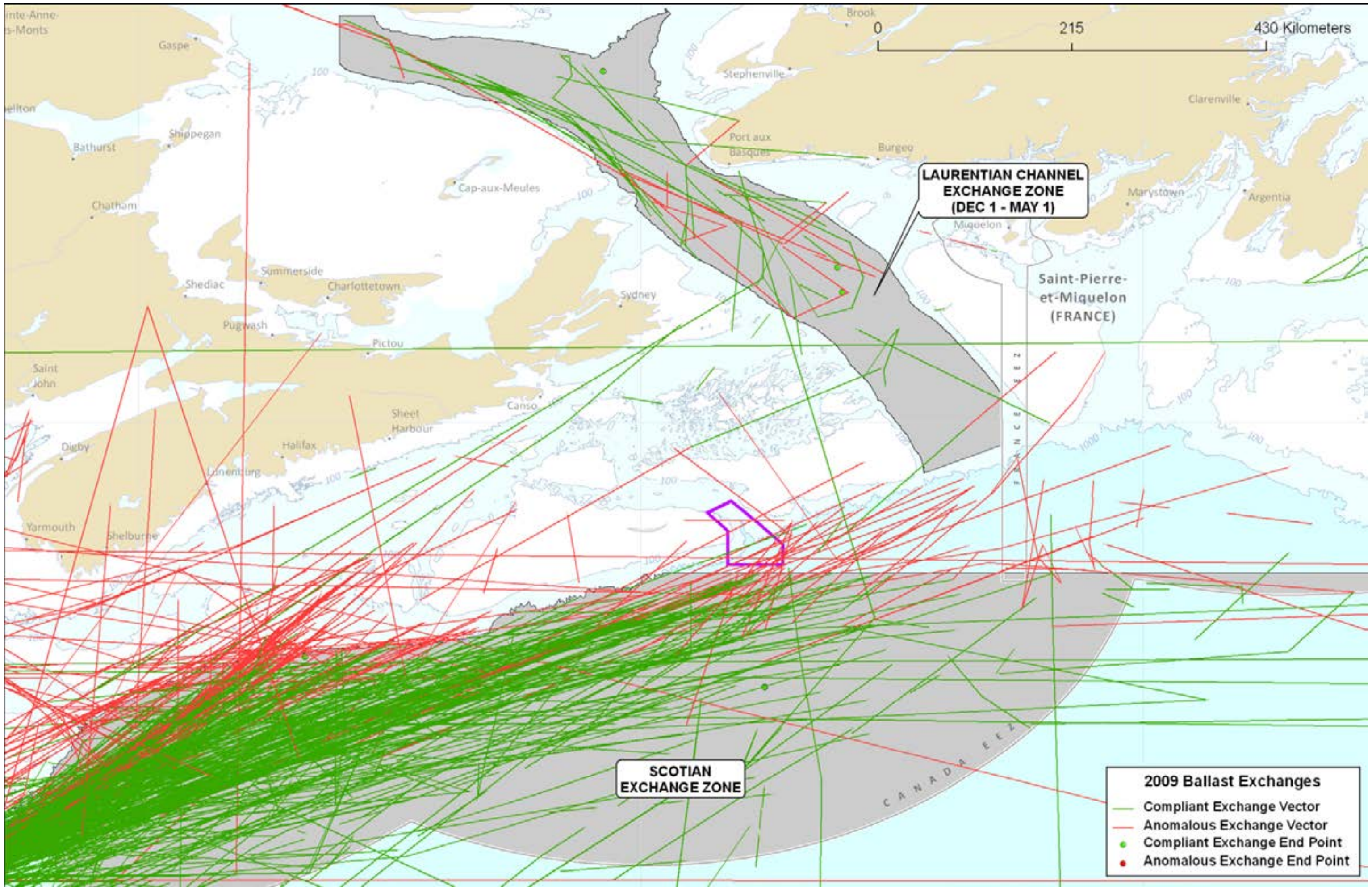


Figure 42-3: Ballast water exchange activity on the Scotian Shelf in 2009. Green track lines and end points indicate exchanges identified as compliant according to the Ballast Water Control and Management Regulations. Red track lines and end points indicate anomalous exchanges. Purple polygon: Gully MPA; dark grey polygons: Alternative Ballast Water Exchange Zones.

Indicator 43: Number, quantities, and types of other discharges from shipping within or in close proximity to the MPA

T. Koropatnick

Suggested improvements to indicator wording

“Number, quantity, and source of oily discharges from marine transportation within or in close proximity to the MPA.”

While it would be very useful and informative to track all types of vessel-sourced discharges, data are not available for most. The scope of the indicator has been adjusted accordingly. ‘Shipping’ has been replaced with ‘marine transportation’ to reflect the fact that oily discharges may come from vessels other than those involved in maritime shipping, such as fishing vessels.

