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2021 REVIEW OF BASELINE INFORMATION, MONITORING INDICATORS, AND TRENDS IN THE GULLY MARINE PROTECTED AREA

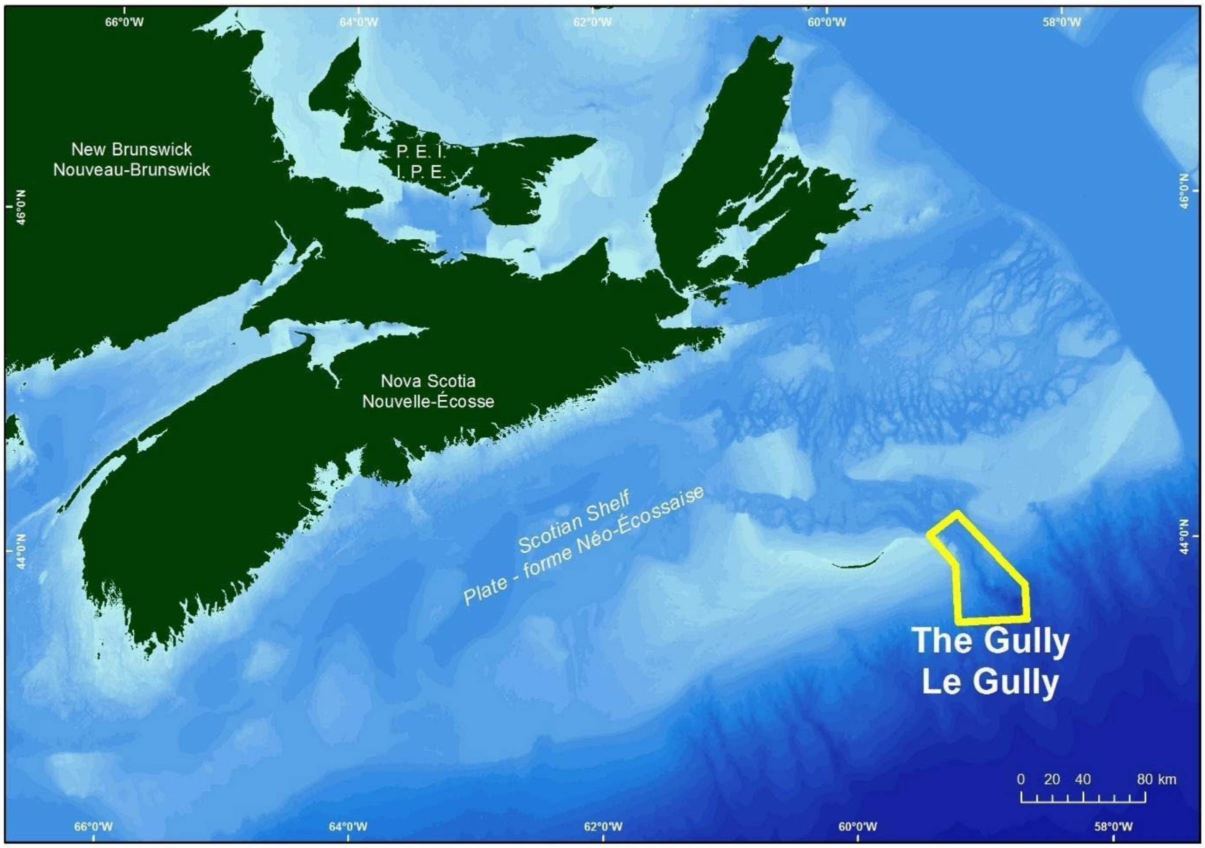

Figure 1. Location and boundary of the Gully Marine Protected Area.

Context:

The Gully is the largest submarine canyon off eastern North America, supporting a rich diversity of habitats and species, including cold-water corals and deep-diving beaked whales. The area is acknowledged, nationally and globally, as a unique and important focus for conservation. Available scientific knowledge of the area was first drawn together by Harrison and Fenton (1998) and later updated by Gordon and Fenton (2002), following additional targeted research. In 2004, the Gully became Canada's first Oceans Act Marine Protected Area (MPA) to be designated in the Atlantic Ocean.

In 2008, a Management Plan was completed, providing support for the MPA regulations and guidance to Fisheries and Oceans Canada (DFO), other regulators, and users on the protection and *management of the MPA. Conservation objectives and sub-objectives specified in 2008 were maintained and recast as conservation goals for the second edition of the Management Plan (DFO 2017). The overarching goal for the Gully MPA is to protect the health and integrity of the Gully ecosystem. The conservation objectives of the MPA are to:*

- *Minimize harmful impacts from human activities on cetacean populations and their habitats.*
- *Minimize the disturbance of seafloor habitat and associated benthic communities caused by human activities.*
- *Maintain and monitor the quality of water and sediments of the Gully.*
- *Manage human activities to minimize impacts on other commercial and non-commercial living resources.*

A framework for monitoring the MPA, including 47 proposed indicators, was prepared in 2010 to support the original conservation goals and objectives (DFO 2010, Kenchington 2010). Available data, sampling protocols, and monitoring programs supporting these indicators were later reviewed in 2012 (Allard et al. 2015). Monitoring and research have continued in the MPA, helping to expand our understanding of its ecosystems, while also establishing baselines and supporting improvements to the efficiency and efficacy of future monitoring.

A decade after the initial proposal of indicators, the Gully monitoring program is being reviewed to examine the utility of the data being gathered, identify gaps in coverage, incorporate new knowledge, document progress towards baselines from which change can be assessed, and interpret any observed trends. This review seeks to evaluate whether the MPA is meeting its conservation objectives and to determine whether the current monitoring activities are suitable for this evaluation. Information gathered from this process will be instrumental to the formalization of a feasible monitoring program and practical implementation strategies for the Gully MPA going forward. As Atlantic Canada's first Oceans Act MPA, a peer review of the monitoring and assessment of the Gully is expected to provide important lessons and perspectives for the development of long-term monitoring programs at other offshore MPAs and for Canada's bioregional MPA networks.

This Science Advisory Report is from the Regional Peer Review Process on the Gully Marine Protected Area Monitoring: Review of Research Activities, Indicators, and Guidance on Next Steps held January 18–22, 2021. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- A review of baseline data and trends for the Gully Marine Protected Area (MPA) monitoring indicators was conducted, as well as discussion of advances in understanding of the ecosystems in the Gully and linkages to the broader Scotian Shelf - Bay of Fundy bioregion.
- There was general agreement that the wide array of data being gathered, through a range of research and monitoring activities in and around the Gully, has increased understanding of its ecosystems and potential human impacts. Though this information provides a broad context to describe the ecosystem, more work is required to fully implement a standardized, long-term monitoring program, to help ensure that monitoring efforts continue to advance our understanding and reporting on the status of conservation priorities, and to detail how human activities influence conservation priorities so that mitigation options can continue to be developed as needed.

