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A Framework for the Identification of Monitoring Indicators Protocols and Strategies for the Proposed Laurentian Channel Marine Protected Area (MPA)

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Foreword

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

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ABSTRACT

During the establishment of a Marine Protected Area (MPA) in Canada, there is a requirement to develop a monitoring plan to ensure the management measures are effective and it is responding appropriately. A suggested framework to be used in the development of that plan for the proposed Laurentian Channel (LC) MPA is outlined in this document based on input and collaboration.

The monitoring indicators that have been proposed are based on direct, indirect and anthropogenic pressure indicators to measure and assess not only the species of interest but also ecosystem components and anthropogenic elements that are intrinsically linked with the identified conservation objectives. Further, potential protocols and strategies are proposed that will enable the monitoring of the indicators which are based upon currently-available technologies and platforms.

It is intended that this document represent the basis for the development of a monitoring plan by MPA managers in collaboration with stakeholders and Fisheries and Oceans Canada (DFO) Science Branch.

Cadre pour les indicateurs, les protocoles et les stratégies de surveillance de la zone de protection marine proposée pour le chenal Laurentien

RÉSUMÉ

Pendant l'établissement d'une zone de protection marine (ZPM) au Canada, il est nécessaire d'élaborer un plan de surveillance approprié afin de s'assurer que les mesures de gestion sont efficaces. Le cadre que l'on suggère d'utiliser dans l'élaboration de ce plan pour la ZPM proposée pour le chenal Laurentien est décrit dans le présent document en fonction des commentaires et de la collaboration.

Les indicateurs de surveillance qui ont été proposés sont fondés sur des indicateurs directs et indirects des pressions découlant des activités anthropiques afin de mesurer et d'évaluer non seulement les espèces d'intérêt, mais aussi les composantes de l'écosystème et les éléments anthropiques qui sont intrinsèquement liés aux objectifs de conservation déterminés. De plus, les possibles protocoles et stratégies permettront la surveillance des indicateurs, lesquels sont fondés sur les technologies et plateformes actuellement disponibles.

Il est prévu que le présent document représente le fondement de l'élaboration d'un plan de surveillance par les gestionnaires de la ZPM en collaboration avec les intervenants et la Direction des sciences de Pêches et Océans Canada (MPO).

INTRODUCTION

On World Oceans Day (June 8th) in 2010, the Honourable Gail Shea, Minister of Fisheries and Oceans (DFO), announced the Laurentian Channel (LC) as a new Area of Interest (AOI) for potential designation as a Marine Protected Area (MPA) under the *Oceans Act*. The identification of an AOI is the first step towards establishing a MPA. It signals DFO's intention to evaluate a part of the ocean in order to decide whether or not it meets the MPA criteria outlined in the *Oceans Act*, and if an MPA is the most appropriate management tool for the area.

Once the LC AOI was selected, a biophysical and socio-economic overview as well as a risk assessment of the area was conducted.

Early stages of the development of the LC AOI also included consultations with stakeholders to provide information and to acquire feedback on the selected area. All available information from the overview and assessment documentation, as well as the feedback received from stakeholders and the LC Advisory Committee, has been used to support DFO's decision-making throughout the designation process.

Post-designation of the LC MPA[1], the next steps of the process involve implementation of a monitoring program to assess the extent to which the LC MPA conservation goals and objectives are being met and the overall effectiveness of the management measures. Under the Health of the Oceans (HOTO) Initiative, DFO Science Branch will provide a framework on which this can be based. The framework involves the identification of monitoring indicators, protocols, and strategies specific to the Conservation Objectives (COs) for the area. An essential component of the management of an MPA is monitoring to assess the effectiveness of management activities and verify whether the goals of the MPA COs are being met (DFO 2013a). Monitoring also provides information to enable MPA managers to learn, understand and adapt to changes in this ecosystem.

