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IDENTIFICATION OF REFERENCE SITES AND A SCIENTIFIC MONITORING APPROACH FOR THE LAURENTIAN CHANNEL MARINE PROTECTED AREA

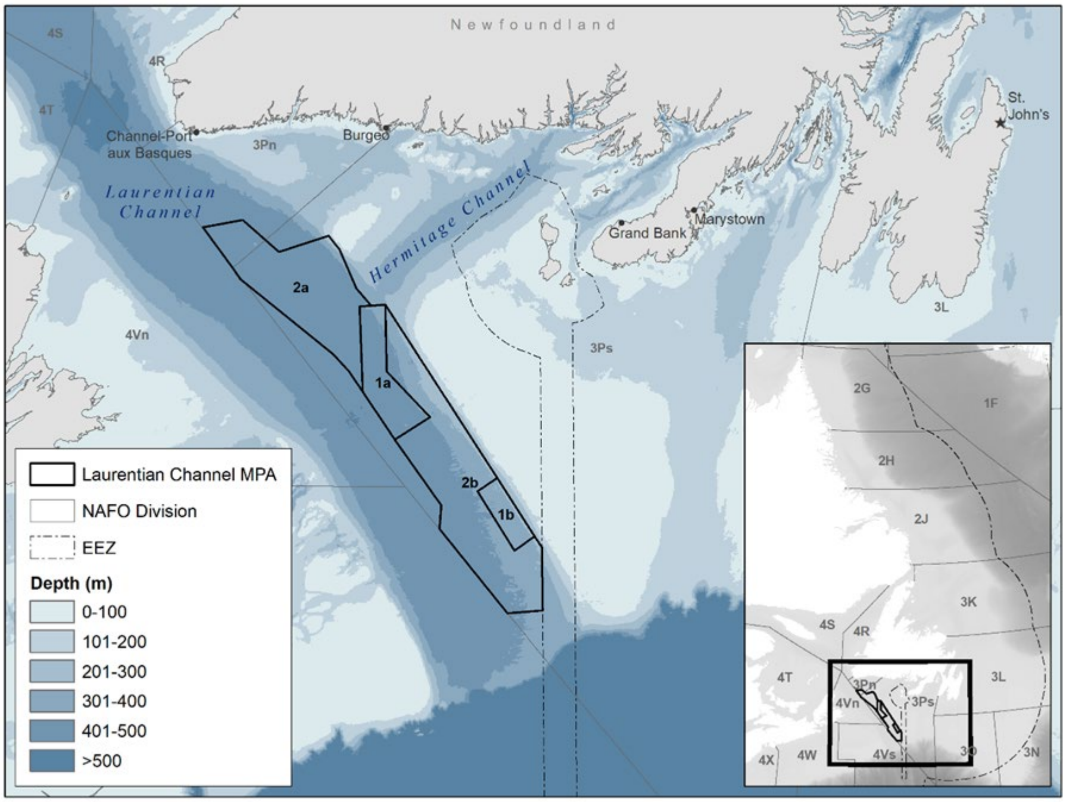

Figure 1. Location of the Laurentian Channel Marine Protected Area (MPA) (black outline) and its management zones (i.e., 1a, 1b, 2a, 2b) off the southwest coast of Newfoundland. The inset map shows the Northwest Atlantic Fisheries Organization (NAFO) Divisions (Divs.) in and surrounding the Newfoundland and Labrador (NL) Region.

Context:

Fisheries and Oceans Canada (DFO) Marine Planning and Conservation requested science advice to identify reference sites and monitoring requirements for the Laurentian Channel Marine Protected Area (MPA). Long term monitoring is required to assess the ability of the MPA to protect the stated conservation objectives and any resultant potential benefits to other species of interest and marine biodiversity.

This Science Advisory Report is from the June 22–24, 2022, regional peer review on the Identification of Reference Sites and a Scientific Monitoring Approach for The Laurentian Channel Marine Protected Area. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule](#) as they become available.

SUMMARY

- The Laurentian Channel Marine Protected Area (MPA) is a large-scale ecosystem that differs from most adjacent areas. The area has had historically low levels of exposure to many ecosystem stressors, including fishing, representing a relatively undisturbed ecosystem where the MPA regulations are not anticipated to result in major changes to human activities in the area.
- A set of indicators was proposed for each conservation objective (CO) to assess the status and trends of these taxa and their contribution to the overall goal of preserving biodiversity. However, for most of the COs, this will be difficult to do effectively based on current survey methods carried out by DFO NL Region (i.e., multispecies trawl surveys). The final set of indicators will evolve over time based on how practical, feasible, and informative they are and can be adjusted based on the results of field trials and power analyses.
- Environmental variables can be indicators of change. They may discern whether observed changes are an effect of the MPA regulations or broader ecosystem processes; for example, drivers induced by climate change.
- A power analysis was conducted to determine the utility of the Research Vessel (RV) trawl survey data to detect change in the status of three CO fish species (Northern Wolffish, Smooth Skate, and Black Dogfish). In addition, a power analysis of sea pen abundance using seafloor imagery was also performed.
- The power analysis showed that, without drastically increasing the number of RV trawl sets within the MPA, detecting change for these CO fish species is improbable because of their low density, distribution, variable catch rate, and/or transient nature. However, based on seafloor imagery data, sea pens appear to have the greatest potential for measurable change within the MPA.
- The overall scientific monitoring approach is based on Core (conducted specifically for the Marine Conservation Targets [MCT] program) and Complementary (conducted external to the MCT program) Monitoring, as well as Targeted Research. These approaches will be used collectively to monitor the Laurentian Channel MPA as a whole, using the data gathered to make inferences for unsampled areas where necessary.
- Core Monitoring will focus on non-invasive, efficient, co-located measurements of key indicators to generate long-term datasets. Complementary Monitoring can provide contextual information to aid with the interpretation of status and trends. Targeted Research can be used to inform Core Monitoring, answer questions specific to observed changes in the CO priority species, and test survey methods.
- Several survey methods and strategies were proposed to inform indicators for the Core Monitoring and Targeted Research of the six CO priority species as well as biodiversity, including seafloor imagery, environmental DNA (eDNA), and autonomous sensors on moorings. In addition, other survey methods will be utilized as Complementary Monitoring, such as trawl surveys, satellite imagery, and the Atlantic Zonal Monitoring Program (AZMP).
- A fixed station approach is proposed for Core Monitoring within the Laurentian Channel MPA whereby data will be collected regularly using at-sea sampling and autonomous sensors on moorings. Four survey lines equally spaced across the MPA with stations along each line were proposed, however additional work is required to refine and test the

proposed study design, including the frequency of sampling (e.g., annually for the first several years).

- The identification of buffered exclusion zones around the fixed stations was proposed to avoid any influence from bottom-contact surveys.
- In general, a reference site comparison (inside vs. outside) is not appropriate for this MPA, given its large size and historically low fishing effort compared to adjacent areas. The approach taken was to instead identify potential monitoring sites to track status and trends of the CO priority species within the MPA. Areas outside the MPA with similar community assemblages or habitat characteristics were identified that could provide contextual information to help interpret observed changes in the indicators for the CO priority species.
- Paired reference sites were proposed only as part of the Targeted Research program to assess recovery of sessile CO priority species in areas with historical fishing activity compared to areas outside the MPA where fishing still occurs.
- The establishment of a relevant and effective monitoring program would benefit from ongoing dialogue with management on the information that would be required to inform potential adaptive management actions, including adjustment of monitoring priorities, or modification of regulatory intent to effectively conserve and report.
- Expectations for timelines and specifics of reporting on monitoring results are not yet fully resolved but it is crucial that these be established to ensure effective scientific monitoring and refinement of the program.
- Sharing best practices and leveraging funds from other sources/collaborators will be a key component to the success of this program. Maximizing data collection, analytical approaches, and diverse expertise will allow for the development of other research initiatives that may enhance the monitoring program.

INTRODUCTION

Protected areas contribute to healthy marine environments by prohibiting or restricting certain human activities that may negatively impact their respective conservation objectives (COs). Fisheries and Oceans Canada (DFO) currently uses two tools to create protected areas in the ocean:

1. *Oceans Act* Marine Protected Areas (MPAs); and
2. *Fisheries Act* closures known as Marine Refuges (referred to as MRs in this document), which are a type of Other Effective Area-Based Conservation Measure (OECM).

Marine conservation has been a priority of the Government of Canada, which has committed to expanding its marine conservation areas from 14% to 30% by 2030 (Government of Canada 2019), and to support monitoring of existing conservation areas, under the Marine Conservation Targets (MCT) Program. The latter is considered an essential pillar of effective management of these conservation areas, as the resulting data are useful in evaluating whether COs are being achieved and how management can be adapted to enhance outcomes.

The Laurentian Channel MPA was established in 2019 to protect an area with complex oceanography and relatively intact habitats (Templeman 2007). While some scientific activities have been conducted in the area, a formal MPA monitoring plan has yet to be developed. A previous Canadian Science Advisory Secretariat (CSAS) process (DFO 2015) developed recommendations for identifying monitoring indicators, protocols, and strategies for the Laurentian Channel MPA focusing on the six priority species (or taxa) from the COs (sea pens, Black Dogfish, Smooth Skate, Northern Wolffish, Porbeagle Shark, and Leatherback Sea Turtles). To support Government of Canada objectives in relation to establishing a scientific monitoring program for the Laurentian Channel MPA, this CSAS process was initiated to:

- Identify direct or indirect indicators and reference sites, where possible, that could be used to monitor the status and trends of the priority species listed as part of the six COs, as well as overall biodiversity for the Laurentian Channel MPA.
- Develop a scientific monitoring approach for the Laurentian Channel MPA based on proposed indicators, survey methods, and strategies identified by Lewis et al. (2016). Each of the priority species listed above will be considered when developing indicators, survey types, and study design considerations.
- Investigate the ability to assess MPA conservation priority species metrics using existing RV trawl survey data and seafloor imagery data.

Our approach to achieving these objectives was to build on, and update, the recommendations of Lewis et al. (2016) with the goal of creating an approach to monitoring that is scientifically robust, practical and feasible, and useful for managers. For a more in-depth look at the first two objectives see Warren et al. (in prep)[1], and for the third objective see Morris et al. (2024). Our recommendations may require adjustments following field trials to ensure program objectives are met.

Advice provided here pertains only to scientific monitoring even though there are several other components that will make up the overall monitoring plan for this MPA. For example, enforcement of the regulations, i.e., compliance monitoring activities, are undertaken by DFO-Conservation and Protection Branch.

Laurentian Channel MPA

The Laurentian Channel includes an area identified as an Ecologically and Biologically Significant Area (EBSA) (Templeman 2007; Wells et al. 2019). EBSAs are special areas that provide important services to one or more species/populations of an ecosystem or to the ecosystem as a whole, but have no management or protection measures. A portion of that EBSA was announced as an Area of Interest (AOI) for potential designation as an MPA under the *Oceans Act* in 2010 (DFO 2015; Lewis et al. 2016). After completing a biophysical overview (DFO 2011), socio-economic review, risk assessments, and consultations with stakeholders, the MPA boundary was modified to exclude important fishing grounds so as to reduce impacts on harvesters. The resulting area (11,580 km^2) was officially announced as an MPA in April 2019 (Government of Canada 2019) (Figure 1). The MPA's primary goal is to conserve biodiversity through the protection of the conservation priority species and their habitats, ecosystem structure and function, and through scientific research. It is an ecologically important area with uniquely intact habitats, and complex circulation and oceanographic conditions (Templeman 2007). The priority species of conservation interest selected for the Laurentian Channel MPA range from non-mobile species such as corals, in particular significant concentrations of sea pens, to highly mobile species like the Porbeagle Shark and Leatherback

[1] Warren et al. (in prep). Identification of Reference Sites and a Scientific Monitoring Approach for the Laurentian Channel Marine Protected Area. DFO Can. Sci. Advis. Sec. Res. Doc.

Sea Turtle. Several of these species were selected based on information provided from the EBSA identification process (see Templeman 2007). The regulations for the MPA prohibit any activity that disturbs, damages, destroys, or removes a living marine organism or any part of its habitat. Therefore, this area is considered a no-take MPA, where all fisheries and extractive activities, except Aboriginal food and ceremonial fisheries, are not permitted in the MPA. Certain activities deemed compatible with the COs can continue. These activities include navigation of vessels (no anchoring in Zones 1a and 1b; see Figure 1), submarine cable installation, repair and maintenance (only in Zones 2a and 2b), scientific research, monitoring, and educational activities (subject to approval of an activity plan), and any other activities related to safety and security (Government of Canada 2019).

