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Newfoundland and Labrador Region

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MONITORING INDICATORS, PROTOCOLS AND STRATEGIES FOR THE PROPOSED LAURENTIAN CHANNEL MARINE PROTECTED AREA (MPA)

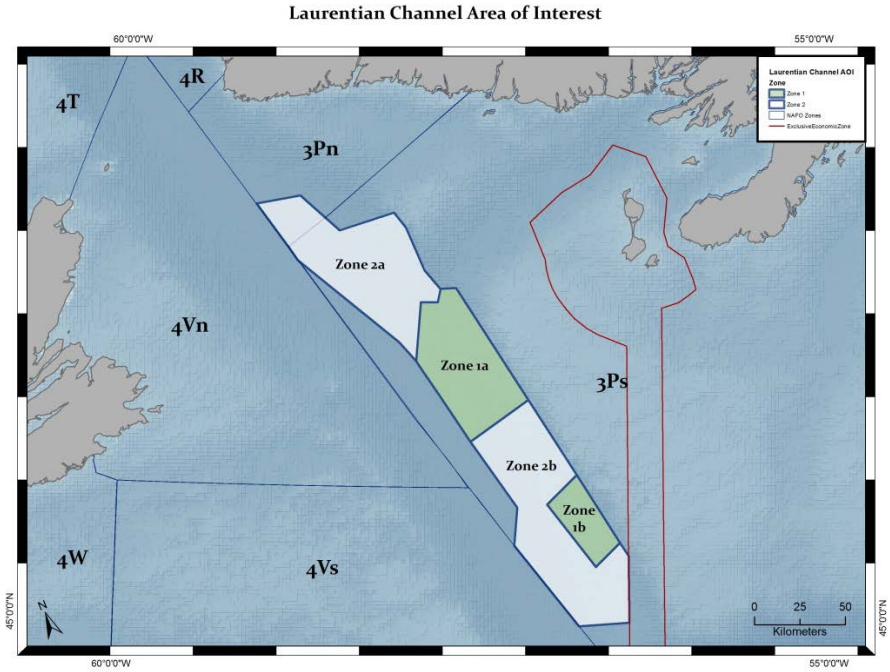

Figure 1. Map of the proposed Laurentian Channel Marine Protected Area (LC MPA), Newfoundland and Labrador Region.

Context:

In support of the Health of the Oceans Initiative, Fisheries and Oceans Canada (DFO) Science sector is required to provide advice on indicators, protocols and strategies for monitoring of conservation objectives for Marine Protected Areas (MPAs).

Monitoring of biological and ecological indicators (and their respective threats) is applicable to:

1) *Incorporation into broader MPA monitoring "plans" or "programs" (addressed by the DFO Oceans sector);*
2) *Tracking status, condition and trends to determine if MPAs are effective in achieving their Conservation Objectives;*
3) *Aiding managers in the review of MPA management plans to achieve conservation objectives; and*
4) *Reporting to Parliament and Canadians. Therefore, the selection of indicators and protocols for collection and analysis of data must be scientifically defensible.*

An Area of Interest (AOI), the proposed Laurentian Channel Marine Protected Area (LC MPA), is located off of the southwest coast of Newfoundland and Labrador, covers approximately 11,908 km^2. Upon designation, it will be the largest "no-take fisheries area" in Canada to date. It represents a strong commitment from multiple stakeholders, and is a significant accomplishment towards meeting the conservation goals outlined by the Convention of Biological Diversity (CBD)(decision IX/20).

This Science Advisory Report represents the June 24-26, 2014 meeting on Monitoring Indicators,

Protocols and Strategies for the Proposed Laurentian Channel Marine Protected Area (MPA). Additional publications from this meeting will be posted on the DFO Science Advisory Schedule as they become available.

SUMMARY

- The indicators, protocols and strategies proposed to monitor the LC MPA are consistent with the overarching goal of conserving biodiversity and the conservation objectives (CO) related to the species of interest. They are also influenced by the location and specific characteristics of the area.
- Three categories of indicators are proposed for monitoring the LC MPA:
  a) **Direct indicators,** which provide information on the status and trends of specific species of interest related to the COs;
  b) **Indirect indicators,** which provide information on biotic and abiotic components of the environment that can inform changes in the COs; and
  c) **Anthropogenic pressure** indicators, which can quantify human activities inside and outside of the LC MPA that may affect the COs.
- Direct indicators of the status of **sea pens** in the MPA include: biomass, abundance and density, size distribution, taxonomic diversity, and various geospatial measurements. These indices are expected to increase or be maintained relative to comparable areas in the post-MPA establishment.
- Direct indicators of the status of **Black Dogfish, Smooth Skate,** and **Northern Wolffish** in the MPA include: biomass, size distribution, frequency and occurrence. Trends in the various indices are expected to increase or be maintained relative to comparable areas in the post-MPA establishment. The indirect indicator, bycatch adjacent to the MPA, can inform on status of a species that is comparable to inside the region.
- Direct indicators of **Porbeagle** in the MPA include frequency and occurrence. These indices are expected to increase or be maintained relative to comparable areas in the post-MPA establishment. The indirect indicator, bycatch of shark species adjacent to the MPA, can inform on status of sharks that is comparable to inside the region.
- A direct indicator of the status of Leatherback Sea Turtle in the LC MPA is frequency and occurrence. Direct indicators of the reduction of harm to **Leatherback Sea Turtles** include: numbers of lethal encounters and non-lethal entanglements, and are expected to decrease relative to comparable areas post-MPA establishment. The indirect indicators, of Leatherbacks include the number and density of jellyfish aggregations within and adjacent to the MPA, can inform on status of this turtle species that is comparable to inside the region.
- **Indirect indicators**, (often representing environmental drivers) which are relevant to understanding the status, trends and anomalies of direct indicators, include several physical, chemical, biological, geological, and ecological parameters that reflect the general behaviour of an ecosystem.
- **Anthropogenic indicators**, which characterize human activities within and adjacent to the MPA which may influence the status and trends of direct indicators, include fishing, oil and gas activities, marine transportation, subsea cables, and research. Marine debris, pollution and accidental discharges are also included as anthropogenic indicators.