Background

Operational vessel-sourced discharges can include bilge water, fuel oil sludge, slop tank releases, sewage, solid wastes and ballast water (GESAMP 2007). Provisions of the *Canada Shipping Act, 2001*, the *Arctic Waters Pollution Prevention Act*, the *Fisheries Act* and the *Canadian Environmental Protection Act, 1999,* as well as related regulations and guidelines, serve to reduce and control vessel-sourced discharges into waters under Canadian jurisdiction. The legislation dictates management requirements for the various vessel-sourced discharges, including the need for on-board holding tanks, treatment facilities and specifications on the quality and/or distance from shore for permissible discharges. However, while vessels are often required to keep on-board records to track discharges and other waste management activities, in many cases these data are not routinely collected and archived in a centralized database. As such, available data for monitoring vessel-sourced discharges is limited.

Transport Canada’s National Aerial Surveillance Program (NASP) provides the primary surveillance mechanism for detecting oil pollution at sea. The NASP fleet includes a Dash-8 aircraft housed in Moncton, New Brunswick, that is used to conduct aerial surveillance for a large region encompassing the Maritime Provinces and the Great Lakes. The program takes advantage of a wide array of remote sensing equipment to help detect and characterize oil spills, including satellite-based oil-like anomaly detections (via Environment Canada’s Integrated Tracking of Pollution program), side-looking airborne radar (which enables sight-lines up to 45 NM on either side of the plane), ultraviolet/infrared line scanners, geo-coded digital cameras and electro-optical infrared cameras.

Available data

NASP surveillance flights are planned and conducted regularly – often daily. Coordinates for the Gully MPA have been provided to NASP flight planners and the MPA is included in surveillance flight plans whenever feasible. Given the large territory covered by the surveillance plane, NASP coverage of the Gully MPA is limited.

NASP pollution sightings data for Atlantic Canadian waters was obtained by request from Environment Canada. Variables in the dataset included detection date and time, location (latitude and longitude), estimated volume and spill source (if known). At the time of the request (May 2012), NASP sightings data were available from April 1, 2007 to December 31, 2011. This program is ongoing and data holdings are updated in a central database on an annual basis.

Analysis

All NASP oil spill sightings in Atlantic Canada from April 1, 2007 to December 31, 2011 were mapped. Graduated colours were used to indicate estimated spill volumes at each location. If data relevant to the Gully MPA had existed, a table detailing each spill event by date, source (e.g., unknown, fishing vessel, tanker) and volume could have been created.

Results

During 2011, 31 flights passed through or close to (within approximately 50 km) the MPA, which equates to 2.6 flights per month. An example of a flight that included this area is in Figure 43-1.

The locations and estimated volumes of spills detected by aerial pollution surveillance in Atlantic Canadian waters from April 1, 2007 to December, 2011 are shown in Figure 43-2. The nearest documented spills were over 100 km away from the Gully MPA.

Evaluation of existing protocols for meeting indicator monitoring requirements

Data on operational vessel-sourced discharges are limited. While the NASP provides data for tracking oil spill detections, oil spill investigations are inherently limited by the vast territory covered by the single Moncton-based plane.

Threats to ongoing monitoring

The NASP program is funded in part by the Health of the Oceans (HOTO) Initiative. With the sunsetting of that funding source in March 2013, there is a risk that surveillance coverage, particularly offshore, may decrease.