In 2010 a biophysical overview was completed for the AOI to compile all available information on the various biological and physical components of the study area (DFO 2011). Baseline information related to ecological conditions, species, and habitat, including knowledge gaps, were compiled. Based on the findings of the biophysical overview, six COs for the Laurentian Channel were selected. These COs are as follows (Government of Canada 2019):

1. Protect corals, particularly significant concentrations of sea pens, from harm due to human activities (e.g., fishing, oil and gas exploratory drilling, submarine cable installation and anchoring) in the Laurentian Channel MPA.
2. Protect Black Dogfish from human induced mortality (e.g., bycatch in the commercial fishery) in the Laurentian Channel MPA.
3. Protect Smooth Skate from human induced mortality (e.g., bycatch in the commercial fishery) in the Laurentian Channel MPA.
4. Protect Porbeagle Sharks from human induced mortality (e.g., bycatch in the commercial fishery, seismic activities) in the Laurentian Channel MPA.
5. Promote the survival and recovery of Northern Wolffish by minimizing risk of harm from human activities (e.g., bycatch in the commercial fishery) in the Laurentian Channel MPA.
6. Promote the survival and recovery of Leatherback Sea Turtles by minimizing risk of harm from human activities (e.g., entanglement in commercial fishing gear, seismic activities) in the Laurentian Channel MPA.

For further information on the site characterization of the Laurentian Channel MPA refer to the biophysical overview (DFO 2011).

Ecosystem stressors and cumulative impacts assessment are an important consideration in the development of COs for MPAs. The relevance of ecosystem stressors depends upon the regulatory objectives of the MPA in question. With respect to the Laurentian Channel MPA, the primary threat identified in MPA regulations is commercial fishing, which resulted in six regulatory COs to guide MPA assessment and evaluation. However, the historic exposure of the Laurentian Channel MPA to fishing is low (Muntoni et al. 2019). Vulnerability metrics have not been formally identified to quantify the impact of various stressors (e.g., fishing, shipping lanes, submarine cables) on habitats in the Laurentian Channel MPA, however other human activities inside the MPA, such as shipping and related noise may create different added stressors to the marine environment. For example, discharges into the water (e.g., wastewater, oil spills, marine litter, invasive species), physical impacts (e.g., noise, collisions with wildlife, anchoring damage), or air emissions (Jägerbrand et al. 2019; Hannah et al. 2020). Shipping lanes through the Laurentian Channel MPA can pose risks to several of the priority species. For example, anchoring can damage or destroy coral species, such as sea pens, and Leatherback Sea

Turtles may be susceptible to ship strikes in the area. The extent of localized effects from climate change on the Laurentian Channel MPA are still unknown, however, it should be considered as a potential stressor for the ecosystem in general and for the CO priority species.

Biodiversity and Priority Species of Conservation Interest

The Laurentian Channel MPA serves as habitat to a multitude of commercially, culturally, and ecologically important taxa, which can provide important ecosystem services (e.g., carbon sequestration). It is the largest no-take MPA in Eastern Canada and is a part of Canada's marine conservation network that collectively seeks to safeguard biodiversity from human induced stressors such as resource extraction and pollution. Moreover, the biodiversity of the Laurentian Channel MPA may create a more resilient ecosystem that will help support the following CO priority species identified as part of the Laurentian Channel MPA COs: corals (particularly sea pens), Black Dogfish, Smooth Skate, Porbeagle Shark, Northern Wolffish, and Leatherback Sea Turtles. For more detailed information on the biology and ecology of these species in the context of the Laurentian Channel MPA, refer to DFO (2015) and Warren et al. (in prep)[1]. As conserving biodiversity is the primary goal of this MPA, it is important to ensure indicators to measure various aspects of biodiversity are included in the scientific monitoring approach as well.

ASSESSMENT

DFO-NL Region initiated a regional working group to develop a monitoring program for NL MPAs and MRs, which includes the development of a scientific monitoring approach for the Laurentian Channel MPA. The NL Monitoring Working Group ('NL Monitoring WG') consists of members from DFO-NL's Science, Marine Planning and Conservation, and Resource Management Branches, as well as the Marine Institute, as part of an ongoing collaborative project for monitoring marine conservation areas in the NL Region. The NL Monitoring WG has been identifying suitable surveys and indicators for each of the conservation areas since September 2021.

One of the first steps taken by the NL Monitoring WG was the development of a detailed spreadsheet with a list of potential indicators and survey types by CO within each of the NL Region MPAs and MRs, including considerations about timing and frequency of surveys per site. Applying the same overall monitoring approach in several of the conservation areas (MPAs and MRs) will allow for more consistent, comparable data collection across the region, and is the most efficient way to test survey methods and strategies, invest in capacity, and implement the program regionally.

The approach agreed upon by the NL Monitoring WG described here will be applied to all NL Region MPAs and MRs, excluding those with well-established monitoring programs (i.e., Gilbert Bay MPA and Eastport MPA). While the approach will be consistent across areas, several of its elements will be specific to the conservation areas and their COs. The approach is described below as follows:

1. Core Monitoring,
2. Targeted Research, and
3. Complementary Monitoring.

- Core Monitoring will focus on efficient and co-located sampling of several key indicators, which can be done annually in all, or most areas. A high sampling frequency will be important, particularly in the first years of the monitoring program's establishment, and may be adjusted. Core Monitoring will aim to use techniques that are minimally or non-invasive, provide cost-effective data collection on most or all COs, and be comparable across conservation areas, generating a long-term regional dataset. Core Monitoring will include operations such as Conductivity, Temperature, Depth (CTD) casts (i.e., oceanographic data), water sampling (e.g., for collection of samples for eDNA and physico-chemical parameters), camera deployments (e.g., drop cameras), and moorings. The complete list of survey types to be completed is still under discussion within the NL Monitoring WG. Core Monitoring sites might include stations along lines crossing the MPA, or be chosen randomly as required (e.g., opportunistic sampling). The protocols will be standardized to facilitate comparison and collaborations with monitoring partners (e.g., Marine Institute).

- Targeted Research will include shorter term, research-oriented programs, aiming to gather more detailed information on the COs/priority species, to test equipment and methods (field testing), to improve rigor or understanding of the assumptions of the monitoring program, as well as to collect additional information to understand observed trends. Studies aiming to improve/add to monitoring design should be planned and conducted as soon as possible so that time series data are not confounded by methodological changes.
- The last part of the approach will focus on utilizing complementary data (Complementary Monitoring) from varied sources, whose surveys have not been specifically designed as part of the monitoring program (e.g., AZMP, RV trawl surveys, satellite imagery, At-Sea Observers, etc.) but which have been and/or are expected to continue collecting data in, or around, the MPAs and MRs. These data can be used to complement and/or assist the interpretation of data collected as part of the Targeted Research and Core Monitoring. There may be limitations to how these datasets can be applied together to inform monitoring, as multiple sampling tools and spatial scales (i.e., the footprint of each sample, coverage across the MPA, and co-location) can be challenging to integrate.

Table 1 shows a proposed timeline for monitoring activities at the Laurentian Channel MPA by survey method for 2022–26 and provides a starting point for discussion. The table includes survey methods and protocols, summarized below, and described in more detail in Warren et al. (in prep)[1] which are categorized based on the approach above. In addition to the proposed annual Core Monitoring, Complementary Monitoring is, in most cases, carried out annually (e.g., DFO RV trawl surveys, AZMP, At-Sea Observers), whereas Targeted Research will likely be conducted at longer time intervals (e.g., 2–5 years for an ROV survey, but shorter and more immediate for testing equipment and methods), or they might be intensive surveys for only a few years at a time (e.g., satellite tagging/telemetry surveys) (Table 1). The table also provides information on the platform used to carry out the surveys. For example, rather than relying on ship time with Canadian Coast Guard vessels, chartered vessels may be used to carry out much of the work including camera deployments, water (eDNA) and sediment sampling (refer to Table 1).

While described here as three separate data streams, data collection from each will likely overlap or occur coincidentally in some cases. This program will be evaluated and adjusted as necessary after the first few years. The scientific monitoring approach described in this document focuses on four main elements:

1. reference sites,
2. survey methods and strategies,

3. indicators, and
4. study design.

The next sections will describe each of these four elements, with a focus on the Laurentian Channel MPA.

Table 1. Timeline for monitoring activities in the Laurentian Channel MPA, 2022–26.

Survey Methods	2022/23	2023/24	2024/25	2025/26	Sampling (Core/ Complementary/ Targeted)	Frequency
DFO multispecies trawl surveys	-	-	-	-	Complementary	Annual (spring)
Aerial surveys (turtle, cetacean, jellyfish)	-	-	-	-	Complementary	Annual
Satellite imagery	-	-	-	-	Complementary	Annual (continuous)
Satellite Tags (PATs)	-	-	-	-	Targeted	no current plans
Acoustic Telemetry (receivers and tagging)	-	-	-	-	Targeted	no current plans
Acoustic receivers (moorings and mobile)	-	-	-	-	Targeted	no current plans
Multibeam/ sidescan sonar	*LCMPA completed (2010–13)				Targeted	no current plans
Oceanographic mooring	-	-	-	-	Complementary / Core	Annual (continuous)
CTD cast	-	-	-	-	Complementary / Core	Biannual (core)
eDNA (water/sediment)	-	-	-	-	Core	Biannual (core)
Sediment corer (benthic grab/ box core)	-	-	-	-	Core	Biannual (core)
Drop and drift/tow camera (Non-ROV camera systems)	-	-	-	-	Core	Biannual (core)
Baited Camera	-	-	-	-	Core	Biannual (core)
ROV	-	-	-	-	Targeted	~every 5–10 years
UVP (Underwater Vision Profiler)	-	-	-	-	Core	Biannual (core)
Observer Data	-	-	-	-	Complementary	Annual
AZMP	-	-	-	-	Complementary	Annual (spring and fall)
Sightings (opportunistic)	-	-	-	-	Complementary	Annual
VMS or logbooks	-	-	-	-	Complementary	Annual
FFAW	-	-	-	-	Complementary	Annual
Dockside Monitoring	-	-	-	-	Complementary	Annual
Large Pelagic Shark Commercial Longline Survey	-	-	-	-	Complementary	~every 5 years
Redfish Survey	-	-	-	-	Complementary	Biannual (late summer)
Halibut Longline Survey (Maritimes)	-	-	-	-	Complementary	Annual (summer)
Gulf winter groundfish survey	-	-	-	-	Complementary	Three year program

Activity	Aerial Survey	Redfish Survey	Chartered Vessel	Non-DFO led/data gathering	Halibut Longline Survey
DFO Trawl Survey	ROV	Gulf Winter groundfish Survey	AZMP/Oceanography	Large Pelagic Shark Longline Survey	

Elements of the Scientific Monitoring Approach

The proposed monitoring approach for the Laurentian Channel MPA aims to collect data on which to assess and interpret the status and trends of the CO priority species. While a significant component of the program will target data on priority species, information on important environmental drivers such as temperature, salinity, and productivity will also be included where feasible as these data will be useful to interpret the status and trends of COs. As indicated in Lewis et al. (2016), there are several data gaps in the Laurentian Channel and addressing some of these with Targeted Research or baseline data collection will be necessary prior to committing to a final set of long-term monitoring protocols.

The framework for the identification of monitoring indicators, protocols, and strategies developed by Lewis et al. (2016) was used as the basis for selecting appropriate scientific monitoring indicators and survey methods for the six COs. Another guidance document, more specific to monitoring corals and sponges, provides much of the basis for indicators and surveys for the sea pens CO (DFO 2021). Using these documents as a starting point, several discussions with subject matter experts were carried out, as part of NL Monitoring WG meetings, to determine the most appropriate, or effective, indicators and survey methods that could be used over the next few years of the monitoring program. Each CO/priority species was investigated, and the relevant monitoring indicators were identified. Survey methods and strategies were also proposed for each indicator. Details on other survey considerations including suggested frequency and/or seasonality of the survey, as well as any caveats or additional details were discussed and recorded as part of these discussions.

The long-term regional monitoring approach will take time to establish. The initial years will be focused on testing proposed survey methods and strategies, gathering baseline data, and investigating the appropriateness of the pre-selected indicators to monitor status and trends of the priority species and biodiversity. Therefore, the implementation of this scientific monitoring approach must be flexible, and as such, the NL Monitoring WG will continue to evaluate and refine these elements, as necessary.

Reference Sites

Evaluating effectiveness is an important part of MPA management since it can inform adjustments to management approaches. Effectiveness is often measured by making comparisons to reference sites that lack the benefit of MPA protection, as these locations allow managers to isolate the effects of MPA protection from broader regional trends or natural variability. However, finding reference sites for large-scale, complex ecosystems is difficult and imperfect in the best of circumstances (Underwood 1992), since, unlike laboratory environments, confounding factors are prevalent in field conditions (Fraschetti et al. 2002). In the case of the Laurentian Channel MPA, these concerns are elevated since the MPA establishment process resulted in a protected area that was not easily comparable to adjacent habitats. Specifically, the original area targeted for protection was characterized by large swaths of habitat that were largely unfished (Muntoni et al. 2019). Prior to finalizing the MPA boundaries, a cost-benefit analysis was used to further reduce impacts to harvesters by removing the few areas that were frequently fished (Government of Canada 2019). The MPA now represents an area that is uniquely characterized by historically low levels of exposure to fishing stressors such as bottom trawling. While this means that the Laurentian Channel MPA represents a relatively intact ecosystem compared to surrounding areas, particularly for fauna sensitive to fishing impacts (e.g., sea pens), finding appropriate reference sites, as was requested in the stated objectives for this CSAS process, is inherently challenging (DFO 2015; Stanley et al. 2015).