- Data for some proposed indicators can be obtained through existing protocols and strategies in the form of surveys/activities in the area: e.g., DFO multispecies, oceanographic, and species-specific surveys; while additional surveys and/or data collection will be required for other proposed indicators.
- Potential strategies for collecting monitoring data include: incorporating/extending and/or continuing existing DFO surveys (e.g., trawl, aerial, and acoustic surveys), Atlantic Zonal Monitoring Program (AZMP), Large Pelagic Shark Commercial Longline Survey, increasing at-sea Fishery Observer coverage, improving commercial fishers' logbook detail and accuracy; implementing local ecological knowledge projects, and developing partnerships in DFO and with other government and non-governmental organizations, industry, and academia.
- Research is required to address data gaps prior to, and during, MPA monitoring. Data gaps exist in the understanding of life histories of all species of interest in the LC MPA. In particular, baseline distributions and detailed taxonomy for corals and sponges are especially required.
- Recommendations for ensuring the quality of MPA monitoring activities include: developing adequate baselines, selecting suitable reference sites, long-term monitoring, understanding lag times, and designing effective protocols for data management, storage, and accessibility.
- Reference areas are required to adequately determine effectiveness of the MPA. Reference area selection should depend on similar habitat areas for species of interest outside the MPA. The power of any sampling design which detects changes between areas should also be evaluated.
- Information requirements for addressing the Research Objectives (ROs) are, in many cases, linked to indicators selected for monitoring the LC MPA, and thus included in the proposed monitoring framework.
- A scientific advisory committee is recommended to further develop the proposed protocols and strategies to inform the indicators as part of the overall monitoring program for the LC MPA. This committee would also be responsible for interpreting scientific results of the monitoring program, and providing oversight on advancing the ROs.

BACKGROUND

The proposed LC MPA is located off of the southwest coast of Newfoundland and Labrador (NAFO Division 3P), covers 11,908 km^2, and includes the water column, seabed, and subsoil to a depth of 5 m. Depths in the LC MPA vary from 86 to 435 m. The majority of the area is deeper than 150 m, with the central basin of the Laurentian Channel being the deepest. The northeast side of the LC MPA is shallowest, delimited by edges of the Burgeo (100-m depth) and St. Pierre (200-m depth) Banks.

The LC possesses a large undisturbed benthic habitat relative to adjacent offshore areas, as well as unique structural habitat offered by the interface of sea ice and open ocean. Important oceanographic processes, including moderate upwelling along offshore slopes and channels, support food webs in this area and enhance productivity year-round. Specifically, the proposed LC MPA contains large sea pen fields. It also contains Black Dogfish (*Centroscyllium fabricii*) and immature Smooth Skate (*Malacoraja senta*). The LC MPA is also a seasonal migration corridor for various marine mammals, large sharks (such as the Porbeagle Shark (*Lamna nasus*)) and sea turtles, (such as the Leatherback Sea Turtle (*Dermochelys coriacea))*.

LC MPA Goal and Objectives

The overarching goal of the proposed LC MPA is to **"*Conserve biodiversity in the Laurentian Channel MPA through protection of key species and habitats, ecosystem structure and function, and through scientific research*".**

As a means of identifying some key species in the LC MPA, six COs have been acknowledged as having significance within the LC MPA. The COs for the proposed LC MPA are:

1. Protect corals, particularly significant concentrations of **sea pens**, from harm due to human activities in the Laurentian Channel MPA.
2. Protect **Black Dogfish** from human induced mortality in the LC MPA.
3. Protect **Smooth Skate** from human induced mortality in the LC MPA.
4. Protect **Porbeagle** from harm and human induced mortality in the LC MPA.
5. Promote the survival and recovery of **Northern Wolffish** by minimizing risk of harm from human activities in the Laurentian Channel MPA.
6. Promote the survival and recovery of **Leatherback Sea Turtles** by minimizing risk of harm from human activities in the Laurentian Channel MPA.

ROs have also been identified for the LC MPA. While having no regulatory implications within the context of the MPA Management Plan, they are based on a recognition that several important components of the LC MPA ecosystem merit some level of conservation, but baseline data is needed prior to these considerations.

The ROs for the proposed LC MPA are:

1. Advance the understanding of the distribution, biodiversity, health and integrity of **cold water corals and sponges** in the Laurentian Channel MPA.
2. Identify important as well as **sensitive marine benthic areas and habitats** in the Laurentian Channel MPA by supporting the conduct of scientific surveys, mapping and habitat association studies.
3. Advance the understanding of **plankton variability** in the area and locations of enhanced productivity supporting benthos, fish and cetaceans.
4. Advance the understanding of **cetacean** distribution, abundance and migration in the Laurentian Channel MPA.
5. Advance the understanding of the spatial and temporal distribution of **sharks** and shark bycatch, and quantify shark bycatch across all fisheries for species frequenting the Laurentian Channel MPA.
6. Advance scientific studies contributing to the identification and understanding of significant or critical habitat for **SARA-listed species** found in the Laurentian Channel MPA.

Identified threats to LC MPA COs

Several key activities/stressors identified for species of interest in the LC MPA include: habitat destruction or disruption (by bottom trawling; oil and gas exploratory drilling; seismic surveys; and accidental oil spills), biomass removal (bycatch from fishing activities such as commercial bottom trawling and longline retrieval), and ship strikes (with sea turtles)), pollution

(anthropogenic debris and marine pollution), and increased sedimentation (oil and gas exploratory drilling).

Other potential threats (e.g., aquatic invasive species) to species of interest in the LC MPA are linked to environmental changes (e.g., climate change, ocean temperature and circulation) and alteration of trophic conditions (e.g., predator and prey relationships and changes in population structure).

LC MPA Management

MPA regulatory COs are part of the site-specific regulations that will be published in the *Canada Gazette* prior to MPA designation. The Regulatory Intent of the LC MPA will focus on management of human activities to achieve these objectives, resulting mainly in a “no-take” fishing zone with additional spatial and temporal limitations on various industries and other activities (e.g., petroleum exploration and production, ship ballast water exchange) occurring within MPA boundaries.

LC MPA Monitoring

Monitoring is an essential component of managing an MPA. It allows for the assessment of the effectiveness of management activities, and verification that the MPA COs and the overarching goal are being achieved.