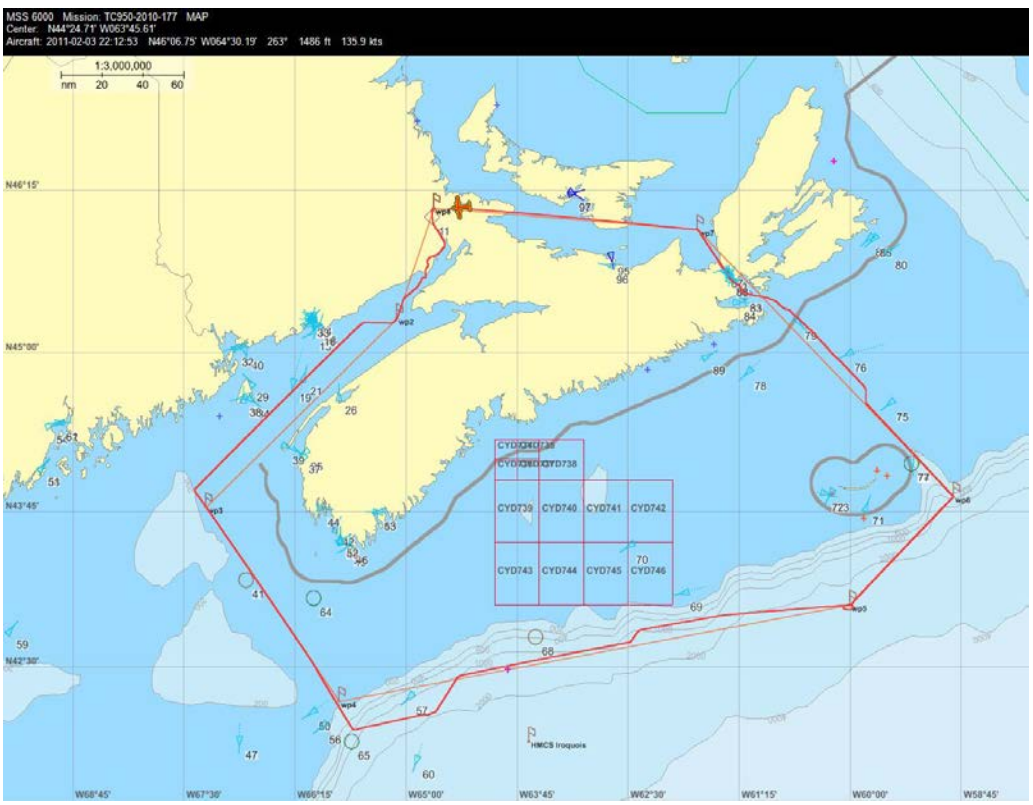


Figure 43-1: The route taken by a National Aerial Surveillance Program (NASP) flight that occurred on February 3, 2011.

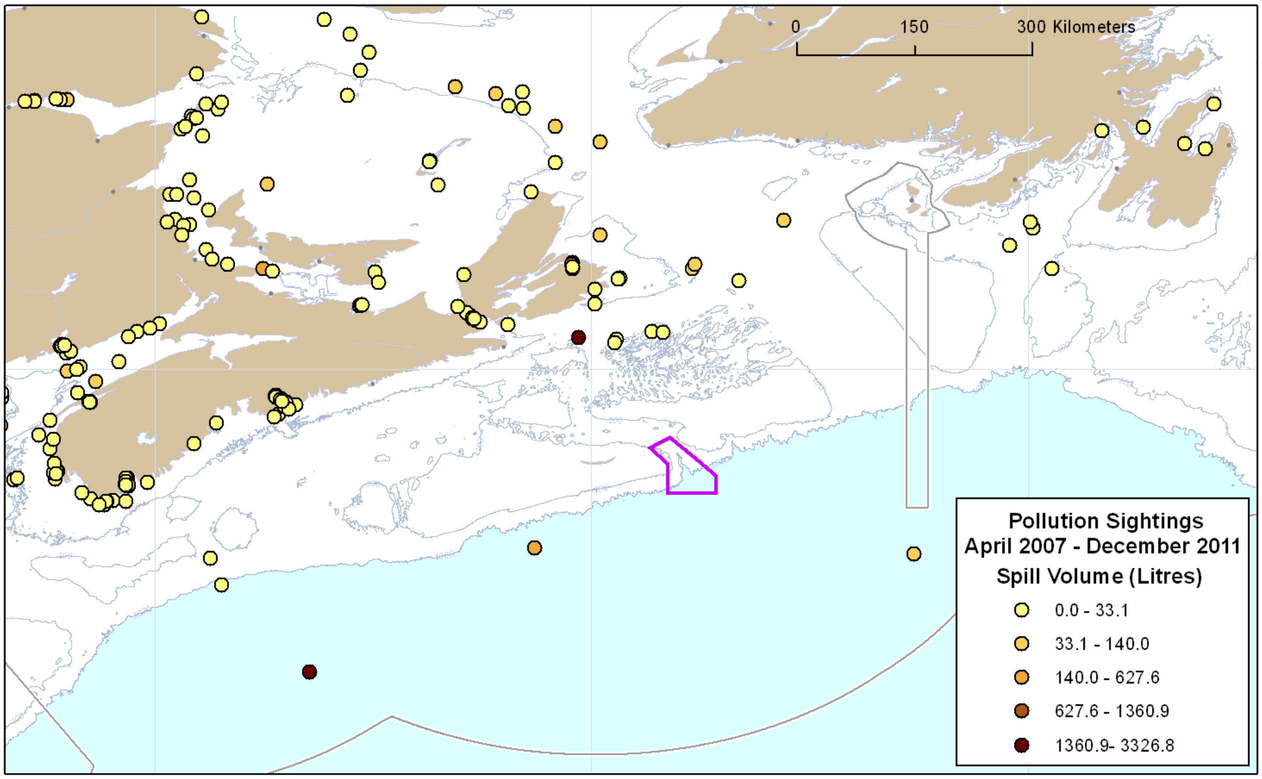


Figure 43-2: Locations and estimated volumes (L) of spills detected by aerial pollution surveillance in Atlantic Canadian waters from April 1, 2007 to December, 2011. The Gully MPA is represented by the purple polygon.

Indicator 44: Quantity of floating debris (i.e., large objects) in the Gully MPA

T. Koropatnick

Available data

There is no ongoing monitoring program that collects data on floating debris in the Gully MPA. However, Dufault and Whitehead (1994) conducted a study prior to MPA designation that provides a useful example of how such a program might be implemented. As part of that research, data on large debris and small particulate pollution were collected during three trips to the Gully in the summer of 1990.

Data collection

Data collection focused on quantifying large debris, small debris and tar.

Large debris

Visual surveys were conducted on a 10 m sailing vessel by one observer. A total of 20 transects (50 m) were conducted: 14 were located at the mouth of the Gully (within current MPA boundaries), while others were done nearby, and one was conducted in the neighbouring Shortland Canyon. Wherever possible, debris was brought on board for identification.