Another difficulty in identifying reference sites for the Laurentian Channel MPA is that two of the priority species of conservation interest in the MPA, the Leatherback Sea Turtle and the Porbeagle Shark, are highly migratory and do not reside solely within the MPA. Therefore, creating traditional reference areas for these two species may not be possible and it may be difficult to detect noticeable changes in what is a relatively small portion of these species' ranges (Lewis et al. 2016). The design and monitoring of an MPA must consider the movement patterns of important species. The adult home range or 'neighborhood' of a species can vary greatly, leading to gaps in protection (Stanley et al. 2015). Therefore, it may be difficult to detect changes in measures of these highly migratory species, and it may take an extended period of time to see a detectable signal of the 'promotion of the survival and recovery' of these species (James et al. 2005). In these two cases, any declines in the population over time cannot be fully attributed to the failure of the MPA to meet its objectives as, either the species spends a significant amount of its life outside the protection of the MPA, or there may be interannual variation in their occupancy of the Laurentian Channel MPA. For example, Leatherback Sea Turtles have been found to transit through the Laurentian Channel MPA, based on satellite data (DFO 2020), but are rarely documented inside. Assessing the benefits of the MPA for these taxa will be difficult as they spend most of their time outside its boundaries. In summary, for these two highly migratory species, reference sites were not chosen in or near the MPA, because the degree of site fidelity and defined habitats for these species in the Laurentian Channel MPA is low. Monitoring sites for the other priority species are discussed below.

Site Selection Methods

The Terms of Reference for this CSAS process requested the identification of reference sites where possible. Given the circumstances described above, our approach focused on identifying potential monitoring sites to monitor trends within the MPA, rather than reference sites, as previously defined. This approach makes more resources available to improve precision on estimates of the priority species' status and trends. Nevertheless, data collection at outside sites, where feasible, can be useful to provide baseline information for future Targeted Research studies and context, should broad-scale changes affect the ecosystem. For example, RV trawl survey data outside the MPA will continue to be collected as part of a long time series of multispecies data (e.g., Complementary Monitoring) and will be useful for providing context on regional trends of some priority species. We therefore identify monitoring sites for Core Monitoring within the MPA (method 1), areas of comparable environmental conditions outside the MPA delineated with unsupervised habitat mapping (method 2), and strata-based community analysis (method 3).

Method 1 provides fixed stations for Core Monitoring within the MPA. The Core Monitoring program aims to be cost-effective, co-located, and representative of habitats within the MPA. The selection of monitoring areas considered the following main criteria as a first step:

- Include different areas of the MPA representing available bottom types and benthoscapes (Figure 2; Lacharité et al. 2020): although benthoscape transitions are gradual and their true boundaries are not fixed by a polygon, they were produced using diverse types of data (e.g., multibeam, seafloor imagery, sediment samples) and by sampling within different benthoscapes we are likely to cover a wide range of habitats.
- Include representative depths: within the MPA, depths range between 116–491 m, with most of the variation being northeast to southwest (shallower to deeper). Areas <150 m are

concentrated along a thin sleeve on the eastern side of the MPA, outside of the large sea pen Significant Benthic Area (SiBA; Kenchington et al. 2016) and the large majority (69%) of the MPA is deeper than 400 m (Figure 2). Therefore, monitoring sites should include stations both at the western and eastern sides of the MPA to account for the variability in depth.

- Include sites within the sea pen SiBA polygons: sea pen SiBAs are, by definition, areas of high sea pen concentrations. Given that the protection of sea pens is one of the COs of this MPA, sufficient stations within the SiBAs are needed to determine the status of the MPAs sea pens.

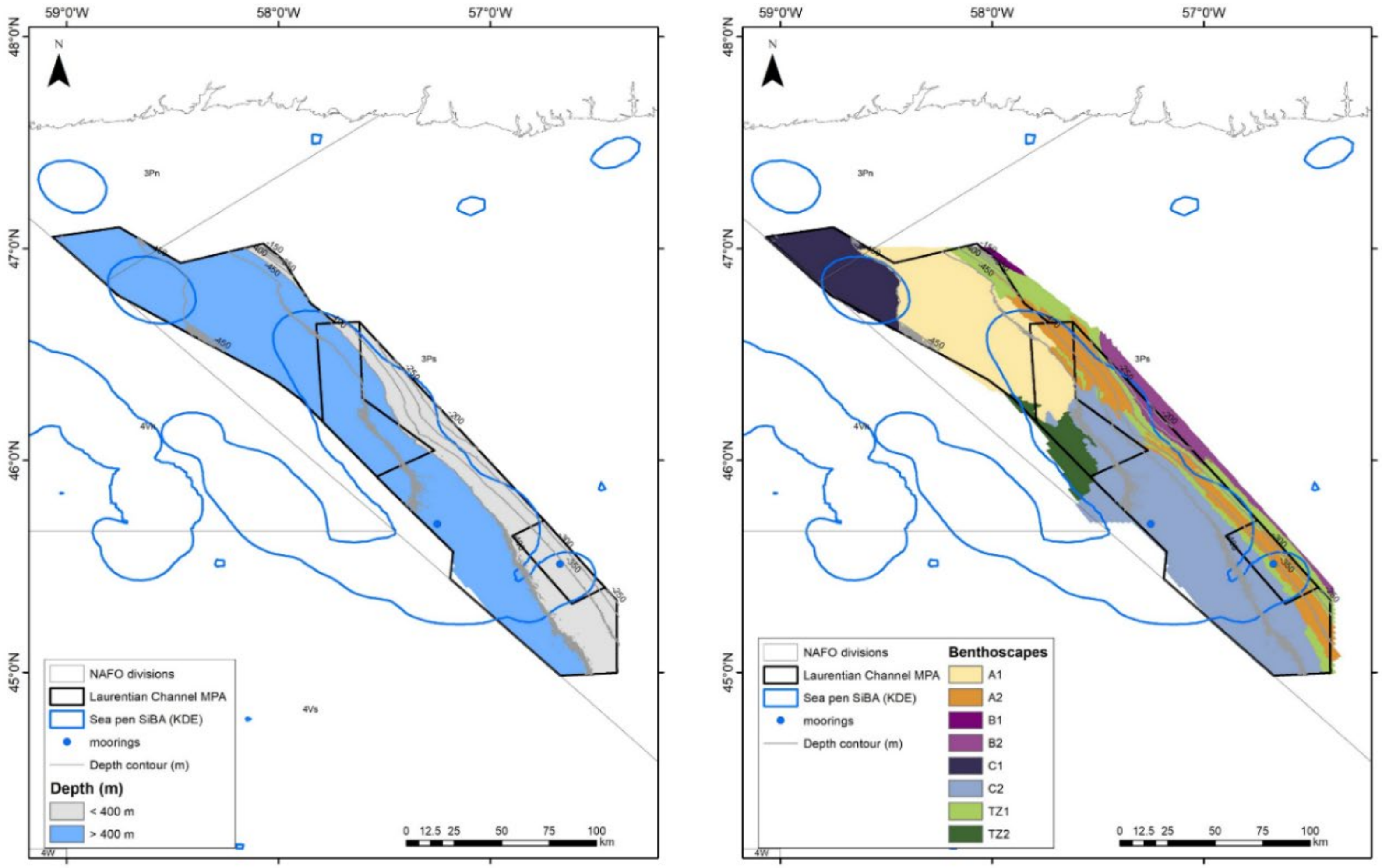

Figure 2. Depth distribution showing how most of the MPA is deeper than 400 m (left), benthoscapes, and sea pen Significant Benthic Areas (SiBA) of the Laurentian Channel MPA (right). Benthoscapes map layer from Lacharité et al. (2020).

In addition to the above criteria, survey efficiency/feasibility was considered to optimize survey time (e.g., time spent collecting data) and cost. Given the large size of the Laurentian Channel MPA (~300 km from north to south), travel time between stations might be considerable, which could be better invested in collecting data. For context, if a vessel is travelling at a speed of eight knots (depending on vessel), it could take ~20 hours to travel across the entire MPA.

Based on the above considerations, we suggest four main sets of stations along four lines crossing the MPA from west to east. These core monitoring stations cover different depths and represent 6 of the 8 benthoscapes. The proposed four lines across the MPA are equally spaced 60 km from one another (Figure 3), with an estimated distance of ~35 km (19 nautical miles) between the first and last stations in a line. This design allows for sampling the benthoscapes that cover the majority of the MPA, however, benthoscapes in the northern part of the MPA (C1 and B1) will not have any core monitoring stations.

- Line 1 would be the northernmost line, outside of the sea pen SiBA, crossing benthoscape A1 (predominantly mud) and some of TZ1 (mixed sediment). Depth is very consistent for most of this line (440–460 m), but it reaches 350 m at the eastern side of the MPA.
- Line 2 is inside the large sea pen SiBA, and crosses four different benthoscapes including the two in line 1, but also TZ2 (fine sediment) and A2 (mixed sediment) not covered in line 1. This line crosses depths of 250–450 m (east-west).
- Line 3 is also inside the large sea pen SiBA, and crosses four different benthoscapes including A2 and TZ1, but also C2 (sandy mud) and a little bit of B2 (muddy, gravelly sand), not covered in the previous lines. This line crosses depths of 250–450 m (east-west).
- Line 4 is partially inside the large sea pen SiBA, and crosses the same benthoscapes as line 3, except for B2. This line would also have stations close to an AZMP mooring deployed at this site. This line crosses depths of 280–430 m.

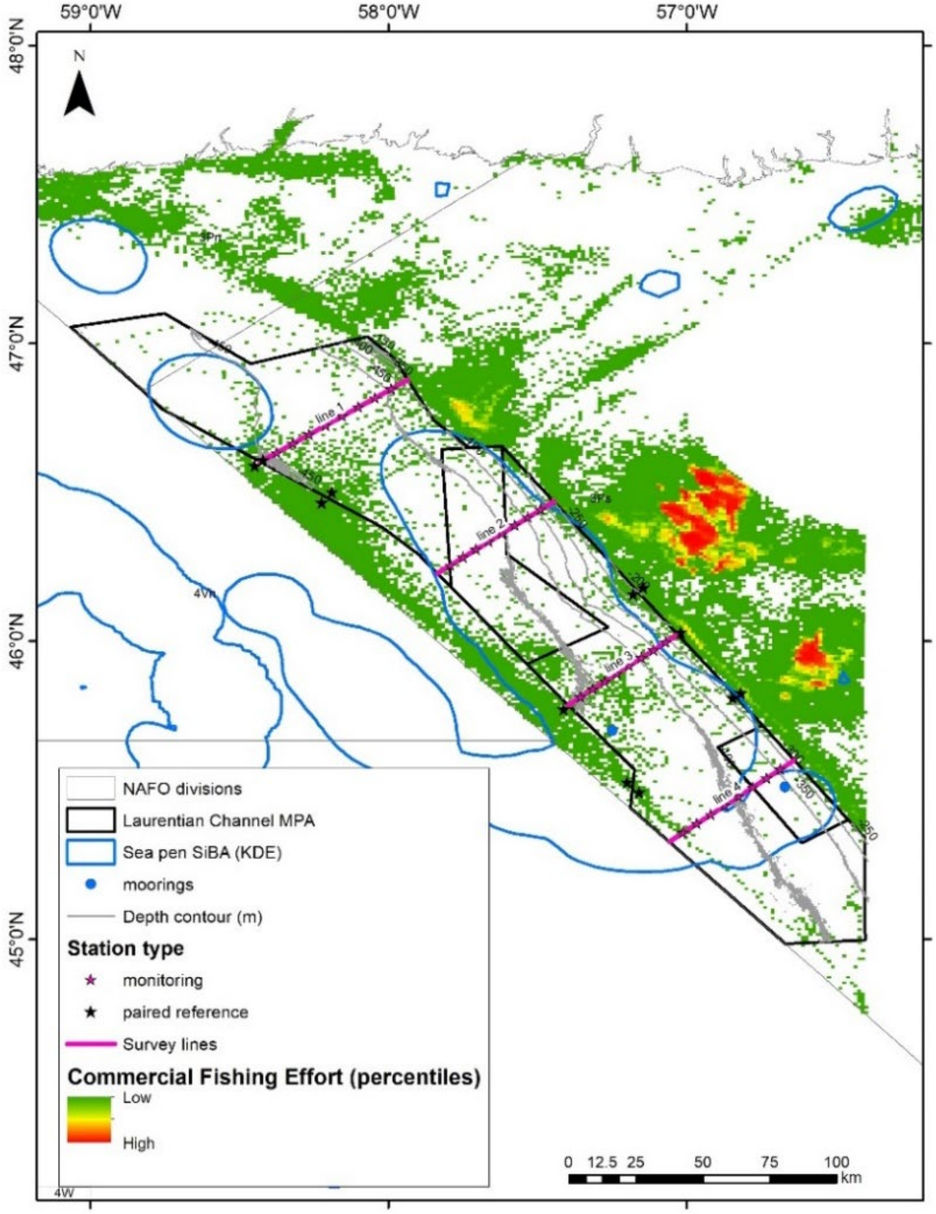

Figure 3. Commercial fishing effort (Vessel Monitoring System [VMS] percentiles) from Koen-Alonso et al. (2018) overlapped with the Laurentian Channel MPA. Areas in red represent high fishing effort and green low. Pink stars along survey lines 1–4 represent potential monitoring stations (8 per line) as part of a possible scenario, and black stars represent proposed paired reference stations where some fishing has taken place both inside and outside of the MPA.