It is the role of DFO Science to provide a framework on which this monitoring program can be based. The framework comprises monitoring indicators, protocols, and strategies specific to the overarching goal and the COs of the MPA, and provides recommendations on biological and ecological monitoring, including anthropogenic pressure indicators. The science-based framework does not include socio-economic considerations – although they are an important component of the overall monitoring program to be developed by MPA managers.

Ultimately, monitoring the LC MPA will enable managers to learn, understand, and adapt site-specific regulations and policies to changes in the ecosystem over time. Unlike for management of fisheries in general, MPAs rarely have quick-response variables upon which short-term decision-making can be based. An MPA is designed as a long-term measure that is adaptable through modifications in its design (e.g., adjustment of its boundaries, internal zoning, and/or designation of permitted activities (and their license conditions)). In the most extreme case, a decision to remove the protected status of a given MPA may also occur if an MPA fails to progress with its objectives.

ANALYSIS

Indicators proposed for monitoring the LC MPA can be grouped into three categories:

1. **Direct indicators** which provide information on status and trends of species of interest related to the COs;
2. **Indirect indicators** which provide information on biotic and abiotic components of the environment that can inform changes in the COs; and
3. **Anthropogenic pressure indicators** which can assess human activities inside and outside the LC MPA that may affect status and trends of the COs.

Protocols (e.g., equipment, techniques) are identified to guide the collection of data for direct, indirect, and anthropogenic pressure indicators for the LC MPA. Potential strategies to undertake these activities are also key aspects of a potential monitoring program.

Indicators, protocols, and strategies that can be used opportunistically as a basis to inform the ROs are also identified.

Monitoring Indicators (Species) – Direct and Indirect

Each species of interest has potential indicators that should be monitored to inform status and trends of the COs (and ROs, where applicable). These parameters are essential to determine whether change is occurring with respect to the species of interest. It is hypothesized that regulation of human activities within the MPA (e.g., fisheries, oil and gas exploration/production) will induce beneficial changes to properties of the COs (e.g., production of biomass, stability over time) in the long term. Specific CO indicator-related hypotheses follow from this overarching hypothesis, and are essential in developing appropriate sampling designs.

It is suggested for all biological indicators that monitoring should occur both inside the MPA and outside in an adjacent reference area(s), with appropriate reference areas to be determined based on input from a scientific steering committee.

Sea Pens

Direct indicators of the status of sea pens in the LC MPA include:

- Biomass
- Abundance and density
- Size distribution
- Geospatial indicators (including patch stability, connectivity)
- Taxonomic diversity and richness

By reducing the risk of human-induced mortality of sea pens inside the MPA, these indices are expected to increase or be maintained in the LC MPA relative to comparable areas outside the MPA. Given the life histories of sea pens, the time-lag of response of these indices can be expected to be greater than 10 years.

Black Dogfish, Smooth Skate, and Northern Wolffish

Direct indicators of the status of Black Dogfish, Smooth Skate, and Northern Wolffish in the LC MPA include:

- Biomass
- Occurrence
- Frequency
- Size distribution

By reducing the risk of human-induced mortality inside the MPA, these indices are expected to increase or be maintained in the LC MPA relative to comparable areas outside the MPA. Given what is known of the life histories of these species, the time-lag of response of these indices can be expected to be one to three generation time(s), depending on the species.

Indirect indicators of the status of Black Dogfish, Smooth Skate, and Northern Wolffish in the LC MPA include:

- Commercial bycatch of these species adjacent to (i.e., outside) the MPA.

These data can inform on the comparable status of each species in the general area of the MPA. It can also indicate threats to these species from fishing activities in close proximity to the MPA or “fishing the line” if such behavior occurs following establishment of this MPA.

Porbeagle Shark

Porbeagle shark is a highly migratory species that moves through the LC MPA. However, further research is required to determine the extent and utilization of the LC MPA by this species.

Direct indicator of the status of Porbeagle Shark in the LC MPA:

- Occurrence
- Frequency

By reducing the risk of human-induced mortality due to fishing such as the longline, gillnet and bottom trawl fisheries inside the MPA, these indices are expected to increase or be maintained in the LC MPA.

Indirect indicators of the overall status of the Porbeagle Shark population include:

- Commercial shark bycatch in the area adjacent to (i.e., outside) the MPA.

These data can also inform the research objectives identified for this MPA.

Leatherback Sea Turtle

The Leatherback Sea Turtle is another migratory species that uses the LC MPA as a transitory route to feeding areas. As such, baseline values of several potential indicators, (e.g., abundance), are not possible. However, using adaptive management, incoming data will inform MPA managers over time regarding any additional indicators or necessary alterations to the program.

Direct indicators of the status of Leatherback Sea Turtle in the LC MPA include:

- Occurrence
- Frequency
- Numbers of lethal encounters and non-lethal entanglements.

Indirect indicators of the overall status of Leatherback Sea Turtle include:

- Size and location of prey species aggregations (e.g. jellyfish) inside and outside the MPA; although the specific methods of measurement remain undetermined.

Monitoring Indicators (Ecosystem) – Indirect

Indirect indicators often represent ecosystem drivers that are relevant to understanding status, trends, and anomalies of the direct indicators, and include several physical, chemical, biological, geological, and ecological parameters. It is suggested that monitoring should occur for all ecosystem indicators both inside and outside the MPA (i.e., in adjacent reference area(s) that should be determined based on further advice from the scientific steering committee). These may be helpful to further understanding of the ecosystem structure and function, and can be used as a tool to evaluate outside factors that can affect species of interest and the ecosystem. Without this critical information, overall validity of any potential monitoring program will be weakened. Both trends and anomalies in the data should be analyzed.

Oceanographic Indicators

Oceanographic conditions vary widely from season to season and from year to year, affecting temperatures, currents, and upwelling patterns that in turn affect marine life. Therefore, monitoring these conditions and their variability at local and regional scales is essential to assessing their impacts on the MPA. Oceanographic indicators can assist in explaining

observed changes of direct indicators (i.e., status and trends) for species of interest (e.g., changing water temperatures to levels within or outside of a species' tolerance range).