- The development of most monitoring indicators is still at an early stage. It is important that as data are collected and monitoring programs implemented, periodic assessments of effectiveness (i.e., the ability to detect change) are undertaken to guide improvements in the program's ability to detect and characterize change.
- Available data give some indication of the success of the Gully in meeting its conservation objectives, but it is not yet possible to say whether it has fully achieved all objectives.
- Data were collected for most indicators though time-series analysis was only available for some, in particular those focusing on cetaceans and oceanography.
- While most indicators revealed little or no detectable change over various timescales, some notable trends were detected and are reported below. Trends reported here are considered to be meaningful (statistically significant) for the Gully, but they may not be reflective of broader regional trends (i.e., may not be reflective of the conservation status of a regional population). For example:
    - Abundance of the Scotian Shelf population of Northern Bottlenose Whales (NBW; *Hyperoodon ampullatus*) has been increasing since 2010, following a period of decline before 2004. Sightings of calves have increased since 1998.
    - Overall male and mature male NBW are more marked (scarred) than females and juveniles. Some mark types (notches, back indents) have increased over the period 1988–2019, which could in part be related to the age of identified individuals. The prevalence of anthropogenic injuries appears stable to increasing over this time period, at an annual rate of 1.7 individuals gaining entanglement or propeller scars per year.
    - Within the Gully, number of sightings of other cetacean species have shown varied trends, since 1988: Sowerby's Beaked Whale (*Mesoplodon bidens*) and Pilot Whales (Globicephala *melas*) sightings have increased, sightings of Humpback Whale (*Megaptera novaeangliae)*, Fin Whale (*Balaenoptera physalus*), and some dolphin species have decreased, and sightings of Blue Whales (*Balaenoptera musculus*) increased in the mid-2000s but have since declined.
    - Oceanographic properties in the Gully fluctuate considerably from year to year due to natural variability. Over the last two decades, when systematic monitoring has taken place, the only significant trend observed has been an increase in mid-depth (100–400 m) temperature due to the growing influence of warm slope water in the offshore region.
    - Based on the joint DFO-Industry longline survey, Atlantic Halibut (*Hippoglossus hippoglossus*) biomass appears to be increasing in the Gully at a rate of about 5% per year, consistent with a population-wide trend.
    - Observed densities of floating debris in the MPA declined between 1990 and 2019.
    - Ocean ambient noise levels in the Gully were examined based on an analysis of Passive Acoustic Monitoring (PAM) datasets obtained from one deep-water site in the Gully between 2012 and 2019. No strong trend in low frequency long-term (6-yr) deep ocean ambient noise levels was observed over this period, though the 100 Hz to 500 Hz frequency band showed a slight increasing rate of approximately 0.30 dB per year.
- *In situ* baseline surveys using underwater imagery for benthic species and habitats have been undertaken throughout the Gully MPA, although no sites have been revisited to assess trends in indicators for coral abundance, diversity, and health.

- Gaps in spatiotemporal coverage for at-sea seabird surveys persist within the Gully and adjacent areas. Three key ecological attributes with associated indicators were identified for seabirds as a conservation priority: areal density, relative use of Gully habitat, and biodiversity. However, potential trends in these indicators have not been fully explored.
- Offshore petroleum drilling activity around the MPA has ceased; the Deep Panuke and Sable Offshore Energy projects were decommissioned at the end of 2020.
- Potential impacts of climate change on the Gully include rising ocean temperatures, ocean acidification, reduced dissolved oxygen availability, and novel combinations of environmental variables, which could lead to physiological responses, reduced growth and survival rates, and potential range shifts in species including NBW. Climate indices (initial focus on temperature, pH, and dissolved oxygen) and biological indicators predicted to respond to climate change should be monitored over the long-term.
- Long-term monitoring programs within the MPA provide an invaluable empirical basis on which to evaluate performance, efficacy, and change over time. Science programs can also make cost-effective contributions through short-term, targeted baseline and characterization work, including process-oriented studies to discover critical pathways that offer potential for more efficient monitoring in the future.

BACKGROUND

The Gully Marine Protected Area (MPA) was established in 2004 under the federal *Oceans Act* to protect its unique canyon ecosystems from anthropogenic activities, such as fishing and petroleum exploitation. At approximately 40 km in length, 15 km in width, and with depths reaching 2000 m at the canyon mouth (from where it extends to more than 5000 m on the abyssal plain), the Gully is the largest submarine canyon in the northwest Atlantic (Figure 1). Its biodiversity is rich, with numerous species of benthic and demersal fishes and invertebrates, a variety of benthic habitats including steep canyon walls that support coral and sponge populations, and high concentrations of cetaceans. The Gully has long been noted as unique in the northwest Atlantic due to the large size of the canyon and its resident population of Northern Bottlenose Whales (NBW, *Hyperoodon ampullatus*).

In 2008, the Gully Marine Protected Area Management Plan (DFO 2008) established conservation objectives for the MPA. In 2017, a second, updated edition of the Gully Marine Protected Area Management Plan (DFO 2017) was published, building on new and revised knowledge on the Gully environment, advice received since 2008, and experience managing the MPA. It provides a vision for the Gully MPA, guiding principles, and four conservation objectives. The conservation objectives were developed to address specific conservation-based priorities for the MPA, and were identified through scientific peer-review and discussions with stakeholders. These conservation objectives are:

- minimize harmful impacts from human activities on cetacean populations and their habitats;
- minimize the disturbance of seafloor habitat and associated benthic communities caused by human activities;
- maintain and monitor the quality of water and sediments of the Gully; and

- manage human activities to minimize impacts on other commercial and non-commercial living resources.

Kenchington (2010) proposed a monitoring framework for the Gully MPA to be undertaken by Fisheries and Oceans Canada (DFO) and its partners. In total, 47 indicators (variables that could be monitored to provide information on the status of the MPA ecosystem) were recommended to be monitored through 18 component programs. Most were intended for tracking changes through time in the state of The Gully's ecosystems and, hence, MPA effectiveness. Generally, a quantitative baseline needs to be established for each indicator from which changes can be assessed.

The 47 recommended indicators comprised 29 "*effects indicators*" and 18 *"threat indicators*". Indicators 1–12 focused on cetacean abundances, population ecology, genetic diversity, health, and human interactions, including ship strikes and gear entanglements. Indicators 13–16 covered coral distributions and diversity. Indicators 17–20 focused on fish and other species, including relative abundances of fishes and invertebrates vulnerable to trawling, longline, and traps, including mesopelagic nekton. Indicators 21–29 addressed the physical, chemical, and biological environment, including temperature, salinity, phytoplankton, zooplankton, and seabirds. Finally, indicators 30–47 focused on threats, including vessel traffic, fishing effort, unauthorized fishing activity, anthropogenic debris, and offshore oil and gas exploration and development.

Allard et al. (2015) reviewed available data for each suite of indicators, as well as providing suggestions on improvements to the wording of some indicators. Allard et al. (2015) found that data availability and analysis had been inconsistent across the various indicators, though most research conducted in the Gully has been targeted with the goal of monitoring the MPA.

This 2021 review of the Gully MPA monitoring program was intended to include:

- peer review of available data (and baselines where they have been developed) for each of the 47 indicators or alternatives developed subsequently;
- evaluation and interpretation of any trends from those indicators with reference to the MPA's conservation objectives;
- consideration of advances in understanding of the ecosystems in The Gully, to provide a foundation for development of more efficient indicators and improved understanding of how the indicators reflect ecosystem function within the MPA;
- determination of which indicators are useful in the evaluation of MPA performance, leading to recommendations for improvements to the existing suite of indicators;
- development of a minimal suite of indicators suitable for MPA performance evaluation and the identification of any gaps in the current monitoring program that should be prioritized for increased scientific effort; and,
- examination of linkages between ecological processes in the Gully and those of the broader Scotian Shelf MPA network planning region.

Scientific experts were asked to present data on their respective indicators, examine trends over time, and identify data gaps. Some indicators were identified as needing to be removed or modified due to a lack of data collection, while new indicators were also proposed to help monitor the health of the Gully ecosystems as a whole.

ASSESSMENT

An assessment of data collected from within and adjacent to the Gully MPA relevant to the proposed indicators was presented and reviewed based on information prepared by meeting participants from DFO, the Canadian Wildlife Service (CWS), Dalhousie University, and the Marine Animal Response Society (MARS). The outcomes of that assessment are presented here with the indicators grouped under their associated Conservation Objective. The methods used to assess each indicator, the key results, and any recommendations for future monitoring are outlined. It is noted where indicators have not been monitored or assessed, or results have not been presented. General considerations or recommendations for future directions in monitoring are also presented for each Conservation Objective.

Cetacean-related Indicators

Conservation Objective

Minimize harmful impacts from human activities on cetacean populations and their habitats.

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

Methods

Sightings and photo identifications of NBW collected by Dalhousie University in the Gully from 1988–2019 were analyzed using Bayesian trend and mark-recapture models.

Results

Results indicate that the population size of NBW was declining in years prior to 2004 and then, since 2010, began to increase.