The final number of stations per line, number of seafloor imagery transects per station, their length, and the method (e.g., photos/videos) have not yet been determined. However, the power analysis conducted by Morris et al. (2024) using data on drop video transects ~1 km in length indicates that at least 30 transects (for the whole MPA) may be required to detect changes in sea pen abundance. If the four lines cannot be surveyed in the same year, the possibility of alternating lines/years could be considered. Since statistical power remains unknown for other

Core Monitoring methods, we recommend that they be co-located with sea pen sampling. However, once preliminary data allows for additional power analyses, sample allocations for other methods can be refined.

We also recommend that all areas selected for monitoring sea pens in the MPA have a buffered exclusion zone around them to avoid direct impacts from bottom-contact scientific surveys that could influence sea pen metrics. For instance, the DFO RV trawl surveys will continue to take place inside the MPA boundaries (DFO 2022), and bottom trawling directly in areas being monitored specifically for sea pens will influence sea pen metrics. Bottom trawling near these areas could also indirectly influence the health, recruitment, or connectivity of sea pen populations being monitored (e.g., due to creation of sediment plumes, or reduction in spawning), but there have been no studies to confirm this yet. RV trawl proximity and intensity near core stations could be assessed as a potential confounding factor. While DFO RV trawl survey set locations are random-stratified, the selection of alternate sets falling outside of the monitoring buffer is strongly recommended. Alternatively, the assessment of alternate set locations could be considered during the activity plan approval process, which is carried out each year.

It is recognized that pockets of historical fishing activity can be identified inside the MPA, in which we might expect to see recovery of sessile CO taxa like sea pens in comparison to outside areas. Identified in Figure 3 above are 10 additional paired reference sites located along the boundaries of the MPA (1 inside and 1 outside). These are offered as potential sites with relatively similar depths and historical commercial fishing effort (see Figure 3) that may be investigated further under Targeted Research, if deemed necessary. Similarly, indirect impacts of trawling outside the MPA on these reference sites are possible. However, since this monitoring approach is still in the early stages of establishment, it is recommended that the focus remain on the monitoring sites described above.

Method 2 uses habitat mapping (HM) with abiotic variables and was initially carried out to identify areas within Northwest Atlantic Fisheries Organization (NAFO) Divisions (Divs.) 3P and 3O (HM study area; Figure 4) with similar environmental conditions that could be used to identify potential reference sites. While reference sites may not be used in the Core Monitoring program of the Laurentian Channel MPA, defining areas of comparable environmental conditions may be of value for understanding regional trends in indicators targeted by the monitoring program.

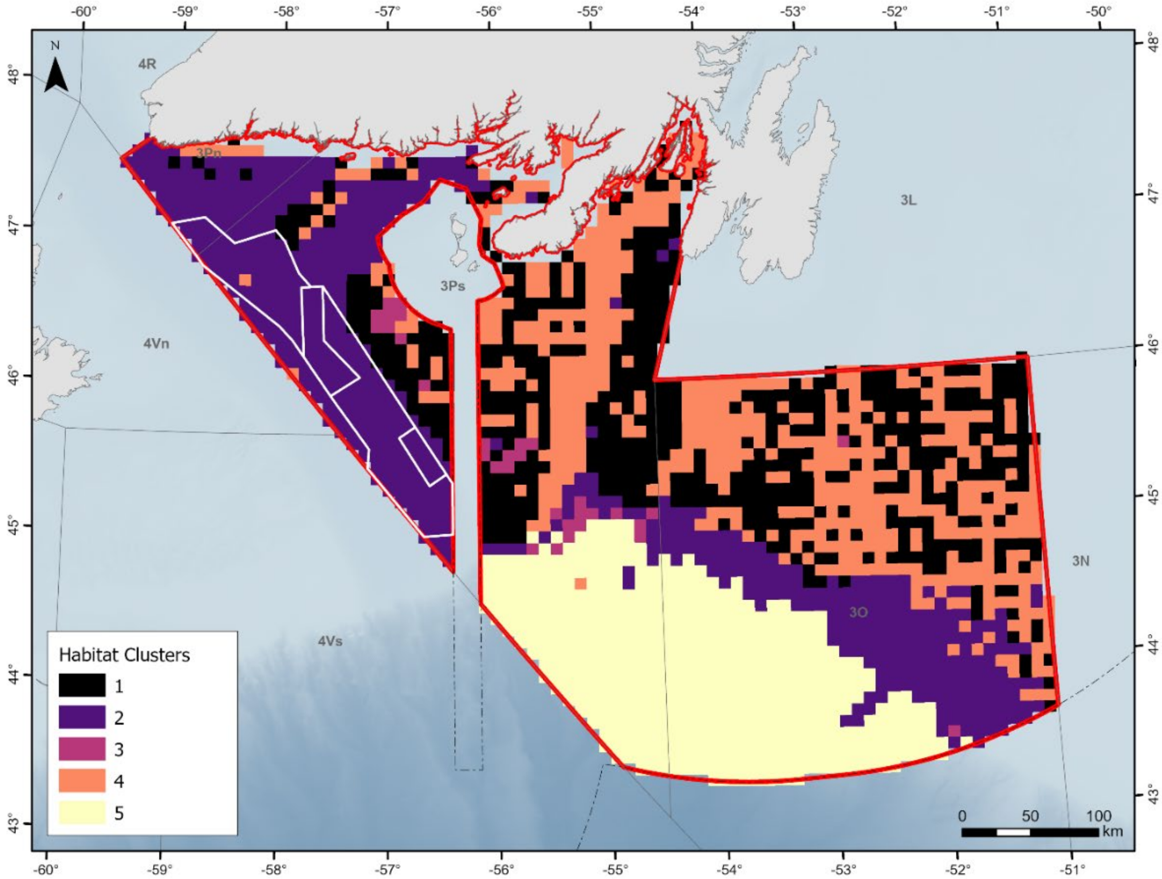

Figure 4. Map of habitat clusters from the k-means clustering analysis. The habitat mapping study area, encompassing NAFO Divisions 3OP within the Canadian Exclusive Economic Zone (EEZ) (dashed black line), is outlined in red. The Laurentian Channel MPA is shown in white.

Habitats within the HM study area were characterized using a dimensionality reduction approach (e.g., Principal Component Analysis) followed by an unsupervised cluster analysis using the methods described in Van Audenhaege et al. (2021). See Warren et al. (in prep)[1] for further details. Eleven abiotic variables (bathymetry, seabed terrain, commercial fishing effort, surface and bottom temperature, salinity, and current velocity) were used to characterize habitats within the study area. Prior to all analyses, the input variables were resampled (i.e., layers were aggregated using the mean value of original input cells) to the same spatial resolution based on the coarsest resolution of the original layers (i.e., 8.7 km).

The results from the unsupervised cluster analysis (k-means clustering) were plotted to visualize where the different clusters are located within the study area (Figure 4). Plotting these clusters spatially indicates that much of the area within the Laurentian Channel MPA boundary belongs to Cluster 2. Cluster 2 is characterized by a mean depth of 280 m, slope of 0.4 degrees, salinity of 34.4 PSU (practical salinity unit), surface temperature of 2.2°C, and bottom temperature of 5.4°C (relatively high compared to other clusters; Table 2). The Relative Deviation from Mean Value (RDMV; a measure of bottom roughness) is close to zero indicating few peaks or pits in the topography within the area and the cluster is generally south-west facing (northness value of -0.39 and an eastness value of -0.53). In addition to the Laurentian Channel, Burgeo Bank, Hermitage Channel, and the south-west edge of the Grand Banks are assigned to Cluster 2 and likely share similar environmental conditions.

Table 2. Mean values (± SD) of abiotic variables across clusters.

Abiotic Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Bathymetry	-80.57 ± 35.34	-280.17 ± 199.51	-250.38 ± 314.24	-120.54 ± 127.35	-2,474.16 ± 983.37
Eastness	-0.01 ± 0.69	-0.53 ± 0.53	0.36 ± 0.51	-0.17 ± 0.7	-0.27 ± 0.49
Northness	-0.1 ± 0.71	-0.39 ± 0.54	-0.6 ± 0.51	0.03 ± 0.7	-0.78 ± 0.3
Slope	0.13 ± 0.19	0.4 ± 0.58	0.96 ± 1.18	0.11 ± 0.18	1.83 ± 0.92
Relative deviation from mean value	0.18 ± 0.19	0 ± 0.17	0.11 ± 0.19	-0.18 ± 0.18	-0.01 ± 0.17
Salinity	32.65 ± 0.31	34.37 ± 0.69	33.29 ± 1.36	32.75 ± 0.32	34.92 ± 0.05
uo velocity	-0.02 ± 0.03	0 ± 0.01	-0.01 ± 0.01	-0.01 ± 0.02	-0.03 ± 0.02
vo velocity	0.01 ± 0.03	0.01 ± 0.02	0 ± 0.02	-0.02 ± 0.03	0.01 ± 0.02
Surface temperature	1.54 ± 0.52	2.2 ± 1	1.87 ± 0.75	1.71 ± 0.67	4.59 ± 0.79
Bottom temperature	0.86 ± 0.89	5.36 ± 1.21	3.43 ± 2.58	0.97 ± 1.05	3.16 ± 0.71
Fishing effort	4.25 ± 10.07	3.62 ± 8.51	133.72 ± 77.97	6.17 ± 12.35	1.47 ± 3.98

Method 3 is a strata-based fish community analysis of DFO RV trawl survey data and is useful for comparative baseline information and to understand larger ecosystem level changes, yet it is currently unknown how this would relate to the sea pen and sea turtle COs. In fact, strata-based community analysis has been used to assist with the selection of reference sites elsewhere (Shackell et al. 2021). For instance, Shackell et al. (2021) selected reference sites based on comparable community dominance structures, species biomass, and depth profiles for three fisheries closures (MRs) on the Scotian Shelf (DFO Maritimes). To examine community structure in and around the Laurentian Channel MPA, our approach focuses on fish functional groups, which are based on species general size characteristics and known feeding habits (M. Koen-Alonso, DFO-NL, pers. comm.). For a complete list of species considered in each functional group, see Appendix A in Warren et al. (in prep)[1].

- Small benthivores – small fish (maximum mean size <45 cm) that feed primarily on benthic organisms.
- Medium benthivores – medium sized fish (maximum mean size >45 cm and <80 cm) that feed primarily on benthic organisms.
- Large benthivores – large fish (maximum mean size >80 cm) that feed primarily on benthic organisms.
- Piscivores (fish that primarily feed on other fish).
- Plankpiscivores (planktivores/piscivores, fish that feed on both plankton and fish or primarily on plankton during early life stages and fish during later stages).
- Planktivores (fish that feed primarily on plankton).

The DFO multispecies survey uses a stratified random survey design and occurs every spring (April-June) in NAFO Divs. 3LNOPs (Figure 1). The strata are used here to group similar depth profiles. For this analysis, only survey sets from Subdivisions 3Ps and Div. 3O were used to limit the extent of the study area and only five years of data were included (2015–19) to reduce the number of data points (maximum of n=1,070). Survey sets that did not include any species from the functional group were removed from the analysis. An additional grouping for all species was included to provide a single holistic analysis and to ensure all species were represented. Using biomass (kg/tow), standardized for tow length, communities among trawl sets were compared for each strata and a cluster analysis was done to evaluate the groups (for further detail refer to Warren et al. [in prep][1]). Based on the cluster analysis, groupings of strata with a dissimilarity value of 50 or greater were used to identify unique 'clusters' of similar functional group community structure.

With all species included in the analysis, the Laurentian Channel MPA falls into Community Cluster 3 (Figure 5). Areas with similar community structure include Hermitage Channel, north of the MPA, and areas along the edge of the shelf to the southeast at similar depths. These areas align closely with those in the unsupervised habitat analysis results (see Figure 4).