Small debris

A total of 25 transects for small debris were conducted, 17 at the mouth of the Gully and 2 in Shortland Canyon. A neuston net with a 0.4 m x 0.4 m opening and a mesh size of 308 μm was towed behind the vessel outside of the wake at approximately 5.5 km/h for 20 minutes.

Transects were approximately 1.85 km in length with an average sampling surface area of 740 m^2.

Samples were strained through a coffee filter and the filters were then stored in resealable plastic bags. In the laboratory, each filter was rinsed with freshwater and air-dried. Dried debris was sorted, identified, and measured with the aid of a dissecting microscope, then weighed. Densities by weight and items/m^2 were calculated for each sample.

Tarballs were removed at sea by hand and stored in plastic bottles. In the laboratory, the bottles were cut open and the tar was scraped out using a scalpel and weighed.

Results

Large debris

The average density of large debris was 31.6 items/km^2 (sd= 27.6) in the Gully region and 11.0 items/km^2 (sd= 11.7) outside the Gully region. Debris included plastic bags, nylon rope, potato chip bags, polystyrene and an ice cream container lid. Items with identifiable labels were all from the DFO Maritimes Region.

Small debris

Plastics were found in 80% of the tows. The average density of small debris was 1.20×10^{-5} g/m^2 (sd= 8.10×10^{-6}) in the Gully region and 7.95 x 10-6 g/m^2 (sd= 7.41×10^{-6}) outside the Gully. Debris included small pieces of polystyrene, textile fibres, fishing line, cellophane, hard plastics and small opaque spherules.

There were measurable amounts of tar in 72% of the samples and 8% of samples contained trace amounts. Average tar density was 4.32×10^{-5} g/m^2 in the Gully region and 1.05×10^{-2} g/m^2 outside the Gully.

In Shortland Canyon, densities of both large and small debris were within the range of those found in the Gully.

Evaluation of existing protocols for meeting indicator monitoring requirements

While the Dufault and Whitehead (1994) study suggests that higher levels of large and small marine debris exist in the Gully region compared to outside the Gully, the small sample size and lack of random sampling precluded the use of statistics to make comparisons.

The protocol for assessing small marine debris seemed somewhat labour-intensive; the visual transect survey protocol for large marine debris was straightforward and could be implemented as part of an ongoing Gully MPA monitoring program.

Threats to ongoing monitoring

Data on marine debris is not currently being collected.

Indicator 45: Quantity of anthropogenic debris at selected monitoring sites in the Gully MPA

An evaluation of this indicator was not conducted.

Indicator 46: Reports of known invasive species in the Gully MPA

An evaluation of this indicator was not conducted.

Indicator 47: Quantitative characterization of anthropogenic sound within the MPA

N. Cochrane and H. Moors-Murphy

Suggested improvements to indicator wording

"Characterization of deep-water natural and anthropogenic acoustic noise within the Gully MPA."

Characterizing the magnitude and variability of natural acoustic noise levels in the deep waters of the Gully will lend perspective to interpreting impacts from anthropogenic sources. While most natural non-biological noise is wind and sea-state related, unreported analysis of the 2003 Gully datasets suggests that minor earthquakes in the Atlantic Basin may constitute a significant natural source of sporadic low-frequency noise within the MPA.

Available data

There are several acoustic datasets from the Gully MPA; however proper analysis of background noise, both natural and anthropogenic, requires recordings from well-calibrated systems with specific acoustical characteristics. Given these requirements, short-term deployments of ocean-bottom seismometers (OBSs) in 2003, 2005 and 2006 and with Autonomous Multi-Channel Acoustic Recorders (AMARs) in 2010 and 2011 (Table 47-1 and Figure 47-1) provide potentially useful datasets. While these datasets may offer useful information about natural and anthropogenic noise, longer-duration deployments (multi-month) are required to reliably characterize noise levels, particularly how noise levels vary over time.

Data collection

Systems are deployed at desired coordinates within the Gully and are returned to the laboratory for data extraction and analysis.

Analysis

Several analytical approaches can be applied to acoustic recordings to characterize natural and anthropogenic noise sources including, but not limited to:

- Examining broadband noise levels in the temporal domain to determine dominant scales of variability and to identify major isolated noise events.
- Calculating the average spectral power level occurring within specific frequency bands over various time scales (e.g., month, season, year) to produce long-term average (LTA) frequency plots. This will provide information on monthly, seasonal and inter-annual variation; natural background noise levels; and the degree of spectral statistical fluctuation present.
- Extracting data from periods where anthropogenic noise (e.g., ship noise) is absent in order to produce LTA frequency plots of natural acoustic noise levels over various time scales. This could be compared to environmental data, such as wind speed, collected simultaneously from nearby weather buoys, such as the Sable Island weather station.
- Extracting data from periods where anthropogenic noise is present to compare its LTA frequency plots with those from natural acoustic noise levels only (no ship noise). From this, the contribution of anthropogenic noise sources to the detected power levels can be determined.
- Measuring ship noise at the closest point of approach to examine differences in the noise spectrum produced by different types of vessels. This requires correlation to ship-track information from LRIT data or from AIS.