Indirect physical and biological oceanographic indicators include:

- Oceanographic properties (such as temperature, salinity, oxygen) of the water column, and in areas adjacent to the MPA
- Bottom oceanographic properties near the seafloor inside and in adjacent waters to the MPA
- Water mass movements
- Sea surface temperature
- Wave height
- Extent of ice cover inside and in adjacent to the MPA.
- Speed of sound, as a proxy for seawater pH (i.e., level of acidity)

Ecosystem Indicators

Ecosystem indicators (e.g., trophic interactions and cascades) are important because they quantify processes that may be occurring on a greater scale than the habitats of single species. These indicators are usually assessed at the scale of the larger system: i.e., both inside the MPA and in adjacent reference area(s).

Ecosystem indicators include:

- Animal/plant/bacterial community composition
- Infaunal and epifaunal composition
- Species distribution
- Trophic structure
- Energy flows
- Biomass of predator/prey species
- Chlorophyll
- Primary production
- Zooplankton variability

Habitat Characterization Indicators

Habitat characterization is an important component of any monitoring program, because it indicates habitat utilization and availability for the species of interest. Coupled with the ecosystem indicators, habitat characterization also enhances understanding of the overall ecology of the area.

Habitat indicators include:

- Habitat physical parameters (e.g., localized seawater temperature and salinity, presence/absence of boulders, rock crevices, seaweeds) and prey items for species of interest; seafloor physiography (e.g. slope, rugosity)
- Sediment composition (e.g., sediment grain size) and chemistry
- Natural gas seeps and pockmarks
- Nutrient flux (i.e., sediment and water)

Other Indicators

- Underwater sound (i.e., natural and anthropogenic)

Anthropogenic Stressors Indicators

The underlying principal of six COs for the LC MPA is the protection of the various species of interest, and their habitats from human harm or risk. Measuring the impact of anthropogenic stressors to each species of interest in areas adjacent to the MPA will assist in determining if adopted management measures are effective in reducing their harm, and also if there are ancillary MPA effects on the adjacent ecosystem that should be considered.

While scientific advice does not recommend socio-economic indicators, certain anthropogenic stressor indicators provide critical information on biological and ecological components of the system, and can be used to understand changes in direct and indirect indicators.

Anthropogenic stressors should be described qualitatively and quantitatively in both space and time to include:

- Regulatory compliance inside the MPA (regarding commercial fishing, oil and gas activities, vessel ballast water, etc.)
- Commercial fishing effort (i.e., bycatch and discards of species of interest and their prey, alteration/destruction of habitat by particular fishing gears) adjacent to the MPA
- Commercial infrastructure development activities
- Vessel ballast water exchanges
- Oil spills and longer-term leaks from marine vessels
- Oil and gas exploration/production discharges
- Seismic surveys
- Anthropogenic debris and other marine pollution inside and adjacent to the MPA
- Ship strikes (i.e., on marine mammals, leatherback turtles) in and adjacent to the MPA
- Anthropogenic sound
- Vessel transits (other than pleasure craft) by mercantile, surface naval, and commercial fishing vessels steaming to fishing grounds.
- Biomass removal by research surveys conducted in the MPA
- Seabed area swept by bottom mobile research and monitoring gear (i.e., total and subdivided by seabed habitat type) in the MPA

Monitoring Protocols and Strategies

Recommended protocols and strategies for collecting data for proposed direct and indirect indicators span a number of existing and new monitoring and research programs. Most favourably, strategies for collecting indicator data would be incorporated into existing DFO monitoring activities where possible (e.g., DFO research vessel multispecies and oceanographic surveys, aerial surveys, benthic surveys, and tagging and other monitoring and research activities), while following existing standardized protocols for those undertakings. This approach would allow for cost-effective research to capitalize on expertise and equipment currently deployed by DFO. Additionally, other monitoring programs under the leadership of DFO (i.e., at-sea fisheries observers, commercial fishers' logbooks, and local ecological knowledge) may be incorporated or improved to meet monitoring requirements. Finally, development of partnerships in DFO and among other government and non-governmental organizations,

industry, and academia can provide opportunities for collaborative monitoring where interests overlap.

Unlike other MPAs in the Newfoundland and Labrador Region, the LC MPA has limited potential to include the collection of indicator data by non-DFO staff and coastal communities, due to its location offshore and higher associated costs and methods of obtaining data.

Where collaborative or contractual agreements are incorporated to collect monitoring data, it is important that the training of individuals who will collect the data occurs to maintain a scientifically-acceptable level of data quality. Potential problems that would interfere with this strategy include changes in long-term funding, and changes in personnel collecting these important data.

Additionally, where monitoring programs rely on existing databases updated by non-DFO organizations, it is essential that the usability and caveats of that information be understood by secondary users (i.e., DFO scientists and MPA managers).

Direct (Species) Indicator Monitoring Protocols and Strategies

DFO multispecies trawl surveys

Trawl surveys are fishery-independent, multispecies research programs conducted by DFO to assess commercial and non-commercial fish, shellfish and other animals in Canadian waters. In addition, information on the distribution and abundance of corals and sponges has also been collected during these surveys in recent years. Surveys are conducted in NAFO Division 3P in April-May every year, using a stratified random sampling design since 1972. A Campelen 1800 Shrimp Trawl has been used in these surveys since spring 1996; prior to this, an Engel 145 High-Lift Otter Trawl was used. In future, it is recommended that enhanced sampling protocols for all fish species of interest be adopted by future multispecies surveys in NAFO Division 3P to obtain at a minimum length, weight, and sex data (when possible for some species); and research on the species of interest (including Black Dogfish, Smooth Skate, Northern Wolffish and Sea Pens), thereby enabling future understanding of their important life history traits by MPA managers.

Large pelagic shark longline survey

Fishery-independent large pelagic longline surveys have been conducted to provide information on the status of population health, abundance estimates, and habitat use (e.g., mating grounds, nursery areas) of Porbeagles and other large sharks. There are no such planned in the near-term in the NL or Maritimes Regions. However, future shark-directed longline surveys in the LC MPA could be established to coincide with similar projects occurring in the Maritimes Region, and on the other side of the LC to obtain a better understanding of the local Porbeagle and large shark population. It is recommended that this survey be conducted every 5 years after a baseline of Porbeagle abundance indices is established in the LC MPA, in addition to other indicators for shark COs and ROs.