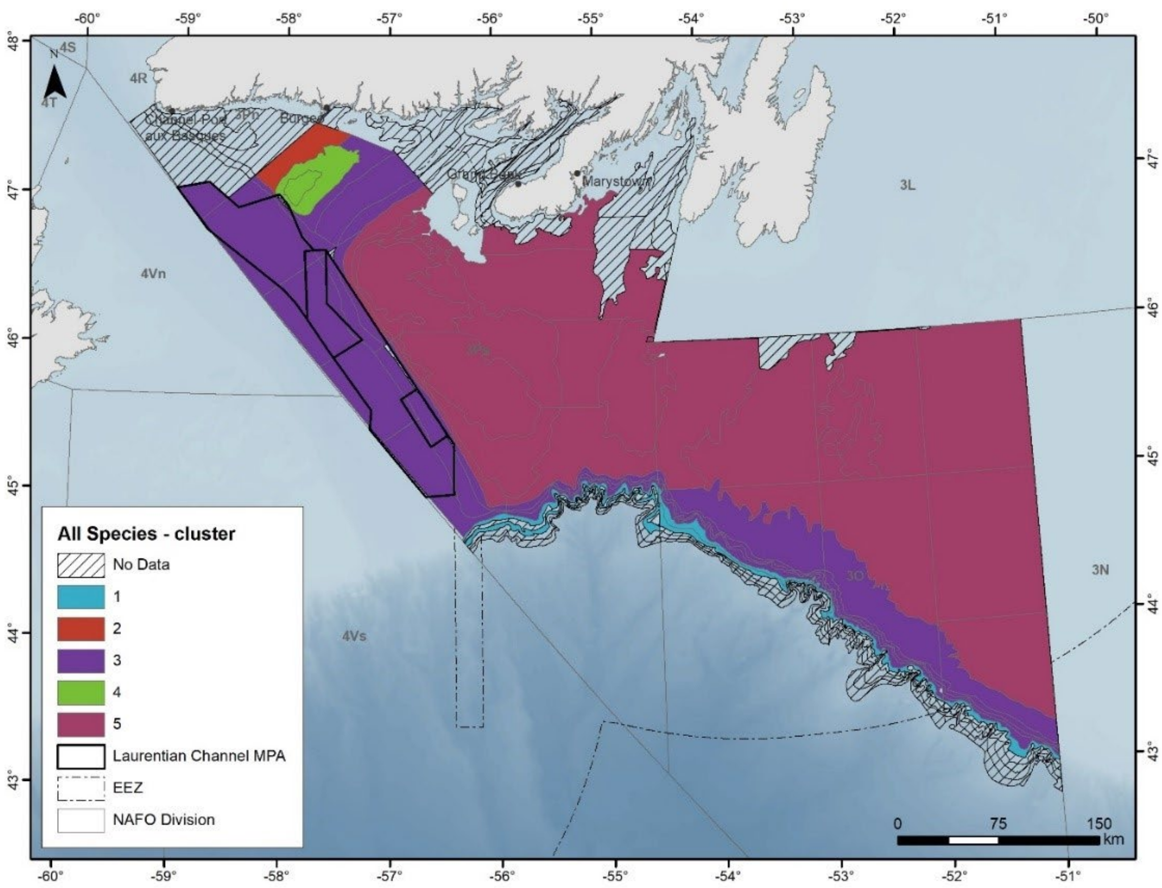

Figure 5. Strata-based community analysis for the all species group. Map of clusters with greater than 50 dissimilarity values.

Further detail on the cluster maps for the individual fish functional groups can be found in Warren et al. (in prep)[1], however, the Laurentian Channel MPA was relatively similar in community structure across all fish functional groups in the Hermitage Channel and along the edge of the southwest slope of the Grand Banks, similar to the patterns seen above.

Tracking trends in the community structure over time using this strata-based analysis is a good way to incorporate the RV trawl survey data into the monitoring approach and will provide useful context for understanding whether potential community shifts in the MPA are driven by larger-scale ecosystem processes.

Survey Methods and Strategies

This section describes survey methods and strategies that are proposed for the Laurentian Channel MPA monitoring program. Table 1 identifies which part of the overall approach (Core and Complementary Monitoring, or Targeted Research) each survey belongs to. In some cases, a single survey may be used in multiple sampling approaches, as is indicated in the table (e.g., CTD casts are carried out as part of the AZMP survey [Complementary] and will likely be used as part of the Core Monitoring as well).

Benthic Sampling

Tools, techniques, and methodologies for the development of benthic surveys as part of the monitoring of corals in Canadian waters have been described in Neves et al. (in prep)[2] in detail (and references therein) as part of a national CSAS process on monitoring of corals and sponges in Canadian OECMs and will not be further detailed here. Instead, from that list we include specific surveys considered suitable to study sea pens and benthic habitats in the Laurentian Channel MPA and vicinities. These include seafloor imagery (e.g., drop cameras), acoustic (e.g., high-resolution multibeam sonar), and sediment surveys. Specific tool selection for the completion of those surveys is described in further detail in the associated CSAS Research Document (Warren et al. in prep)[1] which will provide options once indicator selection has been fully evaluated and finalized (i.e., feasibility of using certain indicators assessed). It should be noted that tools described for the survey of sea pens and benthic/habitat surveys can also be used to survey general benthic biodiversity.

Emerging Non-Invasive Sampling

Technological advancements have provided promising new tools for monitoring marine biodiversity. Like more conventional approaches, the following methods have features that are attractive for use in conservation areas, despite some limitations. Environmental DNA (eDNA) methods fall into two broad categories: methods that target specific taxa (QPCR approaches) and those that sample a broad spectrum of the community (metabarcoding techniques). Both methods rely on collection of DNA fragments that have been shed by animals into the environment (e.g., water column or sediment). The collections of eDNA can be done through water samples or sediment grabs, are non-lethal, and relatively unintrusive to sensitive habitats compared to many other methods (e.g., trawls) (Stoeckle et al. 2020; Valsecchi et al. 2021). Moreover, the method can be applied across different habitat types, making it a strong candidate for comparison across conservation areas. Another type of non-invasive method is baited camera systems, which can be used to monitor fish and other biological communities. As with eDNA, baited cameras have minimal effect on habitats and can be deployed in a variety of environments (i.e., depths, substrates, etc.). Stationary cameras outfitted with lights are soaked

[2] Neves, B.M., G. Faille, F.J. Murillo-Perez, C. Dinn, M. Pućko, S. Dudas, A. Devanney, P. Allen. (in prep). A national monitoring framework for coral and sponge areas identified as Other Effective Area-Based Conservation Measures. DFO Can. Sci. Advis. Sec. Res. Doc.

for a variable number of hours, and videos are later used to observe fish and invertebrates that are attracted to bait (e.g., squid). Similar to baited cameras, the Underwater Vision Profiler (UVP) uses advanced imaging systems in combination with machine learning to capture and classify images of fauna. Unlike baited cameras, the UVP targets zooplankton and is lowered through the water column taking 1,000s of photos as plankton pass through its sensors.

Acoustic Methods

Acoustic telemetry provides a method for tracking movement and behaviour in aquatic environments without recapture. Additional sensors can be added to the transmitters to record environmental and biological data, including but not limited to depth, temperature, and/or predation events (Halfyard et al. 2017; Bangley et al. 2020). While there are no current plans to initiate telemetry studies (Targeted Research) in the Laurentian Channel MPA, some suggested applications are described in Warren et al. (in prep)[1] for future consideration. Further discussion on the specific indicators to be measured and their value to the monitoring program are needed prior to initiation.

Complementary Data Sources

Several ongoing scientific surveys can be leveraged as part of Complementary Monitoring. DFOs multispecies RV bottom trawl surveys provide fishery-independent sampling of commercial and non-commercial species. In the NL Region, the Spring DFO RV trawl survey has been conducted on an annual basis from April to June since 1982. The trawl gear was changed from an Engel Hi-Lift Otter Trawl to a Campelen shrimp trawl in 1995 (McCallum and Walsh 1997). Due to differences in the gear characteristics (i.e., catchability) the data from each time series cannot be easily compared. Further to that, the current RV trawl surveys are undergoing another change as two new vessels were recently added to the Canadian Coast Guard (CCG) fleet, meaning comparative fishing is currently underway. Assuming conversion factors can be computed, the plan is to continue the time series into the foreseeable future based on the current random stratified design. Further details on the DFO RV trawl survey and its application in the Laurentian Channel MPA can be found in Lewis et al. (2016).

Various Canadian programs exist which monitor fisheries catches or landings in the NL Region (e.g., Dockside Monitors, At-Sea Fisheries Observers, logbooks, and Vessel Monitoring System [VMS]), and data relating to some of the COs (i.e., to protect Black Dogfish, Northern Wolffish, and Smooth Skate from human-induced mortality) are collected for these demersal fish species. Two of these programs, Dockside monitoring and Logbooks, are less useful for the Laurentian Channel monitoring program. As part of the Dockside Monitoring program, Northern Wolffish, Smooth Skate, and Black Dogfish are almost always discarded at sea due to no commercial value and/or SARA restrictions. If landed, these species are grouped at a generic level (i.e., wolffish [catfish], skates, dogfish), which eliminates Dockside Monitoring as a source of data by species. To date, harvesters' compliance rates of *SARA* logbook returns have not been assessed; however, data on other logbook requirements indicate that rates of return are usually very low, and thus inadequate to capture actual impacts of harvesting on non-target species (M. Simpson, DFO-NL, pers. comm.).

Only Canadian At-Sea Observers provide speciated catch and discard data on wolffish, skates, and dogfish in Canadian commercial fisheries. Unfortunately, in recent years, Canada's At-Sea Observer program had very little coverage of the majority of fisheries: e.g., less than one percent in many cases, which is grossly inadequate to estimate the actual negative impacts of commercial fishing on bycatch and species at risk. Even with the caveats mentioned here, the COs for Northern Wolffish, Smooth Skate, and Black Dogfish are to reduce bycatch in commercial fisheries (i.e., human-induced mortality within the Laurentian Channel MPA), so Canadian At-Sea Observers (catches and discards by species) and VMS (vessels reporting their geographic position, speed, course, and activity every hour), will help monitor whether commercial fishing occurs within the Laurentian Channel MPA. Given that regulations for this MPA prohibit all commercial and recreational fishing in every zone within its boundaries, these fisheries monitoring tools can support DFO-Conservation & Protection in enforcing those prohibitions in this large MPA.

The Atlantic Zone Monitoring Program (AZMP) collects physical and biogeochemical oceanographic data in the NL Region along cross-shelf oceanographic sections. Two of these sections are located to the northeast of the Laurentian Channel MPA – southeast St. Pierre Bank (SESPB) and southwest St. Pierre Bank (SWSPB) – and are sampled during the spring (April-May) and fall (November-December). Although most stations along these two sections are located outside of the Laurentian Channel MPA, the two southernmost stations on SWSPB fall within the MPA boundaries. The different sampling protocols used by the AZMP are described in Mitchell et al. (2002), and the most recent physical and biogeochemical observations are presented respectively in Cyr et al. (2022) and Maillet et al. (2022). AZMP oceanographic databases in the Laurentian Channel MPA region extend back to fall 2008. Similar procedures can be applied to complement the AZMP databases by expanding the spatial and temporal coverage of oceanographic data collection within the Laurentian Channel MPA. Since 2015, DFO has also been collecting near bottom physical information (current, temperature and salinity) using two moorings deployed in the MPA. They are maintained annually as part of the AZMP and can be augmented with more instruments for better characterisation of the sites and to further contribute data to the MPA monitoring program (e.g., addition of passive or active acoustics, sediment traps, oxygen sensors, etc.).

Several other ongoing surveys and data sources can potentially contribute to the monitoring program such as the large pelagic shark commercial longline survey (DFO Maritimes Region), opportunistic sightings (e.g., marine mammals), the industry-led Redfish survey, the Halibut longline survey, the winter groundfish survey (DFO Gulf Region), and satellite imagery.

External Collaborations

Another valuable source of data for monitoring will come from external collaborations with institutions such as Memorial University through its Fisheries and Marine Institute (MI). In early 2022, a contribution agreement under the Ocean Management Contribution Program was signed between DFO and MI. The project will advance collaborative methods of monitoring marine conservation areas in the NL Region over the next four years (2022–26). The collaborative nature of the agreement will allow for new research partnerships between DFO and academia and increase capacity to monitor not only the Laurentian Channel MPA but other Marine Refuges in the NL Region as well. It will be important, moving forward, to ensure that certain data collection protocols are standardized between groups to maintain a reasonable level of data quality assurance, collation, and comparability (DFO 2015).

Indicators

It is often difficult to measure the impact of MPA management decisions, thus indicators are used to help identify change and the impacts on the ecosystem (Pomeroy et al. 2005). The selection of appropriate indicators is crucial, and they can be either qualitative or quantitative, based on the objectives of the MPA (Pelletier et al. 2005). As part of the framework for identifying monitoring indicators, protocols and strategies for the Laurentian Channel MPA (Lewis et al. 2016), several potential indicators were identified for each CO as well as indirect indicators and other ecosystem and habitat characterization indicators. To keep our approach practical and feasible for the next few years, a subset of those indicators was selected based on several steps outlined in DFO (2013). These steps are:

1. Identify the operational conservation objectives
2. Identify suitable indicators
3. Identify selection criteria
4. Evaluate indicators
5. Assess whether there is redundancy
6. Agree on a final suite of indicators
7. Estimate limit reference levels and target levels.