- Measuring other types of anthropogenic noise identified on the recordings such as exploration seismic noise. Such measurements could also enable synergistic studies with cetacean researchers by comparing those noises with simultaneously recorded cetacean vocalizations.

Results

Characterization of natural and anthropogenic noise requires long-term datasets in order to be meaningful. Since only short-term datasets are currently available, none of the datasets have yet been analyzed. However, the re-analysis of existing OBS datasets from the 2003 Marathon survey is recommended – the Empire and Cortland blocks contain extensive exploration seismic noise recordings. A new analysis using accurate multibeam bottom bathymetric profiles would better define the ability to accurately model noise levels within the MPA from future Scotian Shelf or Scotian Slope seismic surveys. There is insufficient data to clearly discern seasonal and long-term trends in noise.

Evaluation of existing protocols for meeting indicator monitoring requirements

All potentially useful acoustic data collections to date have spanned less than 25 days (Table 47-1). Longer, multi-month deployments and, ideally, yearly coverage are needed to properly assess natural noise levels and to gain an understanding of their variation over time. In addition, most of the existing OBS recordings have an effective upper frequency limit of 2 kHz, which is well below the vocalization frequency range of toothed whales and does not encompass the full frequency band required for assessing natural background noise levels. The OBS hydrophones were also deployed within about one metre of the sea floor, where local acoustic conditions can be modified by the proximate bottom interface. The higher effective-frequency range of the AMAR recordings (>60 kHz) and the mooring configuration which suspended the AMARs (50 m above the sea floor) were more appropriate for assessing noise levels. A system for noise sampling above 30 kHz and the use of omni-directional sea-state zero noise-limited hydrophones deployed at least one quarter wavelength above the bottom at the lowest study frequency are recommended to minimize acoustic interactions with the seafloor. An initial examination of data collected during the short-term deployments in 2010 and 2011 suggests that such systems will be useful for analyzing natural and anthropogenic noise levels, as well as characterizing biological signals, including vocalizations produced by toothed and baleen whales and sounds produced by fish. An optimum sampling strategy including sampling interval and deployment location(s) for acoustic recorders to monitor long-term changes in natural and anthropogenic noise sources also needs to be determined.

The above discussion has focused on collecting data at depth in deep water (>1000 m) because it has been the focus of past data collections (Figure 47-1) and it complements ongoing northern bottlenose whale acoustic monitoring studies. Natural and anthropogenic noise levels at shallower depths (<200 m) and in similarly shallow waters within the Gully may be substantially different than those measured in deep water due to sound refraction and trapping within the cold intermediate layer at the base of the seasonal thermocline. Since stable near-surface acoustic measurements are difficult using deep-water moorings, long-term monitoring may be limited to shallow water locations near the head or along the sides of the Gully. Concurrent acoustic monitoring both at depth in deep water and at shallow water recording locations would provide the most comprehensive dataset for characterization of natural and anthropogenic noise levels within the MPA, though this would require the purchase of multiple acoustic recorders.

Concurrent collection of environmental data such as sea-state, wind speed and precipitation from nearby weather buoys; shipping data from LRIT or AIS databases; and other relevant data on nearby anthropogenic activities would enhance acoustic monitoring results by assessing the contributions of locally generated noise.

Threats to ongoing monitoring

There are currently plans for almost continuous long-term deployments (2012–2014) of AMARs owned by SARMD in slope regions adjacent to the Gully as part of a cetacean acoustic monitoring project. Concurrent long-term deployments within the Gully would greatly enhance this study and support longer-term monitoring of natural and anthropogenic noise levels within the MPA. This continued monitoring is dependent, however, on the purchase of deep-water acoustic recorders (ideally compatible AMAR units), support for additional mooring deployments, maintenance of associated equipment and data analysis by DFO Science.

Additional comments

In the short term, during the above-referenced cetacean monitoring program, field data characterizing anthropogenic noise should be collected at the identical time and location as marine mammal vocalizations. This will facilitate the synergistic study of impacts of ship traffic, seismic surveys and other potentially noisy human activities on cetaceans. In the long term, changes in anthropogenic noise and even natural noise (from oceanic pH shifts or changing storm intensity and frequency) will require commitment of monitoring resources well beyond the time frame of the planned 2012–2014 cetacean monitoring program. DFO Science should retain acoustic expertise within the department to support long-term acoustic monitoring studies.

Table 47-1: Summary of acoustic recordings collected from the Gully that may potentially be useful for analysis for background natural noise levels.