Acoustic telemetry

Tagging in conjunction with installation of acoustic receivers can be useful to inform MPA managers and scientists about migration patterns of individual Wolffish, Porbeagles and other sharks, and Leatherback Turtles in the LC MPA. Migration patterns and habitat use (e.g., Porbeagle mating grounds, Black Dogfish pupping grounds, Wolffish nursery areas) of tagged animals equipped with acoustic tags can be tracked with acoustic receivers installed on the seafloor to record signals as they swim near a receiver. This technique has been successfully used with a variety of species in Atlantic Canada to date including: large sharks,

Atlantic Salmon, Atlantic Cod, and Wolffish, and was proposed for monitoring cetacean presence and anthropogenic sound in the nearby Gully MPA.

Satellite tags (pop-up archival transmission tags [PATs])

Satellite tags deployed on migratory species (e.g., large pelagic sharks, sea turtles) are an appropriate tool to monitor the frequency and occurrence of individuals known to inhabit/transit through the LC MPA. To track movement patterns, individual sharks can be equipped with satellite tags that send a signal when they surface. Other data from tagging include depth, water temperature, and light intensity. This method could be an ongoing component of a monitoring program (with new individuals tagged every year) to learn about frequency, occurrence, and residency of shark and/or turtle species of interest.

Turtle (and cetacean) Aerial Surveys

Large-scale aerial surveys of offshore waters would be a useful component of a larger strategy for monitoring occurrence of marine megafauna. These surveys could be conducted in collaboration with Maritimes Region to benefit both regions, given the potential distribution of these species. A Twin Otter aircraft is typically fitted with bubble windows and high-speed video cameras to record megafauna as it flies over the survey area at reduced speeds. This survey represents the most effective method to monitor marine megafauna in the LC MPA. It could be conducted every 5 years for updates and support of other monitoring and research efforts such as aligning it with the planned 10-year interval for the Atlantic cetacean surveys proposed by DFO's Center of Expertise in Marine Mammalogy (CEMAM).

Coral surveys

Benthic mapping studies are conducted to characterize the biotic and abiotic components of benthic communities in a specific area. As some types of sampling protocols can be destructive to sensitive benthic habitats (e.g., corals, sponges) alternative methods of data collection are required. For example, multibeam sonar data and related acoustic backscatter can be analyzed to produce a number of data products including backscatter mosaics, slope maps, curvature, and aspect to create seafloor maps.

Furthermore, sampling protocols known as "soft-touch" methods can be used to study status and structure of coral and sponge communities, and other sensitive benthic habitats for these indicators: abundance, distribution, species richness, and biodiversity. This equipment has a small footprint when taking grab samples, and thus is suitable for making time series observations at a given location, while offering an alternative to more destructive methods.

Remotely Operated Vehicles (ROVs): ROVs allow controlled sampling and detailed observation of small-scale deep-water habitats (e.g., coral and sponge areas) with the ability to collect samples when necessary. These can be equipped with depth sensors, compass, sub-bottom profilers, multibeam sonars, and laser beams which provide a scale for measuring the size of sampled bottom areas.

Recruitment Trays: Recruitment trays can be deployed with cameras or ROVs and to determine rate of recovery/change in selected coral and other sensitive habitats.

Sidescan sonar: Based on acoustic class and sediment type analysis, a physical habitat map (i.e., texture and substrate characteristics) can be produced, which is important for designing subsequent biological surveys.

Benthic grabs (box core): These grabs sample infaunal and epifaunal organisms. For example, a box core is used as a complimentary tool in many types of marine surveys to collect sediment samples and biota at the sea-floor, which are then used to determine habitat types, utilization, and sediment quality for species of interest.

Towed cameras: Underwater video recording units are useful for benthic surveys on the scale of kilometers. Towcams provide continuous imagery to discern major habitat features, and are readily used over any type of seabed, as long as the bottom relief is relatively low and water is not turbid.

Local Ecological Knowledge (LEK)

Collection of LEK is of great value in monitoring programs, depending on the type of indicator being informed, and how information is collected and used. LEK is especially useful in generating baseline information in data-poor situations, and can be used conjointly with scientific knowledge to provide a larger picture. For the LC MPA, LEK has the potential to provide information where no at-sea fisheries observer data exists on shark, fish, and turtle species of interest. LEK could provide information on occurrences of (discarded) MPA species of interest, but at-sea observer coverage of commercial fisheries is the sole source of reliable data on discards and total catch by species.

Indirect (Environmental and Ecosystem) Indicator Monitoring Protocols and Strategies

Atlantic Zone Monitoring Program (AZMP)

AZMP provides regional and zonal monitoring of a broad suite of biological, chemical, and physical oceanographic variables. In the proposed LC MPA, the St. Pierre Bank, Cabot Strait and Louisbourg lines of the AZMP can provide the necessary oceanographic information for indirect indicators relevant to physical and biological oceanography. Although sampling is not simultaneous, present protocols probably provide sufficient coverage for informing indirect indicators. The existing oceanographic monitoring program has been conducted aboard DFO research vessels in spring and fall every year since 1998, although the St. Pierre line commenced in 2010. Standard AZMP stations regularly collect data on temperature, salinity, pH, nutrients, and phytoplankton (among others). In fall 2014, calcium carbonate chemistry will also be collected and analyzed, thereby providing relevant environmental information for the sea pen CO and the sensitive benthic habitats' RO. Furthermore, during the survey, profilers obtain current data through continuous use of an acoustic Doppler current profiler (ADCP). Zooplankton collection, identification, and enumeration can also be conducted as a component of ongoing AZMP surveys.

Satellite (SST, chlorophyll, ice)

Satellite information can be compiled to provide sea surface temperature (SST), chlorophyll-a, and sea ice distribution data, which will be useful in interpreting other monitoring results. These data can be obtained through DFO, Environment Canada, and National Oceanic and Atmospheric Administration (among other sources).