Recommendations

Due to the long life-history and slow reproductive capacity of NBW, ongoing data collection efforts and reevaluation of population size is important to be able to detect and monitor trends.

Indicator 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.

Methods

Photo identification re-sightings of individual NBW, assembled between 2001 and 2017, were analyzed by modelling lagged identification rates and using Markov movement models.

Results

Residency of NBW in the Gully appears longer (weeks to days) than other canyons. However, there is regular movement between the Gully, Shortland, and Haldimand canyons over periods of days, suggesting the population is not completely closed at this scale.

Recommendations

Monitoring temporal trends in use between areas is effort-intensive and difficult. This indicator could be supplemented with information on fine-scale habitat use within the Gully and/or improved characterization of different types of "use" through behavioural and acoustic analyses.

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

Methods

Age and sex information on NBW was collected using photo-identification data from 1988–2019, linked to analyses of the sexually dimorphic features of NBW melons (distinguishing mature males from females and juveniles) and genetic information on sex (males and females) collected from infrequent biopsies.

Results

Results indicate there are no significant differences in sex structure of NBW among the Gully, Shortland, and Haldimand canyons over this period. There was an increase in mature males in both photo-ID and sightings between 1988–2019, and intra-annual trends suggest the proportion of mature males has increased through the summer. Sightings of calves are more common in the Gully than the other canyons, and also increased over the period 1988–2019.

Recommendations

Age structure is important to monitor as the population recovers from whaling. Body size has not been measured for approximately 20 years, and new data could be used to evaluate whether size structure has changed over this period. This indicator, or a new suggested indicator, could include consideration of body condition.

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

Methods

A detailed analysis of the marks observed on individual NBW in the photo identification catalogue looked at the prevalence and origin of a number of mark types including notches, indents, patches, large fin scars and anthropogenic marks from entanglement and propeller vessel-strikes.

Results

Overall male and mature male NBW are more marked than females and juveniles. Some mark types (notches, back indents) have increased over the period 1988–2019, which could in part be related to the age of identified individuals. The prevalence of anthropogenic injuries appears stable to increasing over this time period, at an annual rate of 1.7 individuals gaining entanglement or propeller scars per year. This estimate represents the minimum number of animals that have initially survived these interactions, and it does not include animals that died before or subsequent to being injured. In comparison with another measure of risk related to population recovery, current rates of scarring are approximately 5 times the level of Potential Biological Removal (PBR; i.e., mortality) established for the population.

Recommendations

This indicator represents a conservative estimate of harm, as it does not include animals that died due to injuries or were entangled in other parts of their body. However, it does provide a baseline for understanding the rate and prevalence of interactions between NBW and fisheries or vessels, and should be continued.

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

Genetic diversity within the Scotian Shelf NBW population has been measured, but repeated measurements have not been made to allow for analysis of temporal trends.

Methods

DNA extracted from tissue collected from historically-whaled NBW in Labrador in 1971, and biopsies collected from NBW in the Gully and across their Canadian range between 1996–2018, were analyzed using microsatellite and mitogenomic sequencing.

Results

Results indicate the Scotian Shelf is a distinct population from NBW in northern areas (Feyrer et al. 2019). NBW have low overall genetic diversity, and the Scotian Shelf population appears to have undergone a recent historic genetic bottleneck (a reduction in population size) consistent with the timing of intensive historical whaling (Feyrer et al. 2019).

Recommendations

Genetic connectivity between the Scotian Shelf and populations to the north is estimated to be very low but should be monitored as populations continue to grow using a population genetics approach.

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

Methods

Blubber collected from NBW in the Gully and the Arctic between 1996–2019 was analyzed for Persistent Organic Pollutants (POPs).

Results

A few individual NBW in the Gully had Polychlorinated Biphenyl (PCB) levels approaching the lower toxicity threshold for cetaceans (17 µg/g lipid weight for general immune and reproductive effects, Desforges et al. 2021), which can lead to adverse health effects. Average values were, however, above the molecular toxicity threshold (1.3 µg/g lipid weight, Desforges et al. 2021), suggesting PCBs may be affecting NBW physiology at a molecular and cellular level.

Recommendations

The source of these contaminants is not known but could be further investigated. Other contaminants of potential concern, such as toxic heavy metals, flame retardants, petrochemicals, and microplastics, that may be emerging in higher concentrations are a concern for other endangered cetacean populations and should be monitored.

Indicator 7: Relative abundances of cetaceans (other than northern bottlenose whales) in the Gully MPA.

Methods

Cetacean sightings were collected by Dalhousie University researchers within the Gully MPA between 1988–2019.

Results

Sighting rates of three species were found to decrease: Humpback Whales at -15%/year, White-sided Dolphins at -5%/year and Striped Dolphins at -7%/year. The sightings of two species increased: Sowerby's Beaked Whales at 13%/year and pilot whales at 7%/year, although with lower rates of increase and abundance stabilization for both species in the final years. The best fit to Blue Whale abundance was a unimodal curve, peaking in about 2005 and then declining. Trends for the whole MPA versus Zone 1 were similar. However, while there was no apparent trend in Zone 1 for Common Dolphins and Fin Whales, a decline was detected for the entire MPA.

Recommendations

Monitoring of cetacean abundances within the Gully MPA should continue.

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

Methods

Year-round Passive Acoustic Monitoring (PAM) has been conducted in the Gully MPA since 2012 using bottom-moored recording systems. Acoustic recordings have been analyzed for the daily presence of several cetacean species, based on well-characterized call types.

Results

Results indicate that multiple cetacean species regularly use the Gully MPA; some are consistent year-round residents (e.g., beaked whales), while others display seasonal patterns in acoustic presence (e.g., baleen whales). In particular, the Gully is a highly-utilized habitat for beaked whales.

Recommendations

PAM provides essential data on cetacean presence in the Gully MPA year-round and can reveal new information about species occurrence that is otherwise difficult to obtain from visual survey efforts. Consistent long-term monitoring is necessary to establish baselines and assess trends in habitat use. Additionally, concurrent monitoring within and outside the Gully provides broader context for cetacean presence in the region, and a network of PAM recorders is important for understanding the relative importance of the Gully.

Analysis of PAM data provides a minimum estimate of species presence, as there is the possibility that whales are present but not calling, or that calls are produced but not detected due to the use of duty-cycled recording schedules, the presence of background noise, and the detection parameters selected. PAM analyses to date have included only a subset of the cetacean species known to inhabit the Gully MPA, and the development of effective automated detectors and analysis protocols for additional call types and species would allow for a more comprehensive assessment of cetacean presence and activity.

Indicator 9: The number of reported strandings of Scotian Shelf Northern Bottlenose Whales.

Methods

Incidents involving dead or distressed cetaceans in the Maritime Provinces are reported opportunistically to the MARS incident hotline from a variety of sources including government, industry, mariners, aerial platforms, and the public. These data were examined by MARS to determine what incidents involving dead or distressed NBW had occurred within and in the vicinity (up to 100 km distance) of the Gully between 2004–2019, as well as review reports from elsewhere in eastern Canada.

Results

There were no reports of live strandings of Northern Bottlenose Whales to the MARS hotline between 2004–2019 within 100 km of the Gully MPA. Strandings here refers to live animals stranded on land, e.g., on Sable Island. No strandings are possible within the open water of the Gully MPA itself.

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

Methods

See methods described under Indicator 9.

Results

No ship strikes of NBW were reported to the MARS hotline between 2004–2019.

Indicator 11: The number of reported gear entanglements of cetaceans in or near the Gully and of entanglements of Scotian Shelf Northern Bottlenose Whales elsewhere.

Methods

Incidents involving dead or distressed cetaceans are reported opportunistically to the MARS incident hotline from a variety of sources including government, industry, and the public. These data were examined by MARS to determine 1) what incidents involving dead or distressed cetaceans, including NBW, had occurred within and in the vicinity (up to 100 km distance) of the Gully between 2004–2019 (and temporal trends), and 2) what incidents involving dead or distressed NBW had been reported anywhere in eastern Canada.