The purpose of this report is to propose a framework of potential indicators, protocols, and strategies for the LC MPA. The provided recommendations are related to ecosystem monitoring, including anthropogenic pressure indicators; however, the recommendations do not address socio-economic considerations. These potential effects of the MPA are also critical to the overall assessment of management but are beyond the scope of this Canadian Science Advisory Secretariat (CSAS) report, and not considered here.

It should be noted that this document does not represent the Monitoring Plan required by DFO to implement as part of the overall management of the LC MPA. Instead, the Monitoring Plan will be developed by MPA Managers based on these recommendations, and in collaboration with stakeholders and DFO Science to achieve the best possible overall monitoring program.

The report presents recommendations that could be used in the immediate five to seven-year time frame, including pre- and post-designation of the MPA. It should be noted that research approaches and technologies are constantly evolving; therefore, the protocols and strategies presented here are representative of the best knowledge at the time of its publication.

[1] For consistency purposes, the acronym LC MPA will be used throughout the document even though most of the information presented in this document refers to the study area of the LC as an AOI.

BACKGROUND

LAURENTIAN CHANNEL AREA OF INTEREST

The proposed LC MPA is located off the southwest coast of Newfoundland and Labrador (NAFO Div. 3P), covers approximately 11,908 km^2, and includes the water column, seabed, and subsoil to a depth of 5 m (Figure 1). Depths in the LC MPA vary from 100 to 500 m, with the central basin of the LC being the deepest (DFO 2010a). The majority of the LC MPA is deeper than 150 m. The northeast side of the LC is the shallowest area, delimited by the edges of the Burgeo and St. Pierre Banks. The depth at those edges varies from 200 m on the Burgeo Bank to 100 m along the St. Pierre Bank. The area slopes gently from northeast to southwest until it reaches the basin of the LC (half-way along the LCMPA).

The LC MPA contains the largest recorded sea pen field in eastern Canada and has large concentrations of Black Dogfish (*Centroscyllium fabricii*) and immature Smooth Skate (*Malacoraja senta*). The LC MPA is also a seasonal migration corridor for marine mammals (such as Humpback (*Megaptera novaeangliae*) and Blue Whales (*Balaenoptera musculus*) and sea turtles (such as Leatherback Sea Turtles (*Dermochelys coriacea*)). Important oceanographic processes, including moderate upwelling along offshore slopes and channels, support food webs in the area and enhanced productivity year-round (Templeman 2007). The LC also possesses relatively undisturbed habitat compared to adjacent offshore areas, as well as unique structural habitat offered by the interface of sea ice and open ocean (Templeman 2007).

The overarching goal of the proposed LC MPA is to: "*Conserve biodiversity in the LC MPA through protection of key species and habitats, ecosystem structure and function and through scientific research*". To achieve this goal, the regulatory intent of the MPA will focus mainly on the management of human activities resulting in a "no take" fishing zone. MPAs that are "no take" fishing areas can be appropriate as a tool for the conservation of habitat, species and biodiversity if the objectives are clear; there is an ability and willingness to effectively maintain and enforce the closure; and there is an ability to monitor and evaluate its performance (Hilborn et al. 2004). The proposed MPA is expected to serve multiple purposes at local and regional scales. The LC MPA will directly contribute to its primary goal of conserving biodiversity within the LC. However, the effects of this management regime could also result in changes to adjacent waters. For example, it is important to be aware of incidental consequences, especially related to fisheries restrictions within the MPA that can result in enhanced fishing effort in surrounding areas (Hilborn et al. 2004; Agardy et al. 2011).

The expectations against which the LC MPA will be assessed should be based upon the goals set for itself, in its design, management and evaluation (Halpern 2003). As shown in the Gilbert Bay MPA (Morris and Green 2014), the LC MPA will not be independent of harvest control rules outside the area, and it should not be expected to work effectively as an isolated conservation strategy; especially taking into account that species of interest range from non-mobile (e.g. corals) to highly mobile species (e.g. Porbeagle Shark (*Lamna nasus*)). Ultimately, the LC MPA will contribute to Canada's commitment to Aichi Target 11 – i.e. the establishment of a network of MPAs by 2020.