Several bilateral meetings were held with members of the NL Monitoring WG, and other subject matter experts, to go through the list of potential indicators and identify suitable ones. Eight selection criteria from Step 3 above helped to guide the discussion:

1. theoretical basis,
2. measurement,
3. historical data,
4. sensitivity,
5. responsiveness,
6. specificity,
7. public awareness, and
8. cost-effectiveness.

Further detail on these criteria can be found in DFO (2013). Each indicator was evaluated for how it would be used in the context of monitoring and the final list of indicators was agreed upon by all members of the NL Monitoring WG. Step 7 was not considered in this process as it was outside of the scope of the request; however, the development of thresholds or targets for some of the indicators could be a future consideration. Aside from the indicators specific to the COs and the overall goal of biodiversity, indicators for physical and biological oceanography were included to provide context for larger scale changes in the environment. In total, 29 indicators (Table 3) along with corresponding survey methods and strategies (Table 4) were identified.

Table 3. Indicators selected for each conservation objective priority species as well as biodiversity and oceanography.

Indicator	Sea Pens	Black Dogfish	Smooth Skate	Northern Wolffish	Porbeagle shark	Leatherback Sea Turtle	Biodiversity	Oceanography
Biomass	X	X	X	X	-	-	X	-
Abundance/Density	X	X	X	X	X	-	-	-
Species/Taxa Diversity	X	-	-	-	-	-	X	-
Species/Taxa Richness	X	-	-	-	-	-	X	-
Size Distribution	X	X	X	X	-	-	-	-
Occurrence/Frequency	-	X	X	X	X	X	-	-
Distribution	-	X	X	-	-	-	-	-
Fisheries Catch Weight	-	X	X	X	-	-	-	-
Length Frequencies	-	-	X	X	-	-	-	-
Lethal Encounters/Non-Lethal Entanglements	-	-	-	-	X	X	-	-
Size (Length)	-	-	-	-	X	-	-	-
Weight	-	-	-	-	X	-	-	-
Movements	-	-	-	-	X	-	-	-
Jellyfish Aggregations (abundance and distribution)	-	-	-	-	-	X	-	-
Temperature	-	-	-	-	-	-	-	X
Chlorophyll-a	-	-	-	-	-	-	-	X
Salinity	-	-	-	-	-	-	-	X
Oxygen Concentration	-	-	-	-	-	-	-	X
Ocean Acidification (alkalinity, pH, DIC, PCO2)	-	-	-	-	-	-	-	X
Soundscape/Acoustic Features	-	-	-	-	-	-	X	X
Nutrient Flux (movement of water masses)	-	-	-	-	-	-	-	X

Indicator	Sea Pens	Black Dogfish	Smooth Skate	Northern Wolffish	Porbeagle shark	Leatherback Sea Turtle	Biodiversity	Oceanography
Currents	-	-	-	-	-	-	-	X
Infaunal and Epifaunal Composition	-	-	-	-	-	-	X	-
Trophic Flows	-	-	-	-	-	-	X	-
Energy Flows	-	-	-	-	-	-	X	-
Predator/Prey Biomass	-	-	-	-	-	-	X	-
Primary Productivity	-	-	-	-	-	-	-	X
Zooplankton Variability	-	-	-	-	-	-	X	X
Threats (e.g., sedimentation, noise, oil spills)	X	-	-	-	-	-	X	-

*Table 4. Indicators selected for each of the survey methods and strategies. * Indicates surveys that may be used in the monitoring program but have not been linked to a monitoring indicator.*

Indicator	Surveys and Strategies																								
	Trawl Surveys	**Aerial Surveys**	**Acoustic and Other Tagging**			**Benthic / Habitat Surveys**				**Other Minimally Invasive Techniques**			**Oceanography**			**Fisheries Related**				**Other Data Collection / Non-DFO-NL Surveys**					
	DFO Multispecies RV Trawl Surveys	Aerial Surveys (turtle, cetacean, jellyfish)	Acoustic Telemetry (receivers and tags)	Acoustic Receivers (moorings and mobile)	Satellite Tags (PATs)	*Multibeam / Sidescan Sonar	Drop and Drift / Tow Camera (Non-ROV)	Sediment Corer (benthic grab / box core)	ROV	eDNA (water/sediment)	Baited Camera	UVP (Underwater Vision Profiler)	AZMP	CTD Cast	Oceanographic Mooring	Dockside Monitoring	Observer Data	FFAW	VMS or Logbooks	Satellite Imagery	Sightings (opportunistic)	*Redfish Survey	*Halibut Longline Survey (Maritimes)	Large Pelagic Shark Commercial Longline Survey	*Gulf Winter Groundfish Survey
Biomass	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Abundance / Density	X	-	-	-	-	-	X	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-
Species/Taxa Diversity	X	-	-	-	-	-	X	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Species/Taxa Richness	X	-	-	-	-	-	X	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-
Size Distribution	-	-	-	-	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Occurrence / Frequency	-	X	-	-	-	-	-	-	-	X	-	-	-	-	-	X	X	X	X	-	X	-	-	-	-
Distribution	X	-	-	-	-	-	X	-	X	-	-	-	-	-	-	X	X	X	X	-	-	-	-	-	-
Fisheries Catch Weight	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	-	-	-	-	-	-
Length Frequencies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-

Indicator	Surveys and Strategies																								
	Trawl Surveys	**Aerial Surveys**	**Acoustic and Other Tagging**			**Benthic / Habitat Surveys**				**Other Minimally Invasive Techniques**			**Oceanography**			**Fisheries Related**				**Other Data Collection / Non-DFO-NL Surveys**					
	DFO Multispecies RV Trawl Surveys	Aerial Surveys (turtle, cetacean, jellyfish)	Acoustic Telemetry (receivers and tags)	Acoustic Receivers (moorings and mobile)	Satellite Tags (PATs)	*Multibeam / Sidescan Sonar	Drop and Drift / Tow Camera (Non-ROV)	Sediment Corer (benthic grab / box core)	ROV	eDNA (water/sediment)	Baited Camera	UVP (Underwater Vision Profiler)	AZMP	CTD Cast	Oceanographic Mooring	Dockside Monitoring	Observer Data	FFAW	VMS or Logbooks	Satellite Imagery	Sightings (opportunistic)	*Redfish Survey	*Halibut Longline Survey (Maritimes)	Large Pelagic Shark Commercial Longline Survey	*Gulf Winter Groundfish Survey
Lethal Encounters / Non-Lethal Entanglements	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	-	-	-	-	-	-
Size (Length)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
Weight	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
Movements	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Jellyfish Aggregations - Abundance and Distribution	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	X	-	-	-	-	-	-	-	-	-	-	-	X	X	X	-	-	-	-	X	-	-	-	-	-
Chlorophyll-a	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	-	-	X	-	-	-	-	-
Salinity	X	-	-	-	-	-	-	-	-	-	-	-	X	X	X	-	-	-	-	-	-	-	-	-	-
Oxygen Concentration	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	-	-	-	-	-	-	-	-	-	-

Indicator	Surveys and Strategies																								
	Trawl Surveys	Aerial Surveys	Acoustic and Other Tagging			Benthic / Habitat Surveys				Other Minimally Invasive Techniques			Oceanography			Fisheries Related				Other Data Collection / Non-DFO-NL Surveys					
	DFO Multispecies RV Trawl Surveys	Aerial Surveys (turtle, cetacean, jellyfish)	Acoustic Telemetry (receivers and tags)	Acoustic Receivers (moorings and mobile)	Satellite Tags (PATs)	*Multibeam / Sidescan Sonar	Drop and Drift / Tow Camera (Non-ROV)	Sediment Corer (benthic grab / box core)	ROV	eDNA (water/sediment)	Baited Camera	UVP (Underwater Vision Profiler)	AZMP	CTD Cast	Oceanographic Mooring	Dockside Monitoring	Observer Data	FFAW	VMS or Logbooks	Satellite Imagery	Sightings (opportunistic)	*Redfish Survey	*Halibut Longline Survey (Maritimes)	Large Pelagic Shark Commercial Longline Survey	*Gulf Winter Groundfish Survey
Ocean Acidification (alkalinity, pH, DIC, PCO2)	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	-	-	-	-	-	-	-	-	-	-
Soundscape / Acoustic Features	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nutrient Flux (Movement of Water Masses)	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-
Currents	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-
Infaunal and Epifaunal Composition	-	-	-	-	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trophic Structure	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Energy Flows	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Predator / Prey Biomass	X	-	-	-	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Indicator	Surveys and Strategies																								
	Trawl Surveys	**Aerial Surveys**	**Acoustic and Other Tagging**			**Benthic / Habitat Surveys**				**Other Minimally Invasive Techniques**			**Oceanography**			**Fisheries Related**				**Other Data Collection / Non-DFO-NL Surveys**					
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Primary Productivity	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	-	-	X	-	-	-	-	-
Zooplankton Variability	-	-	-	-	-	-	-	-	-	X	-	X	X	-	-	-	-	-		-	-	-	-	-	-
Threats (e.g., sedimentation, noise, oil spill)	-	-	-	-	-		-	-	-	-	-	-	-	-	X	-	-	-	X	-	-	-	-	-	-

Biodiversity

Biodiversity assessments can be conducted using data from several sampling methods, all of which specialize in certain taxa due to their associated biases. Emerging methods (e.g., eDNA and baited cameras), like conventional surveys (e.g., RV and drop camera surveys), capture a broad spectrum of taxa. Each can provide data on CO priority species or the communities of which they are part of and rely on. Common indicators for biodiversity are taxa richness and evenness, with higher values representing a system with more biodiversity. But more sophisticated measures that incorporate function and taxonomic diversity could also be explored with these data. Other approaches include food web complexity, which can be estimated using taxa traits of the species found in the area. Beyond RV trawl surveys, there are few datasets with which to evaluate biodiversity in the Laurentian Channel MPA, so the datasets used will depend on cost-effectiveness determined from field trials.

Infauna and Non-Sea Pen Epifauna

While the protection of benthic infauna and non-sea pen epifauna is not specifically listed as one of the COs of this MPA, other epifauna and infaunal organisms are also vulnerable to bottom trawling and should be considered as part of monitoring approaches used in this program (De Juan et al. 2007). Assessments of benthic community patterns and species diversity have often focused on analysis of common metrics such as richness, numerical abundance, biomass and diversity indices (e.g., Shannon-Wiener) (Clarke et al. 2014). But more recently, studies that take an extra step to incorporate biological information (e.g., biological traits related to life history or functional roles) have become more common (Tillin et al. 2006; Parzanini et al. 2018; Lins et al. 2021) and should be considered as part of the design and planning of conservation areas (Miatta et al. 2021). Functional diversity has been considered an indicator of bottom trawling disturbance (Tillin et al. 2006; De Juan et al. 2007), which was the main threat defined during MPA establishment for the Laurentian Channel COs.

Soundscape

Most natural soundscapes are unique and differ depending on a variety of environmental factors (biota, depth, substrate type, ice-cover, etc.). These natural soundscapes are an important part of the habitat for many marine animals who use sound to understand their environment and to communicate. However, climate change and other anthropogenic activities can alter the functionality of MPAs, including its soundscape. Anthropogenic noise is a pollutant that is recognized to negatively affect some marine animals, particularly marine mammals, although the ecological impact of noise on the vast majority of other marine life is poorly understood. Soundscape monitoring can inform scientists and management decisions regarding the potential effects of such noise within MPAs (e.g., Weiss et al. 2021; McKenna et al. 2021). Large MPAs with limited shipping activity, such as the Laurentian Channel MPA, could reduce the potential effects of noise on marine life; however, the propagation characteristics of low frequency noise means that it can travel exceptionally long distances and, for that reason, even the largest MPAs are not free of anthropogenic sounds. Therefore, having a method to detect signs of major issues is useful for marine resource managers. Ideally, multiple measures of the MPA's acoustic environment would be integrated into a soundscape to provide a description of the composite acoustic environment. Characterizing a marine soundscape through only single sound level measures provides an incomplete description, reduces our understanding of distinctive acoustic features, and can hinder comparisons with adjacent areas or other MPAs. Several common acoustic metrics used to quantify underwater sound are root-mean square sound pressure level, power spectral density level, daily sound exposure levels, and daily equivalent continuous sound level (Robinson et al. 2014; Merchant et al. 2015).