Results

One entanglement of a free-swimming NBW was reported in the Gully prior to 2004. No entanglements of NBW have been reported to the MARS hotline since that time within 100 km of the Gully MPA.

Recommendations

Continuation of the monitoring of reported gear entanglements of cetaceans in or near the Gully, and entanglements of NBWs elsewhere is recommended, with supplemental monitoring recommended below.

Indicator 12: The 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.

Methods

See methods described under Indicator 11.

Results

Between 1990 and 2019, three cetacean incidents were recorded within the Gully MPA, two additional incidents were recorded within a 40 km buffer zone around the MPA, and 55 incidents were recorded within a 100 km buffer around the MPA, primarily on Sable Island. One NBW carcass was recorded on Sable Island, while another carcass was observed between Shortland and Haldimand canyons. The cause of death of these animals and whether it was related to human activities is unknown.

Considerations for Future Monitoring

Information collected via the reporting of deceased or distressed cetacean incidents to response organizations is opportunistic, so data related to measuring impacts to cetaceans from human activities (e.g., fishing and vessels) are incomplete. This is particularly the case in offshore regions where research is limited and there are infrequent surveys. Monitoring of dead and distressed cetaceans (e.g., those entangled, as well as floating carcasses) within the Gully and at broader spatial scales, including the Scotian Shelf and throughout eastern Canada, would better enable the long-term evaluation of trends in impacts to cetacean populations from human activities throughout their range in Canadian waters, and it would aid in the identification of potentially significant injury or mortality events. This would, in turn, contribute to monitoring the Gully's conservation objective to minimize the impacts of human activities on cetaceans and cetacean habitat.

Reports of dead and live-distressed cetaceans are an important means to monitor the impacts of human activities on cetaceans, particularly when complete necropsies of dead animals can be conducted to determine the cause of death. However, financial resources for necropsies and access to floating carcasses remains limited, which hinders the collection of important diagnostic data and samples. As a result, the impacts from human activities on these animals are likely underestimated. In addition, data and samples to investigate sub-lethal impacts on cetacean health are rarely collected, and, when data and samples are collected, they typically focus on mortalities. Thus, we are not completely monitoring the impacts to these species from human activities, including harm.

Many human-impacts manifest at sub-lethal levels in cetaceans, so monitoring of the overall health of the animals is needed to fully understand the extent of human-driven effects. A complete picture of health can only be obtained through complementary data collected from research on both dead animals (e.g., through necropsies) and from free swimming animals. Changes in animal health can act as a precursor to population changes providing managers with early warnings of declines to come as well as represent a reflection of the health and resilience of the broader ecosystem. A health indicator comprising measuring a suite of health metrics would be appropriate to include in the evaluation of the effectiveness of the Gully MPA to meet its goal related to minimizing harmful impacts to cetacean populations.

Corals and Benthic Habitat Indicators

Conservation Objective

Minimize the disturbance of seafloor habitat and associated benthic communities caused by human activities.

Indicators

Indicators relevant to this objective comprised:

- **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 zoanthid over-growths and the extent of over-growth in any affected colonies.

Methods

Five missions (2007, 2008, 2011, 2016, and 2019) have collected photo and video transects, which provide suitable baseline data for future monitoring of these indicators in the Gully MPA. However, there has been no repeat sampling on those transects due to the lack of funding for the Remotely Operated Vehicles (ROVs) needed to undertake repeat sampling with the spatial precision required.

Results

Due to the lack of repeat sampling, temporal trends have not been assessed.

Recommendations

Rather than repeat monitoring of previous transects, in the short term, collection of data from the boundaries between Zone 1 and Zone 2 might be a better use of budgetary resources, given that observations of corals in Zone 2 could potentially lead (and has led) to changes of zone boundaries. At the depths of the boundary, DFO cameras could be deployed at relatively low cost. It was also suggested that a focus on the canyon heads, which extend from Zone 1 into Zone 2 on both walls of the Gully, would be a high priority area for collection of new data on seafloor species and habitats.

The list of species for which density is assessed in the future should be expanded beyond corals to include xenophyophores and sponges. The xenophyophores are closely associated with increased carbon content in the Gully sediments and have been linked elsewhere to fish habitat (some liparid eggs being deposited in xenophyophore tests) and in carbon cycling. Sponges are sensitive benthic species and their diversity in the MPA has not been evaluated. They play important roles in nutrient cycling, filtering vast amounts of water, and through provision of structural habitat are known to locally enhance biodiversity. As all invertebrate species are assessed in the baseline imagery, these additions could readily be extracted from the existing data.

Monitoring of live versus dead corals and zoanthid overgrowth should focus on *Keratoisis grayi* to document longer term damage as that species is abundant and found on both the eastern and western walls of the canyon. Their skeletons persist for millennia making them a good choice for evaluating long-term impacts, given the sampling frequency to date. *Paragorgia arborea* skeletons persist only for months to a year and that species is not as widely distributed. However, where it does occur it could be used as a time reference for a live-versus-dead indicator representing recent impacts.

A repository for imagery data (raw and processed forms) is urgently needed to archive the baseline video and image data, especially given the long time lag between repeat surveys.

Fish and Fishery Resources Indicators

Conservation Objective

Manage human activities to minimize impacts on other commercial and non-commercial living resources.

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

Methods

Groundfish-trawl surveys of the Scotian Shelf, including in what is now the MPA, commenced in 1970. However, their stratified-random design introduces large among-sets variations. With the few sets made within the MPA each year, those variations cannot be averaged out, as they are for shelf-wide estimates of biomass. Kenchington (2010), therefore, proposed extending the routine surveys by adding fixed-station sampling within the MPA, but that suggestion has not been implemented. Thus, examination of temporal trends was necessarily limited to the available data from stratified-random sampling within the MPA, despite its limited suitability for the purpose.

In 2015, routine Snow Crab (*Chionoecetes opilio*) trawl surveys, which follow a fixed-station design, were extended into The Gully, with five pairs of stations, each comprising one inside the MPA and one outside. An initial examination of the catch data from the 50 sets made to date was undertaken.

Results

Examination of data from the stratified-random surveys showed that, as expected, among-sets variation is so large that no temporal trends can be discerned with the data from the few sets made in the MPA each year.

With only five years' data, the Snow Crab surveys cannot yet conclusively illustrate any trends, but catches of three species of flatfish have generally increased, while those of some other species (including Haddock [*Melanogrammus aeglefinus]*, Longhorn Sculpin [*Myoxocephalus octodecemspinosis]* and Snow Crab) have declined. For migratory species, notably Silver Hake (*Merluccius bilinearis*), the data are compromised by variations in the seasonal timing of the surveys. Thus, while the Snow Crab survey series shows promise of being useful for MPA monitoring in the future, little can yet be concluded.

Recommendations

Various designs of trawls differ in their selectivity for each species, while all yield highly spatially-variable catches. Thus, monitoring of temporal change in an MPA requires consistent use of standard gear types at fixed-stations. Unless and until the proposed fixed-station sampling is implemented, the utility of the groundfish-trawl surveys for MPA monitoring will be limited. The Snow Crab surveys show potential for MPA monitoring and should be continued. Future surveys should, wherever possible, adopt more consistent seasonal timing than has been the case over the last five years.

Even after a half-century, the groundfish-trawl surveys have not generated sufficient data for the diversity of the groundfish of the Scotian Shelf to be properly quantified, and there is no prospect of monitoring changes in diversity within the MPA. It is recommended that all reference to “diversity” be deleted from Indicators 17–20.

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

Methods

Since 1998, the halibut-longline survey program has annually occupied one fixed station (Station 85 – nominally located in the canyon head) within what is now the MPA. That program also includes "index fishing", in which commercially directed fishing uses survey-standard gear, with many sets having been made in the MPA, mostly in Zone 2. Data recording is less consistent in the index fishery than the fixed-station survey and, for The Gully, only the Halibut catches could be relied on, whereas bycatch information is available from Station 85. The data from both types of fishing were provided by the survey program and examined for temporal trends in catches per standard effort unit.