Type of system	Unit	Date range	Days of recordings (#)	Location	Deployment coordinates		Depth (m)
					Latitude (N)	Longitude (W)	
OBS	A	June 23–July 3, 2003	9.8	GM5	43°39.60’	058°54.90’	1850
OBS	P	June 23–July 3, 2003	9.9	GM6	43°38.14’	059°02.74’	1190
OBS	S	June 28–July 3, 2003	5.1	G C	43°55.43’	058°58.59’	1360
OBS	T	June 23–26, 2003	3.2	G SW	43°48.52’	058°58.06’	1080
OBS	M	June 16–July 11,2005	24.3	G S	43°51.00’	058°55.17’	1935
OBS	Z	June 16–July 11, 2005	24.3	G SC	43°55.95’	058°59.63’	1550
OBS	S	April 22–25, 2006	2.9	G C	43°53.53’	058°57.47’	1740
OBS	Z	April 22–25, 2006	3.0	G SC	43°55.95’	058°59.63’	1550
OBS	M	July 30–Aug 20, 2006	21.1	G C	43°58.96’	058°59.03’	1330
OBS	Z	July 30–Aug 8, 2006	9.0	G S	43°50.98’	058°54.72’	1900
OBS	M	Nov 21–Dec 9, 2006	18.2	G S	43°51.06’	058°55.14’	1920
OBS	S	Nov 21–23, 2006	1.7	G C	43°56.00’	058°59.66’	1540
OBS	Z	Nov 21–Dec 11, 2006	20.0	G N	43°59.00’	058°59.05’	1340
AMAR	N/A	Mar 16–25, 2010	10	G SC	43°57.22’	058°59.97’	1150
AMAR	N/A	Oct 11–12, 2011	2	G S	43°50.94’	058°55.28’	1725

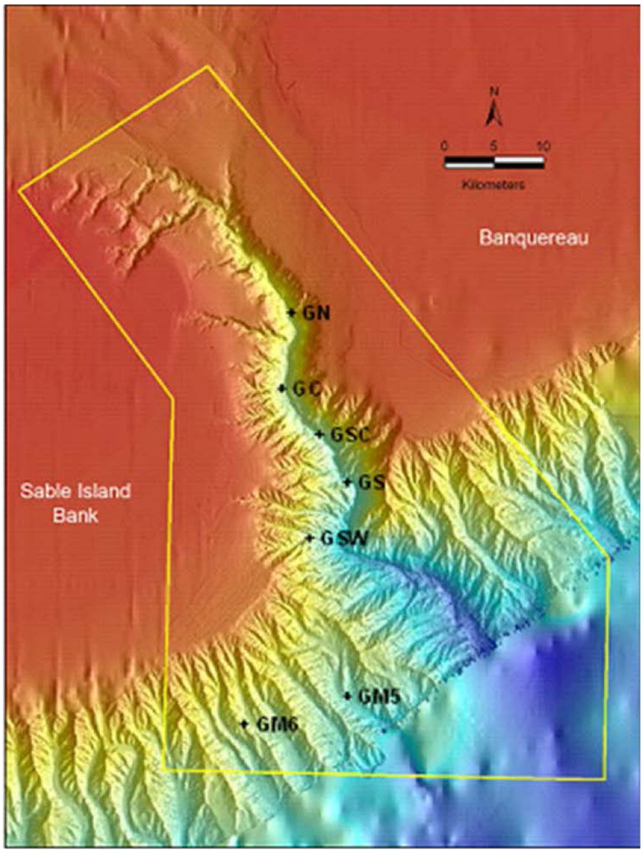


Figure 47-1: General Gully MPA acoustic recording locations as designated in Table 47-1.

SUMMARY

In support of the Health of the Oceans Initiative, DFO Science is to deliver indicators, strategies, and protocols for monitoring the individual conservation objectives of MPAs that have been established pursuant to the *Oceans Act*. When selecting appropriate indicators, consideration must be given to the cost and feasibility of related monitoring, as well as relevance to the conservation objectives or current and potential pressures. A successful indicator has baseline data, reveals links to the ecosystem and to human activities, and distinguishes between natural and human-induced spatial and temporal variation in the ecosystem over the long term.

Indicators related to cetaceans were well-explored. There has been consistent high quality research related to cetaceans in the Gully and there are numerous datasets available. With regards to the conservation of commercial and non-commercial living resources, groundfish and trawl-vulnerable invertebrate species in Zone 3 and trap-vulnerable species in Zones 1 and 2 were not evaluated. An extensive evaluation of data from both halibut surveys and commercial indices for the diversity of selected longline-vulnerable species identified some population trends along with temporal and spatial inconsistencies in sampling that would need to be addressed for effective future monitoring. The majority of data relating to maintaining the quality of the water and sediments of the Gully was from regular AZMP monitoring and satellite data, with other targeted efforts contributing to specific indicators. While the weather conditions at Sable Island weather station were not specifically evaluated for this document, the data does exist and can be assessed if necessary.

Generally, indicators related to current and potential pressures on one or more of the conservation objectives refer to traffic (both generally and specifically for commercial fishing and research); offshore-petroleum (installations and discharges); anthropogenic debris; invasive species; and anthropogenic sound. Data sources include LRIT, logbooks, the DVS database, the At-Sea Observer Program, RV surveys, CNSOPB, Transport Canada (Ballast regulations and NASP) and individual studies from government and academia. Many of these constitute stable sources of ongoing data, and some (e.g., the At-Sea Observer Program) could be potentially modified to enhance coverage specifically in the Gully MPA.

Of the 47 proposed indicators, 44 were evaluated, though some were combined with related indicators at the author's discretion. Author's suggested changes to the indicators themselves, which are summarized alongside the original proposed indicators in Appendix 1: Table A1-1.