Sea Pens

Examples of potential indicators for the monitoring of cold-water corals in Canadian OECMs were listed and described as part of a 2020 CSAS process (DFO 2021). Indicators were described and evaluated based on steps listed above from DFO (2013), however, only steps 1–4 were evaluated in that CSAS process. The final list included 15 suitable state indicators, plus indirect Biodiversity Conservation Benefits (BCBs), and stressor indicators (numerical abundance, biomass, distribution, diversity indices, size structure, live:dead ratio and condition, % corals with zoanthids, patch area and density, patch isolation/proximity, patch connectivity, and contagion index). Continuing on from that process, the selection of indicators here considers steps 5–6 of the 2013 framework (DFO 2013): assessing redundancy and agreeing on the final suite of indicators. The following indicators are likely to be the most useful for the specific monitoring of sea pens, if further analyses indicate that they can, in practice, be collected consistently and with enough statistical power:

- Abundance: Morris et al. (2024) performed a preliminary analysis on the statistical power of sea pen abundance data obtained from seafloor imagery in the Laurentian Channel MPA. The analysis indicates that similar data might be used to detect a decline in sea pen abundance at a relatively high statistical power and realistic sample size. However, as described by those authors, the threshold at which a decline in sea pen abundance might cause irreversible damage to their populations is unknown at this point, as is whether the decline modelled in those analyses is biologically relevant. We suggest that collection of sea pen abundance data should use seafloor imagery as its primary source.
- Biomass: the most realistic way of obtaining biomass data for sea pens is by weighing physical samples, which generally precludes the use of seafloor images for this purpose. In practice, sea pen biomass data have been obtained in the Laurentian Channel as part of DFO's RV trawl surveys for many years. However, a power analysis has not been conducted on RV trawl survey sea pen biomass to assess whether it could be reliably used for monitoring if scientific trawling continues in the MPA at current levels. Furthermore, due to low sea pen catchability of the Campelen trawl (Kenchington et al. 2011), trawl biomass should not be considered as the main indicator for the monitoring of sea pens in this MPA. Data from these surveys can still be used to identify large catches and their locations, to provide samples for other analyses, and to contribute to monitoring of the MPA, as discussed in other parts of this document. If shifts in sea pen trawl biomass are detected over the next years, Targeted Research investigating this metric might be warranted. We also suggest future research towards estimation of biomass from imagery, which, although not common, might be possible (De Clippele et al. 2021).
- Diversity indices: might turn out to be unsuitable for the purposes of monitoring to detect significant changes in the MPA, due to the relatively low number of sea pen taxa in the MPA but can still be informative to assess status and trends. In future iterations of power analyses using imagery data, diversity indices should be included for their evaluation. We suggest that collection of sea pen diversity data should use seafloor imagery as its primary source.
- Size structure: is a challenging indicator because sea pens are difficult to measure from images, and because we have not assessed sea pen size structure bias of the Campelen trawl method. It is known that juveniles are often not retained by the trawl and that sea pen

abundance has not been consistently measured during DFO RV trawl surveys. Nonetheless, size structure constitutes a crucial variable to assess sea pen recruitment in the MPA. While precise measurements are indeed challenging, alternative approaches to assessing size, such as through categories (e.g., large, medium, small) and from counts of polyp leaves (Chimienti et al. 2018) should be considered in future iterations of power analyses using imagery data.

Endoparasitic copepod infestation is yet to be investigated as a potential indicator of change in the MPA, but it deserves to be considered as part of the research objectives for the MPA (see Baillon et al. 2014). Another consideration is that, although some of these indicators are derived from the same dataset, specific power analyses would be needed for all of them, as the number of required samples might not be the same for each one. For instance, the number of samples required to detect change in sea pen abundance might be quite different from the number required to detect change in sea pen diversity (i.e., diversity indices). Rogers et al. (2008) found that the number of samples required to observe change in megafauna metrics (e.g., biomass, abundance, diversity indices) was variable and changed depending on the gear used. The final selection of indicators also needs to consider turnover time between data collection, analysis, and reporting, as well as availability of human resources to do so. The implementation of AI techniques for use with imagery annotation may help to significantly mitigate processing time for the large amount of imagery data expected to be collected in the MPA. Nonetheless, as with other components of the monitoring program, full implementation of AI techniques in this context might require years and, in some cases, will represent a trade-off between lower processing time and lower taxonomic resolution.

In addition to the indicators listed above, environmental and stressor indicators were also suggested for the monitoring of corals and sponges in Canada (Kenchington et al. 2012; DFO 2021). Environmental indicators mentioned in DFO (2021) include commercial fishing, oil and gas activities, and ice, which will not be considered here. There are currently no exploration licenses for oil and gas activities near the Laurentian Channel MPA, so impacts from these activities are not of immediate concern (e.g., transport of drilling waste), although oil spills could still happen in the area. Other anthropogenic stressor indicators include sediment deposition, timing, duration, and magnitude of phytoplankton bloom (may change as a result of climate change impacts; refer to Kenchington et al. 2012), seabed litter presence, and activities related to submarine cables (DFO 2021). These indicators were detailed in Neves et al. (in prep)[3] and will not be further described here. However, they will be considered in the monitoring plan as part of Targeted Research and Complementary Monitoring. While these indicators are listed here as part of coral and sponge CSAS processes and some might be more focused on benthic activities (e.g., sedimentation and submarine cables), they might also be relevant to other priority species and biodiversity in general (see Table 3). While climate change was not specifically detailed here, some oceanographic parameters (environmental indicators) can be used to monitor climate-change induced stressors. Shifts in sea pen carbonate content could be investigated as a potential state indicator related to ocean acidification.

Black Dogfish, Smooth Skate, Northern Wolffish

Monitoring of Black Dogfish, Northern Wolffish, and Smooth Skate relative to their COs will occur mainly through the continuation of existing DFO multispecies Spring surveys, At-Sea Fisheries Observer (ASO) records, and fisheries landings monitoring. The collection of eDNA samples and baited camera video provide options to obtain further information on these species (e.g., presence), although these methods have not yet been tested for these taxa in this area. Multispecies surveys provide data on species distribution, biomass/abundance, length composition, sex, and maturity, and can also be used to collect additional samples (DNA, parasites, isotopes, stomach contents). Fisheries statistics, such as those collected by ASOs and through existing landings monitoring tools (logbooks, dockside monitoring), directly address the main CO of reducing human-induced mortality in the Laurentian Channel MPA. The annual ASO coverage of relevant Atlantic fisheries remains at primarily 0–5% (since 2010; with a few exceptions), while commercial landings monitoring of targeted species does not report bycatch data. Therefore, unreported commercial fisheries bycatch is likely the largest threat to CO priority species human-induced mortality in areas adjacent to the Laurentian Channel MPA.

Deployment of additional acoustic receivers within and outside the Laurentian Channel MPA boundaries can support research on seasonal distribution, movements, and habitat requirements for different life stages of acoustically-tagged Northern Wolffish, Black Dogfish, and Smooth Skates. Previously, wolffish movements and habitat selection were monitored using internal acoustic tags (Simpson et al. 2015); a study which could be repeated in and around the Laurentian Channel MPA. In addition, external acoustic tags can be attached to Black Dogfish and Smooth Skates to capitalize on this acoustic array. Alternatively, Smooth Skates could be monitored using pop-up satellite archival tags (Knotek et al. 2020).

For all three species, these tagging studies could also investigate post-release mortality; especially given that a portion of those species inhabit deeper waters and may experience increased physiological (and potentially lethal) stresses when quickly hauled to the ocean's surface/aboard vessels by fishing gear. This is particularly important for Northern Wolffish because the primary conservation tool of its recovery strategy is the immediate live release of wolffish bycatch with the least possible harm during commercial fishing operations.

In addition to data provided by DFO multispecies Spring surveys, Canadian ASO's are the sole source of speciated catch and discards of wolffish and skates in commercial fisheries. When requested by DFO, ASOs also measure length/weight/sex of individuals from target species/bycatch, and collect standardized non-lethal (e.g., fin clips for DNA) and lethal (fish otoliths for ageing; stomach contents) samples for subsequent scientific analyses.

Porbeagle Shark

The main survey used for monitoring the status of the Atlantic Porbeagle population is the large pelagic shark commercial longline survey. This fishery-independent survey provides time-series data with estimates of distribution, relative abundance, trends, and life stage/size/sex composition. Ongoing tagging of Porbeagle Sharks (with external passive acoustic tags or satellite tags), conducted by DFO in NL Region waters, will provide data on individual Porbeagles and their movements.

Records of all shark encounters (lethal and non-lethal) are also important for monitoring Porbeagle Sharks, however, current fisheries-related methods for collecting this information are limited, even more so due to the lack of commercial and recreational fishing in the MPA. Improvements could be made to better utilize some of these Complementary Monitoring data sources. For example, logbooks are currently used to monitor only the endangered White Shark but should be expanded to include Porbeagle Sharks (and ideally all other Atlantic large pelagic sharks), along with photographic documentation. Furthermore, misidentification of large shark species by Atlantic fish harvesters is common, so a pocket-sized waterproof Sharks Species ID Guide could be distributed to all commercial License holders/fishers when applying for/renewing their Licenses. Ideally, reporting of all Atlantic shark bycatch should be made a Condition of License in Canada. The CO for Porbeagle Shark is to protect from human induced mortality (e.g., bycatch in the commercial fishery) and these encounters will help monitor whether commercial fishing occurs within the Laurentian Channel MPA and also provide additional information on the species from areas adjacent to the MPA.

Leatherback Sea Turtles

Leatherback Sea Turtles range over a large area of the northwest Atlantic. However, they are more likely to occur in certain spaces, such as off the southern coast of Newfoundland, based on data from a systematic aerial survey (2007 Trans North Atlantic Sightings Survey [TNASS]; Lawson and Gosselin 2009). The density of Leatherbacks is highest closer to the Newfoundland south coast in shallower waters, but portions of the Laurentian Channel MPA also have high densities. This general distribution pattern holds true based on a habitat model (kernel density map) of Leatherback Sea Turtles (Mosnier et al. 2019).

Information on the reasons for Leatherback use of habitat in the Laurentian Channel MPA is limited. This turtle species is known to specialize on jellyfish prey (particularly *Cyanea* and *Aurelia* in Newfoundland waters), but biomass and distribution estimates for these prey are lacking. Over almost two decades of aerial survey effort, it is clear that the number and spatial extent of jellyfish swarms in Atlantic Canada are increasing (J. Lawson, DFO-NL, pers. comm.); although as a measure of biomass such observations are speculative and based on visual records with low precision – for example we would not know the vertical extent of most jellyfish swarms seen from the air. In parallel, the regional abundance of Sunfish (*Mola mola*), a fish that also specializes on jellyfish prey, has increased in recent years, and could be used as an indicator of the presence of jellyfish prey for themselves and Leatherbacks.

Reporting of Leatherback Sea Turtle interactions with fishing gear and vessels (both lethal and non-lethal) is very important for monitoring this species. Fishery logbooks should be expanded to include non-landed turtle captures (since Leatherbacks are rarely brought aboard fishing vessels), along with photographic documentation of the sea turtles in gear. As with Porbeagle Sharks, reporting of all Leatherback Sea Turtle bycatch should be a Condition of License. While most Leatherback Sea Turtle fishing gear encounters have occurred on the (predominantly southern) coastal areas of Newfoundland, there are several reports of these sea turtles being bycaught in nets off the southern coast of Labrador. Several lethal entrapments of Leatherbacks are reported in fishing gear each year around Newfoundland, but this is an underestimate of the true number; about one third of Leatherbacks entrapped in fishing gear die (Hamelin et al. 2017). Leatherback Sea Turtles are more likely to be caught in the vertical lines of fixed gear (such as whelk or crab pots), or nets (such as groundfish or bait gillnets).

Oceanography

The ocean climate of the Northwest (NW) Atlantic changes on interannual and decadal time scales (Cyr and Galbraith 2021). These changes in the climate are accompanied by fluctuations of the physical (e.g., temperature, salinity, currents, etc.) and biogeochemical (oxygen and nutrient concentrations, pH, chl-*a*, plankton composition and abundance, etc.) environments, with potential larger impacts on the ecosystem. In order to disentangle the status of the MPA's ecosystem and the changes associated with other factors such as climate change, physical and biogeochemical indicators must be closely monitored. Environmental indicators (e.g., habitat-related parameters, temperature, chlorophyll *a* concentration and zooplankton abundance) were also proposed in DFO (2021) as part of the national monitoring framework on corals and sponges.

It is recommended to continue the existing monitoring of oceanographic indicators routinely collected as part of the AZMP, or with the deployment of moorings as described above. In addition to these existing indicators, other variables such as surface chlorophyll-*a* concentration (estimated using satellite observation of ocean color), nutrient flux to benthic habitats using sediment traps, soundscape monitoring, and fisheries acoustics (from moorings) could also be considered.

Study Design

For long-term monitoring programs, establishing a robust, well-thought-out study design is essential. Guidance for developing effective study designs for monitoring have been well covered elsewhere (Quinn and Keough 2002; Parks Canada Agency 2007) and are only touched on here. DFO (2021) also included a detailed section on methodologies/design for the monitoring of coral and sponge OECMs, which can also be used as a reference. Study designs should dictate where and when (time of day, season, frequency) sampling is conducted and reflect well defined questions of the monitoring program and reporting requirements. Flaws in study design can result in erroneous conclusions, loss of confidence in the program, costly corrections, disruptions of time series, and/or misalignment with program objectives.