Results

Fish assemblages typically vary markedly with water depth. Although Station 85 is a nominally a fixed location, the starting positions of the sets made there have averaged 2.7 km from their mean, while one set began 7.6 km away. With the steep slopes around the canyon, those offsets mean that longlines have been set at depths from 134 to 520 m – altering the assemblages sampled and confusing temporal trends.

Halibut catch rates have risen, both at Station 85 and in the index fishing within the MPA, which is consistent with a known region-wide trend. The linear rates of increase in weight caught, per standard set, have been 8.9 kg per year at Station 85 and 7.1 $kg \cdot y^{-1}$ in index fishing. Those are equivalent to 5% and 4% of the long-term means of annual average catch rates in the respective time series – the temporal correlation in each series being statistically significant (Spearman’s r = 0.51 and 0.59, respectively), though biomass increase may be confounded with the effects of varied sampling depths.

The limited data on various bycatch species taken at Station 85 hint at assorted trends, some increasing and others declining, while most conformed to observed Shelf-wide trends in the species concerned. There is nothing in the data to suggest overall shifts in ecosystem structure or function.

Recommendations

While limited in location and the species that can be tracked, the halibut surveys, and particularly the sampling at Station 85, provide useful MPA-monitoring information. That work should be continued, with tighter control over the positions (or, more importantly, the depths) at which the fixed-station sets are made, if possible.

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

The idea of a trap survey in the MPA was discarded in 2012 because technical limitations of available pot haulers would have meant that long lengths of rope would have had to be deployed for each trap, which was inconsistent with work in an MPA featuring cetaceans and corals.

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

Routine sampling of the mesopelagic micro-nekton and macro-plankton in the MPA has never been implemented, though intensive surveys during 2007–09 have established a firm, quantitative baseline for future monitoring.

Those surveys have led to a hypothesis that the squid prey of NBW may themselves be supported by an influx of mesopelagic biomass from the open ocean, through the canyon’s mouth. Given this potential link, continued monitoring of mesopelagic biota would be important to future management of the MPA.

Oceanographic Indicators

Conservation Objective

Maintain and monitor the quality of water and sediments of the Gully.

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.

Methods

Oceanographic properties have been sampled at stations within the Gully MPA by the Atlantic Zone Monitoring Program (AZMP) for nearly 20 years. Details of this program, including map of sampling stations in the Gully MPA, can be found in Jackson at al. (2021).

Results

Consistent with observations from other areas of the Scotian Shelf, oceanographic properties of the Gully MPA were highly variable over the near 20-year period (Jackson et al. 2021). Nonetheless, significant, increasing trends in temperature at mid-depths (100–400 m) were observed at the three stations across the Gully mouth and one station inside the Gully canyon (GULD_03). These trends can be attributed to an increasing influence of warm slope water, and are consistent with trends observed along the shelf break from the Laurentian Channel to the Gulf of Maine, and in the deep basins of the Scotian Shelf. As the time series on which these analyses were based was relatively short, these trends should be considered in the context of longer-term regional trends (1950 to present).

Water column properties at the three Gully mouth stations were comparable at similar depths, suggesting redundancy in the existing AZMP sampling scheme for the MPA. Conditions within the Gully canyon (station GULD_03) were different from those at the other three stations, with a greater contribution of shelf water leading to cooler, fresher conditions in the near-surface layers, compared with the MPA stations beyond the shelf-break. Dedicated monitoring of the Gully MPA should continue at GULD_03 and GULD_04 (at the Gully mouth).

There were no apparent trends in nutrient or *in situ* chlorophyll *a* concentrations over time, but further analyses (e.g., nutrient ratios) may be more informative. Parameters describing the carbonate chemistry system (pH, total alkalinity), light levels, and pigments are routinely measured in the Gully, but were not evaluated for this report.

Recommendations

Consistencies in the oceanographic conditions evaluated at the three AZMP stations across the Gully mouth highlight redundancies in the AZMP's existing sampling scheme of the MPA. While monitoring should continue at station GULD_03 near the Gully head and GULD_04 located at the Gully mouth, continued monitoring at stations SG_23 and SG_28 provides little additional value. These stations should be redistributed elsewhere in the canyon, either over the thalweg, to better monitor the canyon's flow-through system, or at the location of areas of biological significance.

The significant increasing trends in mid-depth temperatures observed in the Gully MPA are based on relatively short time series (< 20 years), representing a source of uncertainty. Monitoring of these conditions should continue in order to place these trends in the context of interdecadal/shorter changes versus long-term climate change.

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.

Methods

Water mass properties have been routinely sampled on the Louisbourg Line and Halifax Lineduring spring and fall since the start of the AZMP in 1998.

Results

Conditions upstream of the Gully MPA on the Louisbourg Line (at AZMP core station LL_07) were similar to those at the head of the Gully (station GULD_03), but conditions downstream of the MPA (AZMP core station HL_06) were warmer and more saline than those in the Gully (Jackson et al. 2021).

Recommendations

Continued monitoring of water mass properties is recommended.

Indicator 23: Physical (temperature, salinity, wind, sea-surface height) and biological (ocean colour) sea surface properties in the MPA and the surrounding region.

Results

There were no trends in the average annual values of sea surface chlorophyll nor in any of the four metrics used to describe spring bloom dynamics (start date, amplitude, duration, magnitude) in the Gully or nearby regions (Jackson et al. 2021).

Remotely-sensed salinity, and wind and sea-surface height were not evaluated in this report. Remotely-sensed sea surface temperatures from 1998 to 2018 trended upward in the Gully and downstream, but not upstream, of the canyon.

Recommendations

Some variables included in this indicator are not easily accessible (satellite salinity) or are, at present, of low resolution. Higher-quality products should be evaluated as they become available.

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.

Data are available for this indicator from the Sable Island weather station, but were not compiled for this report.

Recommendations

It is recommended that analysis of data collected at weather buoy sites (Banquereau and Laurentian Fan) be removed from this indicator, as these data are not consistently available. Air temperature data from the land-based Sable Island weather station are evaluated and reported annually by the AZMP. Wind direction and speed are also measured at the Sable Island weather station and could be evaluated.

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

Routine monitoring of this indicator has not been implemented due to the cost and limited availability of moored instrumentation. This indicator was intended, in 2010, to provide interpreted summaries of the physical-oceanographic information captured under Indicators 21, 22, and 23. No summaries have been prepared.

Recommendations

Data collected during the AZMP biannual surveys augmented with observations from year-round moorings would greatly enhance the program's ability to effectively monitor temporal changes in the MPA, should resources become available in the future.

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

Results

Phytoplankton production has been calculated using a model that includes remotely sensed measurements of sea surface chlorophyll concentration and ambient light, and information on the relationship between these and primary production derived from *in situ* primary production measurements and which is contained in a Bedford Institute of Oceanography (BIO) database. The database contains values for photosynthetic parameters, which vary by season and region: the appropriate values are assigned based on remotely-sensed measurements of sea surface temperature and location.

Community composition in terms of size structure can be obtained year-round from remotely-sensed data and in terms of broad phytoplankton taxonomic composition from detailed pigment analysis of samples collected *in situ*. The pigment analyses are performed on a routine basis in AZMP, but the taxonomic analyses are not performed.

Recommendations

Phytoplankton production and community composition are more research-focused and are not routinely evaluated or reported by the AZMP.

Continue monitoring of spring-bloom metrics, including their start, duration, magnitude, and amplitude.

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

Zooplankton are routinely monitored by vertical ring net hauls at the AZMP stations within the Gully.

Results

There is high inter-annual variability in zooplankton abundance and composition that is mainly associated with the presence of different water masses within the Gully MPA and with inter-annual differences in the timing of sampling and biological events (e.g., the timing of the spring bloom; Jackson et al. 2021). With long-term monitoring, trends in zooplankton biomass and community composition will likely emerge.