Ocean observatory station/acoustic moorings

Ocean observatories and moorings are valuable tools to collect real-time oceanographic conditions. Sensors on ocean observatories can include conductivity, temperature, and depth sensors (CTDs), ADCPs, hydrophones (acoustic monitoring), fluorometers, and dissolved oxygen probes. These can be anchored and configured with a variety of sensor payloads to collect data on an ongoing basis. Similarly, autonomous acoustic recorders can be installed with bottom-mounted anchoring systems to record soundings of anthropogenic activities, and natural sound sources (e.g., weather, cetaceans). Several moorings throughout this MPA would yield better data coverage, and accommodate the variable sound propagation previously observed in the LC.

Anthropogenic Pressure Indicator Monitoring Protocols and Strategies

At-sea fisheries observers

Professional at-sea fisheries observers constitute the sole source of reliable, fishery-independent data on commercial discards and total catch by species, and are also trained in standardized scientific sampling protocols. Given the ongoing impact of bycatch mortality on LC MPA species of interest, at-sea observer coverage should be increased (and also initiated in select fisheries with no current coverage) on specific fisheries that catch significant numbers of species of interest (e.g., Swordfish and Tuna longline and groundfish gillnet fisheries with Porbeagle bycatch, trawl fisheries with either Black Dogfish or Smooth Skate bycatch).

Vessel Monitoring System (VMS)

VMS data are collected on a continual basis by DFO, and could be accessed by MPA managers to determine the level of vessel activity in the LC MPA and adjacent waters before and after the establishment of this MPA. The schedule of vessels required to have a VMS is available through DFO Fisheries Management (FM), and can change depending on vessel size and type of fishery. In Canada, data has been collected since 2004 when there were less than1500 vessels equipped with VMS. As of 2012, more than 2800 Canadian vessels were equipped with VMS. Information on vessels that do not carry a VMS unit could be collected via fishers' organizations and logbooks.

Commercial landings and logbook data

This information is collected by DFO FM as part of fishing license requirements. The main limitations of fishers' logbook data are:

a) Accuracy of information reported by fishers, which differs depending on whether an at-sea fisheries observer is on board;

b) Discarded species are never recorded;

c) Some landings of bycatch are not recorded by species (e.g., "sharks", "wolffish/catfish"); and

d) Total catch per gear retrieval is not reported, because discarded individuals of even target species are never recorded.

Specific projects could be designed to collect missing details or complimentary information on fishing trips; but only with approval by the fishing industry.

Databases of other relevant human activities and infrastructure

Information is collected by various agencies that are also members of the LC Advisory Committee, including Canadian Hydrographic Service (CHS) and the Canada-Newfoundland and Labrador and Canada-Nova Scotia Offshore Petroleum Boards (C-NLOPB and C-NSOPB, respectively), and can be requested by MPA managers to provide data on the development of infrastructure in the LC MPA (e.g., oil and gas exploration/production, submarine cable laying/occurrence). Human activities that could potentially affect resources in the MPA should be accurately monitored in case events occur that could directly or indirectly impact the MPA. This requires updated information from partners within DFO (e.g., Fisheries Protection Program), and among other governmental organizations (e.g., Transport Canada, NL provincial government), which could be input into the overall data management system.

Vessel ballast water reports

Reports on ballast water exchange must be submitted by vessels and pleasure crafts as part of the Ballast Water Management Plan (see the *Canada Shipping Act*). A request to Transport

Canada may yield this information, as they are a stakeholder on the LC Advisory Committee. Information on small-scale oil spills are also collected by Transport Canada, and should be acquired by Oceans managers.

Research on sea turtle-human interactions

A database on sea turtle entanglements in fishing gear, ingestion of marine debris, and ship strikes can be developed in conjunction with DFO, the fishing industry, NGOs, and academia. Voluntary observers from the Canadian Wildlife Service and the Sea Watch Program represent other potential sources of information on sea turtles in and adjacent to the LC MPA. Since there are currently no ongoing programs for this research, the logistics and feasibility of acquiring this information should be explored by the LC Advisory and/or Scientific Steering Committees.

Identification of Reference Areas

A critical component of testing environmental hypotheses is a “control” or reference site as a comparison, to demonstrate if any change has occurred in the area of interest as a result of treatment or manipulation. Appropriate selection and use of a reference area in the assessment of MPAs provide scientific defensibility for any monitoring program. Reference area(s) should be selected to represent habitat, species composition, and conditions that are similar to the treatment area (i.e., inside the MPA). For the LC MPA, delineation of such reference area(s) can be complex due to its size and diversity of species of interest. Determination of reference site(s) will require careful planning in conjunction with the Science Steering Committee, to ensure that the number of sampling sites, both reference and treatment sites, has a scientifically acceptable level of statistical power.

Monitoring Planning

A Scientific Advisory Committee is recommended to further development of proposed protocols and strategies, and to assess the logistic feasibility of incorporating them into the overall LC MPA monitoring program, which will use internal and external sources. This committee would also be responsible for interpreting scientific results of the MPA monitoring program, and the provision of oversight on progressing ROs.

Sources of Uncertainty

Sources of uncertainty always exist when attempting to understand the functioning of a complex marine ecosystem, as well as understanding potential impacts that anthropogenic activities may have on an ecosystem’s natural processes and variability. For monitoring the LC MPA, it is uncertain whether proposed indicators and their respective protocols and strategies will be effective in detecting quantifiable change(s) beyond natural variability in the ecosystem’s structure and function, in context of the conservation objectives.

Knowledge Gaps

There are life history gaps for all species of interest in the LC MPA, as well as gaps in the knowledge related to overall functioning of the LC ecosystem. Research is required to address data gaps prior to designation and during MPA monitoring.

Corals (including sea pens) and sponges constitute a relatively new area of study for cold water marine ecosystems. Although research efforts in recent years aimed to identify areas of cold water coral concentrations in the Northwest Atlantic and have included life history studies, baselines related to occurrence and distribution (including abundance and diversity) of these corals require further work. Information on growth rates is a gap that would be especially useful

for monitoring status and trends of corals in the LC MPA, and in determining how quickly coral populations in this MPA would be expected to respond to its establishment.