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APPENDICES

APPENDIX 1. LIST OF INDICATORS

Table A1-1: Proposed monitoring indicators for the Gully MPA from DFO (2010b) on the left and suggested changes to indicators (altered wording or merged indicators) proposed in this document by the authors.

Proposed Indicators		Suggested Changes to Proposed Indicators
Protect cetaceans from impacts caused by human activities		
1	Abundance of the Scotian Shelf population of northern bottlenose whales	No change
2	Use of the Gully MPA by northern bottlenose whales, measured as the percentage of the Scotian Shelf northern bottlenose population within the Gully MPA	Residency of the Scotian Shelf population of northern bottlenose whales within the Gully MPA
3	Size, age, and sex structure of the Scotian Shelf population of northern bottlenose whales	Age and sex structure of the Scotian Shelf population of northern bottlenose whales
4	Percentage of individuals in the Scotian Shelf population of northern bottlenose population showing fresh scars	Percentage of individuals of the Scotian Shelf population of northern bottlenose whales showing marks likely caused by interactions with humans
5	Genetic diversity within the Scotian Shelf population of northern bottlenose whales	No change
6	Levels of contaminants in the blubber of individuals in the Scotian Shelf population of northern bottlenose whales	No change
7	Relative abundances of cetaceans (other than northern bottlenose whales) in the Gully MPA	Sighting rates of cetaceans (other than northern bottlenose whales) in the Gully MPA
8	Cetacean presence and activity in the MPA, year-round	No change
9	Number of reported strandings of Scotian Shelf northern bottlenose whales	Number of reported northern bottlenose whale incidents likely to be caused by human interactions (entanglements, ship strikes, strandings and other human-caused mortalities) in the northwest Atlantic
10	Number of reported ship strikes on cetaceans in or near the Gully, and of strikes on Scotian Shelf northern bottlenose whales elsewhere	Number of reported cetacean incidents likely to be caused by human interactions (entanglements, ship strikes, strandings and other human-caused mortalities) in or near the Gully
11	Number of reported gear entanglements of cetaceans in or near the Gully, and of entanglement of Scotian Shelf northern bottlenose whales elsewhere	Merged with Indicators 9 and 10
12	Number of reports of other interactions between human activities and cetaceans in or near the Gully, and of interactions with Scotian Shelf northern bottlenose whales elsewhere	Merged with Indicators 9 and 10
Protect seafloor habitat and associated benthic communities		
13	Coral distribution, density and size structure by species at selected monitoring sites within the MPA.	No change
14	Coral diversity at selected monitoring sites within the MPA	No change
15	Proportions of live and dead corals, by species, at selected monitoring sites within the MPA	No change
16	Proportions 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	No change

Proposed Indicators		Suggested Changes to Proposed Indicators
Conserve commercial and non-commercial living resources		
17	Relative abundances, size distributions, and diversity of selected groundfish and trawl-vulnerable invertebrate species in Zone 3 of the MPA	Not evaluated
18	Relative abundances, size distributions, and diversity of selected longline-vulnerable species in Zones 2 & 3 of the MPA	No change
19	Relative abundances, size distributions, and diversity of selected trap-vulnerable species in Zones 1 & 2 of the MPA	Not evaluated
20	Relative abundances, size distributions, and diversity of selected mesopelagic nekton in Zones 1 & 2 of the MPA	Evaluated at the workshop but not presented here
Maintain the quality of the water and sediments of the Gully		
21	Temperature, salinity, oxygen concentration, alkalinity, pH, light levels, chlorophyll pigments and nutrients in the water column within the MPA, including in close proximity to the seabed	No change
22	Temperature, salinity, oxygen concentration, light levels, chlorophyll pigments and nutrients in waters flowing past the MPA, as measured on the Louisbourg Line, the Halifax Line, and the Extended Halifax Line	No change
23	Physical (temperature, salinity, wind, height) and biological (ocean colour) sea surface properties in the MPA and the surrounding region	No change
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	Not evaluated
25	Three-dimensional distribution and movements of water masses within and around the MPA	No change
26	Phytoplankton production, community composition and the timing of the spring bloom in the MPA and the surrounding region	No change
27	Zooplankton biomass, community composition, and the biomass of selected species (e.g., *Calanus* spp. and carbonate-forming) within the MPA	No change
28	Acoustic scattering in the water column within the MPA (as a measure of mesopelagic and zooplankton densities and distribution)	Acoustic backscattering in the water column within the MPA (as a measure of mesopelagic and zooplankton densities and distribution)
29	Distribution and abundance of seabird species within the MPA, including an index of planktivorous seabird species	No change
Indicators to monitor pressures		
30	Number of transits through the MPA by vessels other than pleasure craft, such as mercantile vessels, surface naval vessels, and ecotourism vessels	Number and average speed of transits through the MPA by vessels other than pleasure craft, such as commercial 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, such as research and monitoring vessels, other government vessels, and ecotourism vessels	Hours of operation within the MPA by vessels other than commercial fishing vessels or pleasure craft, such as research and monitoring vessels, other government vessels, and ecotourism vessels AND Quantities of organisms (other than corals) removed from or discarded within the MPA by research activities
32	Commercial fishing effort within the MPA	Commercial demersal and pelagic longline fishing effort