For MPAs, monitoring questions should naturally follow COs and survey timing should be planned to complement reporting schedules (yet to be defined). For the Laurentian Channel MPA, one monitoring question might be: Are the densities of Black Dogfish maintained within the MPA boundaries? A study design addressing this question will identify sampling locations and times that minimize bias across the area in question. Operational limitations often restrict sampling (e.g., sampling depths, substrates, seasons, size of the MPA, etc.), which in turn limits the representation of the data and the generality of the conclusions. In other circumstances, resource limitations may require that efforts be focused on an important subset of the MPA (e.g., core habitats), to ensure sufficient sampling to detect change. These intentional restrictions to the sampling frame (i.e., temporal and spatial extent of area sampled) are often necessary and can be accommodated if the limitations are clearly understood in the design process and articulated when reporting the results. More insidious problems with study design are those that result in unplanned biases or those that affect the independence of data. The former issue can be resolved by unbiased sample site selection techniques such as random, systematic, or random stratified sampling. Attempts to free sampling from bias can be undermined by the forced inclusion of historic sampling sites, particularly in cases where the selection criteria of those data are unknown or not aligned with program objectives (e.g., a site selected because it was particularly good habitat for an indicator or priority species might bias resulting analyses to misrepresent MPA status in a more positive light). The latter issue of independence among samples is a common assumption of many statistical analyses. For example, samples collected in spatial and temporal proximity are more likely to be similar than those that are less proximal (i.e., spatial and temporal autocorrelation). Datasets with high correlation can lead to falsely inflated statistical power and can cause Type-I errors (detection of statistical changes that are not there) if not addressed. In practice, correlation is widespread in nature and more advanced statistical methods can account for and correct such issues during the analysis stage, but these come at the expense of statistical simplicity. Moreover, not understanding correlation patterns can lead to inefficient study designs. Ideally, a subset of data are used to understand the correlation that should be expected across sampling scales and to optimize sampling strategies in a way that minimizes redundant sampling.

A final important aspect of study design is establishing a program with sufficient statistical power to detect change. Power analysis is a statistical tool used to evaluate and compare design approaches, assess program feasibility, and optimize sampling intensity to meet project objectives. Statistical power is influenced by factors within (e.g., desired detectable effect size, sample size, and accepted Type I error rates, statistical test used) and beyond (inherent variability of the indicator of interest) the control of monitoring program designers. More coarse detectable effect sizes, larger samples and greater tolerance of Type I errors (i.e., false positives) all can improve statistical power. In contrast, higher intrinsic variance in the indicator negatively affects power. Often, additional variables, if included in the models used to detect change, can account for some variation and improve statistical power. Furthermore, statistical tests and supporting study designs can also differ in their efficiency to detect change (Morris et al. 2018). As with understanding correlation structure, existing data are valuable for informing power analyses. For example, existing RV trawl survey data were used to inform a power analysis by Morris et al. (2024) as described below.

Power Analysis Results

One of the objectives for this CSAS process was to investigate the ability to assess MPA conservation priority species metrics using existing DFO RV trawl survey data and seafloor imagery data. Predicting and measuring changes resulting from MPAs has posed a challenge for practitioners, in part because ecosystems are complex and can change in unanticipated ways, but also due to MPA design factors (boundaries, conservation objectives, monitoring programs) that leave little chance of meeting stated goals. Morris et al. (2024) evaluated

1. whether it is realistic to expect improvements in the MPA for four of the CO priority species, and
2. whether existing scientific surveys are capable of detecting changes in these taxa should they occur.

Three CO priority species were sampled in the DFO RV trawl surveys (Black Dogfish, Smooth Skate, and Northern Wolffish) and a fourth CO, sea pen taxa, were enumerated using seafloor imagery. Simulations indicate that the trawl surveys have very little chance of detecting change in the abundance of the three fish species examined, while seafloor imagery data had higher statistical power for sea pen taxa. This analysis highlights the inefficiencies of using RV trawl survey data to detect changes in three Laurentian Channel MPA CO priority species. In many cases, even quadrupling existing sampling intensity would not provide sufficient power to detect catch per unit effort (CPUE) declines of 50%.

Power analysis using simulations in this way can inform us on the likelihood of determining effectiveness of the MPA COs in achieving their goals. However, the fact that the MPA was established in an area of minimal fishing pressure ensures that the newly created fishery restrictions will not generate measurable improvements in its COs. While positive change in existing COs is unlikely to be induced by the MPA, or be detected if they occurred, this MPA could provide conservation benefits if COs and monitoring approaches were realigned to match the unique features, with measurable indicators, of this area represented by largely unimpacted sensitive benthic habitats. These recommendations offer monitoring program designers the opportunity to pivot to other more effective approaches or COs better aligned with monitoring programs that can generate usable results to inform decision making. For more information on this power analysis see Morris et al. (2024).

Sources of Uncertainty

MPA Size and Location

Research has shown that large MPAs are advantageous as they cover more unique habitats and contain multiple species, allowing a greater potential to protect ecosystems (Sheppard et al. 2012). Although a large MPA allows for a focus on large-scale ecological processes, it also comes with monitoring challenges (Stanley et al. 2015). The Laurentian Channel MPA is a relatively large offshore MPA which results in challenges in the creation of monitoring programs. The high cost of mobilizing sampling programs to areas offshore can be prohibitive and limit the scale and types of monitoring possible (Lewis et al. 2016). Additionally, the current limited access to vessels and vessel-time for the purpose of scientific monitoring in Canada is not a negligible issue. While multiple DFO surveys depend on Canadian Coast Guard vessels, it will be important to consider access to alternative suitable vessels. Application of this monitoring approach across all MPAs and MRs in the NL Region will provide opportunities for testing of survey methods and strategies in other areas as well as more capacity building to be able to implement them in the Laurentian channel MPA more effectively. Broad coordination (between and within DFO Regions, including with external partners) and discussions regarding prioritization of sampling sites and/or survey methods will be key when planning these surveys.

Reference Sites

With only minimal historical fishing effort in the area selected for protection, potential MPA-related improvements in COs resulting from the removal of fishing activities in the Laurentian Channel MPA are expected to be limited. Rather than focusing on MPA improvements relative to outside reference sites, a more appropriate/realistic approach would be to assess biodiversity-related status and trends in the MPA. Under this scenario, more resources could be allocated toward measuring the conditions within the MPA, with the use of Complementary Monitoring data from outside the boundary of the MPA to provide regional (larger scale) context to interpreting change within. For example, data at the scale of the NAFO Division (from RV survey) or from Fishery Logbooks would help scientists understand if potential measured declines in CO priority species seen within the MPA are the result of local issues or broader scale stressors (e.g., widespread declines in productivity due to climate change). Analysis of such information may only be triggered following measured declines within the Laurentian Channel MPA, provided suitable baseline data exist. Therefore, as discussed through this document, while we recommend the selection of monitoring site for interpretation of monitoring data on some COs, we do not advocate using these sites for assessing MPA effectiveness within a formal hypothesis testing framework.

Reporting

Little guidance has been provided on reporting requirements or reporting timelines for the Laurentian Channel MPA thus far. It is recommended that standardized annual reports be developed that include information on MPA-related surveys and data gathered each fiscal year. The use of reproducible reporting templates (e.g., R markdown files) could be produced by the NL Monitoring WG and updates fed into the templates to maintain a consistent reporting format. While the set-up of R markdown files for the different groups working on the monitoring program will require coordination and time investment, it will largely facilitate reporting in the long run. Dedicated support for database management and the automation of feeding data sources into these reproducible reports will also be essential. Specific contents of the reports will be based on the indicators described herein but the actual analyses to be completed will be dependent on available data. It is possible that, with sufficient data, a more in-depth report could be produced after several years (e.g., 5 years) that would aim to evaluate whether or not the current monitoring approach is providing valuable information on status and trends of the priority species and biodiversity in the area.

It is recommended that after the first five years of this monitoring approach are complete, a workshop be planned to provide both scientists and managers with an overview of lessons learned, highlighting successes and challenges associated with monitoring in the Laurentian Channel MPA. This would also be an ideal venue for providing advice and feedback for adaptive management of the MPA.

Long-Term Monitoring

Monitoring requires a long-term commitment to data collection (Noble-James et al. 2018). An important consideration is the continuity of data collection going forward. Ideally, once the program is started, there should be a consistent effort to maintain the Core Monitoring activities. The frequency of Core activities, as described above, may need to be adjusted based on resources available each year (i.e., financial and human resources). However, lack of consistency will negatively influence the program and careful planning should take into consideration expected limitations of those resources, without compromising scientific quality. The department will also continue to make every effort to collect samples and data using other research platforms of opportunity, and by collaborating with academic, non-government organizations, and citizen scientist researchers.

Another consideration for many long-term programs are challenges associated with climate change. For example, our current understanding of the ecosystem may no longer be valid in the future. The COs created during the MPA establishment process, which can be lengthy, may become outdated if species shift their distribution outside of the MPA boundaries. Similarly, other important species may move into the area and benefit from the MPAs protection measures. We can anticipate future stressors by using climate forecasts (e.g., low O_2, species shifts), however, building a monitoring program in a way that accounts for, and provides some value for, species replacement (e.g., biodiversity measures) may be the best approach. Maintaining a long-term monitoring approach that covers multiple marine conservation areas in the region will also help assess any changes at scales larger than just the MPA itself.

Statistical Power and Design

To ensure we have a scientifically robust monitoring program, it is recommended that various methods for increasing statistical power and improving experimental design be considered. Quinn and Keough (2002) devote an entire chapter of their book to experimental design and we emphasize some of their points in this section. Considerations regarding replication, independence, and ways to reduce unexplained variance are critical, and the use of power analyses can increase our confidence that an effect will be detected, if such an effect exists. Power analysis was previously highlighted in other parts of this document and is the focus of a Laurentian Channel case study by Morris et al. (2024). Power can be improved at the expense of increased Type 1 errors (detecting changes that do not exist), which is a common approach for environmental monitoring and impact assessments (Quinn and Keough 2002). Moreover, restricting statistical tests to detecting declines or improvements, but not both (i.e., 1 tailed statistical tests) can also enhance statistical power. Finally, inclusion of covariates can reduce unexplained variance and positively affect power.

Co-location of sampling (where possible) can reduce field costs and help leverage other datasets. For example, eDNA collections in the same place as UVP drops can help us understand the fine-scale taxonomic composition of the plankton community quantified by the UVP. Similarly, eDNA data can be ground-truthed by observations from baited and drop cameras as well as infauna sampling. In summary, there are multiple ways to increase statistical power and improve experimental design and these often require preliminary data to fully assess.

Seasonality

Ecosystems in temperate areas such as the Laurentian Channel experience pronounced seasonality in environmental conditions and faunal communities, particularly for migratory taxa, including CO priority species like Leatherback Sea Turtles and Porbeagle Sharks. As it is infeasible to track all indicators through all seasons, we recommend restricting Core Monitoring activities to late summer when most CO priority species occupy the Laurentian Channel MPA, and sea state conditions are most amenable to sampling. This will maximize the efficient use of vessel time and avoid adding confounding season-related factors to monitoring datasets. These data will be supplemented where possible with year-round autonomous data collection (e.g., remote sensing, moorings, etc.). Data sources from established external monitoring programs (i.e., Complementary Monitoring) will maintain existing seasonal timing. Some specific considerations on seasonality were provided in Warren et al. (in prep)[1] for sea pens (epifauna) and other benthic habitats.

Adaptive Management

As there are uncertainties and changes in any marine ecosystem – adaptive management is essential so that management strategies are progressively adjusted in response to new information (Government of Canada 2019). The monitoring program for the Laurentian Channel MPA will provide useful data for adaptive management of the MPA, triggering management action, or Targeted Research when management outcomes are not being achieved. Moreover, it may be necessary to modify the monitoring plan should new threats emerge. A future consideration for the NL Monitoring WG should be establishing those thresholds or trigger points for the monitoring indicators to provide clarity on when adaptive management measures should be considered. Ensuring ongoing dialogue with management on the status of not only the CO priority species, but also what scientific information might be required to inform potential adaptive management actions (e.g., adjustments to monitoring priorities or modification of regulatory intent) will also be key to the monitoring program success.

CONCLUSION

The scientific monitoring approach proposed here strategically supplements existing regional programs (Complementary Monitoring) with specific cost-effective MPA monitoring (Core Monitoring and Targeted Research) and will serve as a foundation that supports useful and scientifically robust monitoring of the Laurentian Channel MPA. We believe it can also be used as a template for other NL marine conservation areas, enabling the possibility of integrated regional conservation area assessments for common indicators. Many unknowns remain and this program will require re-evaluation and refinement (particularly after field trials) to ensure MPA objectives can be assessed over the long term.

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SOURCES OF INFORMATION

This Science Advisory Report is from the June 22–24, 2022, regional peer review on the Identification of Reference Sites and a Scientific Monitoring Approach for the Laurentian Channel Marine Protected Area. 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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