Information currently collected for fish species of interest is severely limited by DFO research vessel coverage in the Laurentian Channel (i.e., especially in deep water), and a lack of commercial catch and discard data. Longevity, among other aspects of Black Dogfish is unknown, as larger animals are not generally caught. The detailed life history and trophic role of Smooth Skate remain unknown. Northern Wolffish is designated as a Species at Risk under Canada's *Species at Risk Act*; therefore, protocols involving their collection and associated mortality due to discarding as bycatch aboard DFO surveys and commercial fishing vessels requires caution.

Migratory species of interest (i.e., Porbeagle Sharks and Leatherback Sea Turtles) are not well documented in the LC MPA, and have only recently been included in targeted research and survey activities by DFO NL Region. Consequently, knowledge gaps exist surrounding the most basic understanding of their spatial and temporal distribution in this MPA. Similarly, gaps exist in understanding the specific, and potentially critical, role(s) that this area may have in their life histories.

Research objectives were identified early in the developmental phase of the LC MPA, because several important ecosystem components merit conservation, but lack baseline data to be considered in the regulatory intent of this MPA. ROs promote focused scientific research that could lead to enhanced knowledge of these components and, ultimately, to modified/new COs through adaptive management (if required).

Finally, there is an existing gap in the knowledge of linkages between LC MPA species groups, impacts of physical environmental parameters on local biological communities, and the overall role of the Laurentian Channel ecosystem.

CONCLUSIONS AND ADVICE

Three categories of indicators are proposed for monitoring the LC MPA:

a) Direct indicators, which provide information on status and trends of species of interest related to the COs;

b) Indirect indicators, which will provide information on biotic and abiotic components of the environment that can help account for changes in the COs; and

c) Anthropogenic pressure indicators, which can assess human activities that may affect the COs inside and outside of (i.e., adjacent to) the LC MPA.

Overall, 14 direct indicators, 24 indirect indicators and 13 anthropogenic indicators have been identified to monitor the LC MPA (Appendices I and II). Analysis of status and trends of these indicators will provide MPA managers with the necessary information to assess effects resulting from establishment of the LC MPA. They will also allow assessment of the direct effects of management measures enacted through establishing this MPA, in context of the overall variation or changes within the ecosystem. Assessment of effects of the MPA on the COs requires appropriate selection and use of control/reference areas; to be determined in conjunction with a Scientific Steering Committee. These areas, outside of the MPA, should be selected to represent habitat, species, assemblages and conditions similar to the treatment area (i.e., inside the MPA), and to evaluate the abilities of monitoring protocols and strategies to detect changes between these areas as compared to natural variability within the MPA. Hypothesis-driven assessments of MPAs provide scientific defensibility for any monitoring program.

Strategies for the collection of indicator data include incorporating and/or extending the existing DFO monitoring activities, where possible (e.g., DFO research vessel multispecies and oceanographic surveys; aerial surveys; benthic surveys; and tagging and other monitoring and research activities) and following existing standardized protocols for those undertakings (Appendix II). However, where collaborative or contractual agreements are necessary to acquire indicator data, it is important that data collection protocols are standardized if DFO-lead surveys are not used – thus requiring a level of instruction and/or training to those collecting the data that will provide a reasonable level of data quality assurance in the monitoring program.

There are knowledge gaps in the understanding of specific aspects of the life histories for the species of interest, as well as gaps related to the overall functioning of the Laurentian Channel ecosystem. Baseline distributions and detailed taxonomy for corals and sponges are particularly limited. Research is required to address data deficiencies prior to and during MPA monitoring.

A scientific advisory committee is necessary to further the development of the proposed protocols and strategies, and to assess the logistic feasibility of incorporating these into the overall monitoring program for the LC MPA. This committee would also be responsible for interpreting the scientific results of the monitoring program and the provision of oversight on advancing Research Objectives.

It is recommended that once MPA monitoring has been initiated, long-term maintenance of the program be established given that most indicators are slow to respond and short-term changes may be difficult to detect.

OTHER CONSIDERATIONS

Considerations for enhancing the value of MPA monitoring activities include ensuring adequate baselines; understanding lag times; and establishing protocols for data management, storage, and accessibility. Coordination of monitoring with similar activities in Departmental programs is also recommended.

For many of the proposed indicators, well-established baseline status and trends either do not exist, or have not been developed for the AOI. In these cases, existing information on marine resources from sources including studies conducted by local, provincial and federal agencies, academic institutions and from peer-reviewed scientific literature may be available to inform pre-monitoring states.

As populations vary in their ability to grow, lag times are an important consideration in MPA monitoring. The maximum rate at which a population can increase (when resources are unlimited and environmental conditions are ideal) is dependent on the species' reproductive/lifespan (how long an individual is capable of reproducing and at what age/size); the frequency of reproduction (how often an individual can reproduce); fecundity (number of gametes produced) or production rates (how many offspring are born each time); and survival rate (how many offspring survive to reproductive age). As such, the length of time required for the various species to demonstrate changes should be carefully considered in assessing monitoring results to determine MPA success against its objectives.

Development of a data management system is an integral component to a monitoring program, as it will ensure data integrity and access. Data management will be necessary to compile historic information, for completing risk assessments, and for current and future monitoring activities.

Coordination of MPA monitoring with other existing departmental monitoring strategies (i.e. fisheries management, marine mammal, species at risk monitoring) is suggested for enhanced efficiency and cost-effectiveness in monitoring.

It should be noted that technologies and approaches to research are constantly evolving. Therefore, the protocols and strategies proposed to monitor the LC MPA are representative of the best available knowledge at present, and may change over time.

Finally, implementing an MPA monitoring program requires long term commitments to obtain a useful, scientifically defensible time-series.