Proposed Indicators		Suggested Changes to Proposed Indicators
		within and in close proximity to the MPA
33	Commercial fishing effort in close proximity to the MPA boundary	Quantities of organisms removed by commercial fishing activities in close proximity to the MPA
34	Suspected and confirmed unauthorized fishing activity within or in close proximity to the MPA	Unauthorized fishing activity within the MPA
35	Quantities of corals removed from or discarded within the MPA by commercial fishing and by research activities	Quantities of corals removed, discarded or damaged by commercial fishing and research activities within the MPA
36	Quantities of targeted organisms removed from or discarded within the MPA, and of bycatch organisms (other than corals) removed from the MPA by commercial fishing	No change
37	Quantities of organisms (other than corals) removed from or discarded within the MPA by research activities	Merged with Indicator 31
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.	Potential seabed area impacted by bottom-tending gear from commercial fishing and scientific research and monitoring within the MPA
39	Length of lines of, and seabed area occupied by, bottom-set fixed commercial fishing, research and monitoring gear set within the MPA, both as a total and subdivided by seabed habitat type	Merged with Indicator 38
40	Number and types of offshore-petroleum exploration and development activities (e.g., number of wells, platforms, etc.) on the Eastern Scotian Shelf	Number and types of offshore-petroleum exploration and development activities (e.g., number of wells, platforms, etc.) on the Eastern Scotian Shelf
41	Number, quantities and type of discharges from offshore-petroleum installations and activities on the Eastern Scotian Shelf	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 close proximity of the MPA and the quantities of ballast exchanged	Number and quality of ships’ ballast-water exchanges conducted within or in close proximity to the MPA
43	Number, quantities and types of other discharges from shipping within or in close proximity to the MPA	Number, quantity, and source of oily discharges from marine transportation within or in close proximity to the MPA
44	Quantity of floating debris (i.e., large objects) in the Gully MPA	No change
45	Quantity of anthropogenic debris at selected monitoring sites in the Gully MPA	No change
46	Reports of known invasive species in the Gully MPA	No change
47	Quantitative characterization of anthropogenic sound within the MPA	Characterization of deep-water natural and anthropogenic acoustic noise within the Gully MPA

APPENDIX 2. ABBREVIATIONS

ABWEZ	Alternative Ballast Water Exchange Zones
ADCP	Acoustic Doppler Current Profiler
AIS	Automatic Identification System
AMAR	Autonomous Multi-Channel Acoustic Recorders
AZMP	Atlantic Zone Monitoring Program
AZOMP	Atlantic Zone Off-Shelf Monitoring Program
BIO	Bedford Institute of Oceanography
BIONESS	Bedford Institute of Oceanography Net Environmental Sampling System
C&P	Conservation and Protection
CCGS	Canadian Coast Guard Ship
CNSOPB	Canada-Nova Scotia Offshore Petroleum Board
COE	Centre of Expertise
CSSF	Canadian Scientific Submersible Facility
CTD	Conductivity, Temperature, Depth
CWS	Canadian Wildlife Service
CZCS	Coastal Zone Color Scanner
DFO	Fisheries and Oceans Canada
DMSO	Dimethyl Sulphoxide
DVS	Department Violations System
ECSAS	Eastern Canada Seabirds at Sea
GAPS	Global Acoustic Positioning System
HPLC	High Performance Liquid Chromatography
ITIS	Integrated Taxonomic Information System
IYGPT	International Young Gadoid Pelagic Trawl
LRIT	Long-Range Identification and Tracking
MARFIS	Maritime Fishery Information System
MARS	Maritimes Region Cetacean Sightings
MERIS	Medium Resolution Imaging Spectrometer
MODIS	Moderate Resolution Imaging Spectroradiometer
MPA	Marine Protected Area
NAFO	Northwest Atlantic Fisheries Organization
NASP	National Aerial Surveillance Program
NSERC	National Sciences and Engineering Research Council of Canada

OBS	Ocean-Bottom Seismometer
OCMD	Oceans and Coastal Management Division
ODF	Ocean Data Format
ODIS	Ocean Data and Information Services
OESD	Ocean and Ecosystem Sciences Division
PAR	Photosynthetically Active Radiation
PIROP	*Programme Intégré des Recherches sur les Oiseaux Pélagiques*
POM	Particulate Organic Matter
PU	Pop-up Hydrophone
ROPOS	Remotely Operated Platform for Ocean Sciences
SARA	*Species at Risk Act*
SARMD	Species at Risk Management Division
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SDL	Significant Discovery Licence
SOEP	Sable Offshore Energy Project
SOLAS	International Convention for the Safety of Life at Sea
SSC	Sea Surface Chlorophyll
SSIP	Scotian Shelf Ichthyoplankton Program
SST	Sea Surface Temperature
USBL	Ultra-short Baseline
VDC	Virtual Data Centre
VMS	Vessel Monitoring System
VRN	Vessel Registration Number