Recommendations

Continue monitoring zooplankton community composition, abundance, and biomass to identify emerging trends.

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

Routine monitoring of this indicator has not been implemented.

Recommendations

Enhanced estimates of zooplankton biomass in the Gully could be obtained using acoustic measurements collected from towed or moored devices. New Canadian Coast Guard (CCG) research vessels with the capacity to collect acoustic measurements could be considered as a source of these data in the future.

Seabirds

Conservation Objective

Manage human activities to minimize impacts on non-commercial living resources.

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

Methods

Seabird observers employed by CWS participate in all AZMP oceanographic missions and survey for seabirds when the vessel is in transit (along transects and between sampling stations). In addition to AZMP missions in April and October, CWS and CWS-trained seabird observers conduct opportunistic surveys from vessels both within and beyond the Gully MPA using a standard CWS protocol (Gjerdrum et al. 2012). Seabird at-sea surveys are the primary source of information contributing to Indicator 29.

Results

Gaps in spatiotemporal effort for at-sea seabird surveys persist. No trends in abundance or distribution of seabirds have been analyzed, though three key ecological attributes with associated indicators were identified for seabirds as a conservation priority: areal density, relative importance of Gully habitat, and biodiversity.

Recommendations

It was proposed that Indicator 29 be represented using three Key Ecological Attributes (KEA) and their associated indicators: 1) areal density KEA, for selected species representing different foraging guilds, with the indicator measured as distance-corrected birds/km^2 for the Gully, 2) important habitat area KEA, for relevant foraging guilds, with indicator measured as area within the Gully falling within the top quintile divided by area falling within the top two quintiles calculated for the Scotian Shelf bioregion, and 3) biodiversity KEA, for seabirds, measured as an index of number of seabird species occurring at a to-be-determined minimum frequency within the Gully.

It was acknowledged that spatiotemporal effort gaps persist and should be addressed to more comprehensively characterize Indicator 29 within the Gully. Given technological advancements, telemetry is emerging as a potentially valuable additional source of information that can be both confirmatory and complementary to at-sea surveys. Telemetry can overcome spatiotemporal gaps in at-sea survey effort, gaps related to rare species for which at-sea detection rates are too low to inform the Indicator, and provide insights into behaviours and time-budgets of individuals (e.g., transit, searching, active foraging).Generally broad patterns of occurrence of seabirds contributes to low specificity (i.e., strength of linkage between Gully-specific conditions and Indicator 29) while high natural variability contribute to low sensitivity. These limitations apply to indicators associated with the three KEAs. Given present levels of effort, detection of a response to trigger management action would be expected to require multiple years of data collection. While additional survey effort would contribute to enhanced sensitivity of the three

KEA indicators described above, it is expected that with the emergence of telemetry additional new KEAs could be added to Indicator 29, with potential to enhance specificity. For example, telemetry already presents evidence enabling assessment of certain linkages (e.g., time budgets and behaviours of individuals using the Gully) for some members of the Gully seabird community.

Despite improved characterization of Indicator 29, through identification of three KEAs and their associated indicators, limitations related to specificity and sensitivity persist. For this reason, only with improved monitoring of pressures (i.e., threats) acting on seabirds and associated pressure indicators within the Gully and more broadly, can any benefit from the specificity and sensitivity required to respond adaptively through appropriate and timely management interventions.

Threat Indicators

The data sources for each threat indicator (30–46) are included below and more detailed information regarding the data sources and analyses used are available in McConney et al. (in prep.[1]).

Indicator 30: Number of transits of the MPA by vessels other than pleasure craft, broken down into mercantile vessels, surface naval vessels and fishing vessels not fishing in the area.

Methods

Maerospace satellite Automatic Identification System (AIS) data from 2018 and 2019, obtained and provided to DFO by the Canadian Space Agency, were examined to quantify the commercial vessel (cargo and tanker) presence within the Gully MPA. Fishing vessel locations obtained from the National Vessel Monitoring System (VMS) from 2011–2018 were used to calculate the amount of time spent in the MPA within 3 speed categories: < 5 knots, 5–10 knots and > 10 knots, the first of which is indicative of fishing activity while the others include transiting vessels.

Results

There were 111 days in 2018 and 118 days in 2019 during which at least one commercial vessel occurred within the Gully MPA. There were 80 unique commercial vessels within the MPA in 2018 and 92 in 2019. There was only one commercial vessel present during the majority of days in both years in the Gully MPA. Occasionally, there were two vessels present per day, and only during one day in each year were there three vessels present. Average reported speeds for both cargo and tanker vessels were approx. 11.5–14.2 knots.

Fishing vessels spent a total of 16,377 hours within the Gully during 2011–2018. They spent 86% of that time travelling at less than 5 knots, and rarely travelled at greater than 10 knots (0.2%). On an annual basis, there is a decreasing trend in the amount of time vessels spent in

[1] McConney, L., Wingfield, J., Rozalska, K., Schram, C., Pardy, G., Will, E., Feyrer, L., and Whitehead, H. (In prep.). The current state of pressures monitoring in the Gully Marine Protected Area. Can. Tech. Rep. Fish. Aquat. Sci.

the MPA travelling at less than 5 knots. From 2011 to 2018, time spent in the MPA in this speed category decreased from 3,205 hours to 781 hours.

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

Methods

Activity plans and post-activity reports from 2012–2019 and Maerospace satellite AIS data from 2018 and 2019, obtained and provided to DFO by the Canadian Space Agency, were used to assess non-commercial non-fishing vessel presence in the MPA.

Results

Approximately 95 days were spent in the MPA for research/monitoring and tourism activities. The majority of trips were 1–2 days in length with the exception of research activities associated with marine mammals. This is only an estimate of the hours of operation due to the varying levels of detail provided by activity proponents in their documentation.

Analysis of Maerospace satellite AIS data from 2018 and 2019, obtained by the Canadian Space Agency, revealed the presence of research, offshore supply, cruise, military, and Canadian Coast Guard vessels and a mobile drilling rig within the MPA. These vessels occurred within the MPA during only 15 days in 2018 and 13 days in 2019. Of these vessel types, research vessels were present within the MPA for the greatest number of days in both years.

Indicator 32: Commercial fishing effort within the MPA.

Methods

Logbook data on commercial fishing within the MPA were extracted from the Maritime Fishery Information System (MARFIS). That source is informative for overall estimates of landings, temporal trends and the distribution of fishing effort. However, the spatial data contains coordinate errors, due to rounding of coordinates and human error. In addition, certain fisheries where the gear deployed on each set spans multiple kilometres (e.g., demersal and pelagic longlining) are only recorded by a single location for each set. Thus, sets recorded as inside the MPA may have fished outside, in whole or in part, and vice versa.

Results

An analysis of fishing sets over time showed that the average annual effort of demersal longline effort inside the MPA decreased from an average of 79 ± 25 (mean ± standard deviation) sets per year from 2005–2011 to 55 ± 20 sets per year between 2012–2018. The average yearly effort of pelagic longline inside the MPA increased from 6 ± 4 sets from 2005–2011 to 18 ± 10 sets from 2012–2018. Spatial distribution of sets within the MPA and the temporal distribution of sets across seasons for both demersal and pelagic longline maintained similar patterns in both time periods.

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

Methods

The MARFIS data on fishing in a 10 nautical mile buffer around the MPA were examined.

Results

Demersal and pelagic longlining in a 10 nautical mile buffer around the MPA both increased from 2005 to 2018. In 2005–2011 and 2012–2018, the average number of demersal longline sets per year in the 10 nm buffer around the Gully was 109 ± 49 sets (mean ± standard deviation) and 131 ± 40 sets, respectively. In 2005–2011 and 2012–2018, the average number of pelagic longline sets per year in the 10 nm buffer around the Gully was 29 ± 18 sets and 60 ± 36 sets, respectively. Spatial and temporal *patterns* for both demersal and pelagic longline maintained fairly similar patterns in both reporting periods. An analysis of effort for fisheries other than longline that occur in the buffer around the MPA was also included. Fisheries for Hagfish (*Myxine glutinosa*), Snow Crab, Arctic Surfclam (*Mactromeris polynyma*) and Sea Cucumber (*Cucumaria frondosa*) also operate within 10 miles of the MPA but their fishing effort has not been quantified.