SOURCES OF INFORMATION

This Science Advisory Report is from the June 24-26, 2014 meeting on Monitoring Indicators, Protocols and Strategies for the Proposed Laurentian Channel Marine Protected Area (MPA). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

APPENDIX I

Table 1a. Summary of Proposed Direct Indicators in the LC MPA – Overarching Goal

Direct Indicator	Hypothesis
Biodiversity	Biodiversity will be maintained or increased within the LC MPA relative to the reference areas

Table 1b. Summary of Proposed Direct Indicators in the LC MPA – Sea pens

Direct Indicator	Hypothesis
Biomass	Biomass is expected to increase or be maintained with the reduction of harm inside the MPA as compared relative to a reference areas
Size distribution	The size range of sea pens should increase or be maintained especially larger individuals by reducing the risk of human induced mortality inside the MPA and outside
Geospatial indicators	Patch stability, connectivity and area should increase or be maintained with the reduction of harm due to human activities as compared to outside areas of similar structure
Taxonomic diversity and richness	Taxonomic diversity and richness should increase or be maintained as a result of reduced disturbances to population compared to reference area
Abundance and density	Number of individuals should increase or be maintained relative to reference areas

Table 1c. Summary of Proposed Direct Indicators in the LC MPA – Black Dogfish

Direct Indicator	Hypothesis
Biomass	Biomass is expected to increase or be maintained with the reduction of harm inside the MPA relative to a reference area
Size distribution	Size distribution should increase or be maintained with reduction in harm, in particular pups, and larger individuals relative to a reference area
Abundance	Number of individuals should increase or be maintained relative to reference areas
Mean life span	The mean life span should be expected to increase or be maintained if there is a reduction in harm to black dogfish from human activities

Table 1d. Summary of Proposed Direct Indicators in the LC MPA – Smooth Skate

Direct Indicator	Hypothesis
Biomass	Protection measures should increase or maintain biomass of smooth skate within the MPA relative to the reference areas
Size distribution	Proportions of YOY and reproductive females should increase or be maintained from protection of the MPA relative to reference areas
Abundance	Number of individuals should increase or be maintained relative to reference areas
Mean life span	The mean life span should increase or maintained if there is a reduction in harm to smooth skate from fishing

Table 1e. Summary of Proposed Direct Indicators in the LC MPA – Porbeagle Shark

Direct Indicator	Hypothesis
Lethal encounters with fishing gear or vessels, immediately non-lethal entanglements	There will be fewer mortalities resulting from human activities relative to the reference areas
Occurrence and frequency	Increase number of sightings of porbeagle

Table 1f. Summary of Proposed Direct Indicators in the LC MPA - Northern Wolffish

Direct Indicator	Hypothesis
Biomass	Numbers of Northern Wolffish should increase or be maintained over the long term resulting from protection of the MPA area relative to reference areas
Size distribution	The range in size should increase or be maintained with reduction in harm relative to reference areas
Mean life span	The mean life span should be expected to increase or be maintained if there is a reduction in harm to Northern Wolffish relative to reference areas
Occurrence and frequency	Number of individuals should increase or be maintained relative to reference areas
Lethal encounters with fishing gear or vessels, immediately non-lethal entanglements	There will be fewer mortalities and injuries resulting from human activities relative to the reference areas

Table 1g. Summary of Proposed Direct Indicators in the LC MPA – Leatherback Turtle

Direct Indicator	Hypothesis
Lethal encounters with fishing gear or vessels, immediately non-lethal entanglements	There will be fewer mortalities and injuries resulting from human activities relative to the reference areas

Table 2a. Summary of Proposed Indirect and Anthropogenic Indicators in the LC MPA – Indirect Key Ecosystem Drivers/Indicators

Number	Indicator
1	Temperature, salinity, oxygen concentration, alkalinity, light levels, chlorophyll, pigments, nutrients, currents, and pH of bottom waters inside and in waters adjacent to the MPA.
2	Water mass movements
3	Extent of ice cover inside and in waters adjacent to the MPA.
4	Sound speed as a proxy for pH
5	Acoustic backscatter
6	Gas seeps and pockmarks
7	Nutrient flux sediment and water
8	Sediment composition and chemistry
9	Underwater sound produced by cetaceans, as well as the sources and propagation characteristics of other natural and anthropogenic sources.
10	Community (benthic and pelagic) function and structure (species distribution, trophic structure (predator/prey), energy flow, etc.)
11	Primary production
12	Habitat

Table 2b. Summary of Proposed Indirect in the LC MPA – Secondary Indicators for the COs

Number	Indicator
1	Jellyfish aggregations inside and in adjacent waters to the MPA Species: *Cyanea capillata* (most common) and *Aurelia aurita*.
2	Occurrence and/or frequency of turtles
3	Occurrence and/or frequency Porbeagle and other sharks
4	Occurrence and/or frequency Northern Wolffish

APPENDIX II

Table 3a. Summary of Proposed Protocols and Strategies for Monitoring Indicators in the Laurentian Channel Marine Protected Area – Direct Indicators

Survey Method	Indicators Application	Status
DFO Multispecies Bottom Trawl Survey	Fish species; corals and sponges	Ongoing
Shark Longline Survey	Porbeagle (shark species)	Not planned
Coral surveys (camera, box core, ROV)	Corals	Planning
Tagging (passive acoustic – sharks)	Porbeagle/sharks	On going
Tagging (satellites tags – turtles)	Turtles	Not planned
Aerial Flights	Turtles/Cetaceans	Planning
Bottom Mooring (acoustic)	Cetaceans/other community species	Planning

Table 3b. Summary of Proposed Protocols and Strategies for Monitoring Indicators in the Laurentian Channel Marine Protected Area – Indirect Indicators

Survey Method	Indicators Application	Status
Bottom moorings (oceanographic)	Oceanographic	Planning
AZMP	Oceanographic	Ongoing
Dockside monitoring	Anthropogenic/fish species	Ongoing
At sea observers	Anthropogenic/fish species	Ongoing
Multibeam Acoustic Surveys/benthic grabs	Habitat/ecosystem	Processing

Table 3c. Summary of Proposed Protocols and Strategies for Monitoring Indicators in the Laurentian Channel Marine Protected Area - Anthropogenic Indicators

Survey Method	Indicators Application	Status
DFO databases (logbooks, landings, etc)	Fishing effort; bycatch; compliance	Accessible
DFO Vessel Monitoring Systems (VMS)	Compliance; traffic inside MPA	Accessible
DFO Fisheries Protection Program – Program Activity Tracking for Habitat (PATH)	Infrastructure and human activities	Accessible
Partner information (e.g. Transport Canada, Environment Canada, CNLOPB)	Infrastructure; seismic surveys; sound; ship strikes	Accessible

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