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

Methods

Information on unauthorized fishing was provided by the DFO Conservation and Protection's Department Violations System. Because of confidentiality concerns, Conservation and Protection are unable to comment on suspected unauthorized activity and information is only available on confirmed events.

Results

Three incidents of unauthorized fishing occurred in the Gully MPA between October 2012 and July 2020.

Recommendations

In view of the restrictions on information about suspected activities, this Indicator should be re-worded as "unauthorized fishing activity within or in close proximity to the MPA".

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

Methods

MARFIS and DFO's At-Sea Observer databases were searched for reports of coral removal from, or discarding within, the MPA during commercial fishing operations between 2012 and 2018. Information on encounters with corals during research operations were taken from post-activity reports filed with MPA managers.

Results

No coral was recorded as discarded from commercial fishing gear in the MARFIS and At-Sea Observer databases between 2012 and 2018. From 2013–2019, 12 sea pens were incidentally removed and four other coral samples were collected for research and monitoring activities.

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

Methods

An analysis of biomass removals for both targeted and bycatch organisms (other than corals) was conducted using a combination of MARFIS logbook data and At-Sea Observer records.

Results

Between 2012 and 2018, 218,088.4 kg of Atlantic Halibut, 106,676.1 kg of Swordfish (*Xiphias gladius*), 6965.1 kg of Bluefin Tuna (*Thunnus thynnus*), and 2150.5 kg of other tunas were removed from the MPA by commercial fishing. Removals of the top three bycatch species from the demersal longline fishery across 2012–2018 include Cusk (13,382.1 kg), White Hake (7,768.8 kg), and Cod (2,171.7 kg). Catch rates for bycatch species (as recorded in MARFIS) declined in 2012–2018 relative to 2005–2011.

Approximately 5% of demersal sets and 43% of pelagic sets in the MPA had At-Sea Observer coverage. Differences in At-Sea Observer coverage between the two time periods make overall comparisons difficult.

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

Methods

Information from post-activity reports for research and monitoring activities was compiled for this indicator.

Results

A total of 92 different species were removed from, or discarded within the MPA during 2013–2019. The top ten species by weight removed or discarded from the MPA amounted to 7,786.64 kg. The top species by weight were Atlantic Halibut (5,331.72 kg), Barndoor Skate (*Dipturus laevis*; 617.40 kg), and redfish (*Sebastes* spp.; 433.07 kg).

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.

The Snow Crab trawl survey and the DFO Research Vessel (RV) ecosystem trawl survey both operated within the Gully MPA from 2012–2020. These surveys swept a total of 2.038 km^2 (< 0.1% by area) of seabed within the MPA during this time.

Indicator 39: Length of lines of, and seabed area occupied by, bottom-set fixed commercial fishing and research and monitoring gears set within the MPA, both as totals and subdivided by seabed habitat type.

Commercial fishing records (MARFIS) show that approximately 1,556.6 km of demersal longline (386 fishing sets x 4.03 km longline length) or 156 km^2 of seabed was contacted by fixed longline gear across 2012–2018. The spatial extent of commercial fishing has declined throughout the study period. Scientific research and monitoring activities that use bottomset fixed gear include Halibut longline surveys (approx. 20 km^2 of seabed contacted), Halibut commercial index surveys (approx. 26 km^2 of seabed contacted), and passive acoustic monitoring samples (less than 11 m^2 of seabed contacted).

Indicator 40: Number and types of offshore-petroleum exploration and development activities on the eastern Scotian Shelf.

Methods

Information on offshore oil and gas exploration and development were provided by the Canada-Nova Scotia Offshore Petroleum Board (CNSOPB).

Results

Since 2012, there have been no wells drilled or seismic surveys within 50 km of the Gully MPA. The Sable Offshore Energy Project shut down production in December 2018 and was decommissioned by November 2020. The Deep Panuke natural gas field shut down production in 2018 and the field was decommissioned by October 2020. While there are two non-expiring significant discovery licences within the Gully MPA boundary, no oil and gas exploration has occurred since MPA designation.

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

Methods

Information regarding discharges from offshore petroleum installations and activities were obtained from the Canada-Nova Scotia Offshore Petroleum Board (CNSOPB) from October 2012 to April 2020.

Results

The total spill volume within 50 km of the Gully MPA was 2.14 L, which was a decrease since 2005–2011. Additionally, no unauthorized discharge was reported from April 1, 2018 to March 31, 2020 within 50 km of the Gully MPA.

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

Methods

Ballast water exchanges near and within the Gully MPA were mapped using data from 2010 to 2019 provided by Transport Canada.

Results

Twenty out of the 22 track lines that crossed through the Gully MPA over the 10 year period were likely to represent exchange of coastally-sourced ballast water. The risk to the Gully ecosystems from ballast water has not been assessed, but is thought to be low.

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

No oil spill sightings within or in the immediate vicinity (50 km) of the Gully were recorded through the Transport Canada National Aerial Surveillance Program (NASP) between April 2012 and November 2017. Similarly, no oil spill sightings were recorded by the Canadian Coast

Guard Marine Pollution Incident Reporting System (MPIRS) between 2013 to 2017 within the MPA. During this period the MPIRS had 3 recorded sightings within 50 km of the Gully MPA.

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

Visual transects for large debris and net tows for small debris and microplastics were conducted by researchers from the Whitehead laboratory at Dalhousie University in multiple years between 1990 and 2019. Density calculations for visual transect surveys suggest a significant decrease in large debris over this period. An assessment of microplastics from recent surveys (2015–2019) is currently underway.

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

No monitoring of seabed debris in the MPA has been implemented.

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

There have been no reports of known invasive species in the Gully MPA. Environmental DNA metabarcoding could be used as a sampling method to supplement existing monitoring and research activities to determine the presence/absence of non-native species in the Gully.

Indicator 47: Quantitative characteristics of anthropogenic sound within the MPA.

Methods

Data from Passive Acoustic Monitoring (PAM) gathered at one deep-water site (MGL) during 2012 to 2019 were analyzed to determine ambient noise levels in the Gully.

Results

No strong trend in low frequency long-term (6-yr) deep ocean ambient noise levels was observed over this period, though the 100 Hz to 500 Hz frequency band showed a slight increasing rate of approximately 0.30 dB per year. Case studies of specific sources contributing to low frequency deep ocean ambient noise levels were investigated, and suggested that natural meteorological sources (i.e., wind) showed the greatest correlation with lower limit and median ambient noise levels at this deep water site, while sources such as shipping noise (from 30 km to 360 km distance) contributed only to short-term (in the order of a few hours) ambient noise level fluctuations. Occasional signals from seismic airguns and potential low frequency military sonar were observed on these datasets, among other anthropogenic noise.

Recommendations

Data collected from the MGL site represent the longest series of PAM data available for assessing long-term trends in ambient noise levels, and this PAM site should be maintained into the future. However, because the MGL recorder location is much deeper than the depths to which most vessel noise is expected to propagate, a second shallower PAM mooring site (around 500 m depth) would improve our ability to monitor ocean ambient noise levels in the Gully, including noise contributions from vessel activities. Monitoring noise within the Gully temporally at several statistical levels (e.g., mean, 5% and 95% exceedance, etc.) can provide information on consistent, typical and higher levels commonly experienced by the animals within. Similarly, this can be used to track the rate of occurrence of high-level noise events (e.g., naval sonar or seismic surveys) within the Gully. Monitoring these provides information on the likelihood of most potential noise impacts on marine wildlife, but additional thought into how to best measure and report on chronic and acute noise events likely to impact cetaceans is needed.

Sources of Uncertainty

A primary source of uncertainty is how the Gully ecosystem will respond to climate change. The impacts of climate change will include rising ocean temperatures, ocean acidification, and potentially reduced dissolved oxygen availability, which could lead to physiological shifts, reduced growth and survival rates, and potential range shifts in species like NBW. It will be necessary to monitor the biological indicators including cetacean presence and population sizes in the Gully, demersal and mesopelagic fishes, and benthic invertebrates in conjunction with oceanographic data on temperature, pH, and dissolved oxygen to reveal cause and effect relationships among indicators under climate change. The identification of climate tipping points or thermal thresholds for species of conservation interest could help structure programs monitoring how the Gully ecosystem is being influenced by climate change. For example, temperature thresholds linked to physiological inhibition or declining fitness could be used as benchmarks for designing monitoring programs (i.e., frequency of monitoring relative to projections) and to direct additional monitoring efforts (e.g., enhanced monitoring for conservation priorities after thresholds have been recorded). This information can also be used to predict future changes in distribution if direct monitoring is not possible or is infrequent.

Discussion is needed on how to best make use of the DFO Research Vessel (RV) ecosystem surveys and Snow Crab surveys as platforms for monitoring of conservation areas including the Gully. A DFO national review concluded that bottom trawl surveys have minimal impact on all but the longest lived species or biogenic features, though a switch to alternative monitoring methods or modifications to existing survey gear may be used to mitigate potential impacts (DFO 2018). The area swept by bottom trawling during these surveys within the Gully annually is minimal and they actively avoid biogenic and/or sensitive habitats. While these surveys are not specifically designed for monitoring the Gully, they deploy a variety of sampling instruments, including bottom trawl, CTD, plankton net, water sampling (for physical and biological oceanographic and Environmental DNA [eDNA] analyses), and active acoustics. They also provide a platform from which other sampling could be undertaken. Sampling tailored for the localized objectives should be considered to maximize their utility for monitoring the Gully. As an example, towed-body video technologies, in coordination with acoustic data collection, could be an option to expand data collection into areas that are not sampled with bottom trawls. Coordination among surveys is required to ensure research vessels are used to their full potential as platforms for additional sample collection methods.

Trophic linkages and energy pathways through the Gully ecosystem remain uncharacterized. A better understanding of these pathways would help provide a more comprehensive understanding of the ecosystem, and help inform monitoring efforts. Potential linkages among indicators, including their sources for data collection as well as their potential impacts on one another (e.g., impacts of human stressors on ecological indicators) can be developed and visualized through the design of one or more conceptual models. Conceptual models can help managers identify energy pathways and processes, and potential impacts of human activities, which can allow researchers to forge linkages in data collection and monitoring. This could provide benefit to other research programs, such as Marine Spatial Planning. Once tested and verified, these conceptual models can also be used to identify gaps in knowledge and hypotheses about ecosystem function that can be used to direct/prioritize research within the MPA. However, the individual components of such a conceptual model still require identification through basic research conducted in the MPA.

CONCLUSIONS AND ADVICE

Despite logistical and financial challenges in conducting research and monitoring activities in a large offshore MPA such as the Gully, data have been collected for most of the indicators proposed in 2010, with the exception of those concerning corals and other benthic invertebrates. The majority of data collected over the past decade have been the result of targeted monitoring programs, either as part of Gully-specific programs, or from survey data collected across the Maritimes Region. Collaborations with partners, including Dalhousie University, the Canadian Wildlife Service, the Marine Animal Response Society, the fishing industry, and those internal to DFO, have proven invaluable in gathering baseline data and examining trends over time for the majority of indicators.

Designation of the MPA and its associated management measures have provided opportunity to examine direct evidence for change over time. While establishing cause and effect relationships between management and impacts on commercial and non-commercial living resources is a challenge in open ocean systems, the continued aggregation of whales, seabirds, and sensitive benthic species affirms that the MPA remains a valued physical, chemical, and biological refuge for which management of human activities merits further study. However, financial and logistical constraints make acquiring monitoring data that would comprehensively support all indicators challenging.

Monitoring of cetaceans within the MPA has been achieved through years of direct visual observation and collection of photographs, biopsy/tissue collection, application of passive acoustic monitoring technology, and records of vessel strikes, entanglements, and other incidents. The Northern Bottlenose Whale population has been increasing since 2010 and appears stable, and sightings of Sowerby's Beaked Whale and pilot whales have also increased. Cetaceans persist within the MPA and continue to be a conservation priority, so there is an ongoing need to monitor both their abundance within this area, as well as the human activities that impact them, including vessel traffic, underwater noise, and fishing activity within the MPA.

MPA monitoring has guided management toward reduction or restriction of known stressors and threats to the seafloor and benthic communities for corals, sponges, and their associated species. However, there have been no repeat surveys and trends cannot be assessed. While it is apparent that continued monitoring of these communities will provide information on persistence, distribution, and changes in the indicators, it is also recognized that efforts to obtain baseline information on additional regions within the MPA would further support this objective. It was suggested that a focus on the canyon heads, which extend from Zone 1 into Zone 2 on both walls of the Gully, would be a high priority area for collection of new data on seafloor species and habitats. These areas can be sampled with benthic camera systems and, should concentrations of corals/sponges be found, there is scope for management action (i.e., zonal boundary changes) as has been demonstrated already. Established deep-water transects require a remotely-operated vehicle with self-propulsion to enable repeated sampling. This should be a high priority for monitoring when such vehicles are available in the region.

Establishment of the MPA has focused and improved oceanographic monitoring in this area. While changes in many physical and chemical parameters are driven by forces outside the jurisdiction of MPA management, their continued monitoring is essential if ecological trends, such as species presence, abundance, and food availability, are to be understood.

As technologies advance, there will be opportunities for new sampling methods to complement or potentially replace existing sampling strategies that may be invasive or costly in a large, offshore MPA. Environmental DNA (eDNA) metabarcoding, for example, can be collected with relative ease representing a promising non-invasive and cost-effective approach for biodiversity monitoring that could be added to or complement existing surveys (e.g., the summer RV ecosystem survey or acoustic moorings cruises). Depth-based water sampling through a program like the AZMP can provide novel baseline data on biological diversity for specific depths. These approaches can be developed and deployed relatively rapidly, and repeat sampling at specific stations could reveal changes in biological diversity over time. The adoption and benefits of any new sampling technique must be carefully gauged against the disruption of any historical sampling approaches, and may be specifically dependent on the ability to inter-calibrate between methods.

It is recommended that data reviews and analyses be discussed more regularly on an informal basis, as part of the Gully Advisory Committee and/or through communication among DFO and its partners. Informal discussions on data acquisition and shared opportunities for fieldwork could be discussed on an annual or semi-annual basis, with formal peer reviews occurring every five years, rather than every ten. Finally, indicators could be graded using a report-card approach similar to the Tarium Niryutait MPA monitoring report (Brewster et al. 2021), which is based on the frequency the indicator has been measured over the monitoring period and its ability to convey information on conservation objectives. Similarly to Tarium Niryutait, the indicators could be graded by external stakeholders and managers through regular engagement opportunities.

There is an interest in developing both a Gully data portal archive (e.g., website or internal database) to foster data sharing and collaboration among scientists, and a public information portal to engage stakeholders and the general public. Although those requirements are shared with other components of the growing network of protected areas, the Gully represents a particular opportunity to develop this approach given the maturity and diversity of the monitoring programs reporting on its status. Suggested next steps are to move the 2010 monitoring framework (Kenchington 2010) into a monitoring plan for the Gully MPA. This monitoring plan should include a description of the roles and responsibilities of DFO and its partners for monitoring specific indicators, suggested sampling protocols, regular analysis of data, sample archiving, and regular reporting on the state of the MPA. Socio-economic and governance indicators are still needed, as noted by Kenchington (2010), and should be included in a monitoring plan as well.

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SOURCES OF INFORMATION

This Science Advisory Report is from the Regional Peer Review Process on the Gully Marine Protected Area Monitoring: Review of Research Activities, Indicators, and Guidance on Next Steps held January 18–22, 2021. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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