Management of the LC MPA

The LC MPA will consist of two management zones (Figure 1). Zone 1a/b consists of sensitive benthic areas where unique sea pen fields are located, and will provide the highest level of protection within the MPA. Zone 2a/b is a multiple use area, which will allow several anthropogenic activities as long as they do not: "*Disturb, damage, destroy or remove any living marine organism or any part of its habitat including seabed and subsoil to a depth of 5 m*".

Activities allowed within Zone 2a/b (and some within Zone 1a/b) are related to Aboriginal Fisheries (regulated by the *Aboriginal Communal Fishing Licenses Regulations*); oil and gas exploration and production (regulated by the Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment); marine transportation (regulated by the *Canada Shipping Act*); subsea cables (regulated by the *Fisheries Act*, *Telecommunications Act*, *Canadian Environmental Protection Act 2012*, and *Species at Risk Act (SARA)*); emergency, safety, security, and sovereignty situations; and scientific research (Table 1). Non-regulatory measures and agreements towards best practices are being pursued to address ship strikes and marine debris (both identified as key threats to Leatherback Sea Turtles) in collaboration with the LC MPA Advisory Committee.

The Management Plan to be developed as part of the final designation process will provide further guidance on the regulations, and will be used to implement management strategies to meet MPA conservation objectives. DFO will have overall responsibility for compliance and enforcement measures as per departmental legislation, such as the *Oceans Act* and the *Fisheries Act*. The primary means of departmental enforcement will be through existing surveillance programs.

Conservation Objectives

In support of the overarching goal, COs have been developed in conjunction with the Advisory Committee, and following national guidelines for the phrasing of such objectives. The COs focus on the effect of human activities on six species of interest including corals and sponges, especially sea pens, Black Dogfish, Smooth Skate, Porbeagle shark, Northern Wolffish, and Leatherback Sea Turtle.

The COs of the proposed LC MPA are[2]:

1. Protect corals, particularly significant concentrations of **sea pens**, from harm due to human activities in the LC 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 Shark** from 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 LC MPA.
6. Promote the survival and recovery of **Leatherback Sea Turtles** by minimizing risk of harm from human activities in the LC MPA.

DFO NL Oceans Division identified the key activities/stressors for COs within the LC MPA include habitat disruption and/or destruction (caused by fishing including bottom trawling, and oil and gas exploratory drilling), biomass removal (fishing mainly from bottom trawling, longlining and associated bycatch, and line entanglement and ship strikes in the case of Leatherback Sea Turtles), waste (marine debris), and increased sedimentation in the water column (oil and gas exploratory drilling). In a broader context, by selecting these COs, the LC MPA will contribute to

[2] As an editorial note, the COs presented here have been adapted based on changes recommended by a CSAS review meeting in June 24-26, 2014.

the conservation and protection of non-commercial fishery resources, unique habitats, and endangered or threatened marine species and their habitats (reasons for establishing MPAs as stated by *Oceans Act*) (Figure 2).

To provide context for potential proposed indicators within this framework, species information is provided based on the Biophysical Overview (DFO 2010a), which considered the 2010 boundary in relation to NAFO Div. 3P (the study area). Updated information is included where appropriate. In addition, data gaps and missing life history information are also identified.

Primary Species of Interest

Sea Pens

Sea Pens (Pennatulaceans) are whip-like, colonial corals that grow to ~ 2 m in height (Kenchington et al. 2011). The sea pen takes the form of a rigid, erect stalk (the rachis) with one or more polyps raised into the water column, and a bulbous "root" or peduncle at its base which anchors it in soft sediments of the sea floor (Williams 1995). Sea pens have been recorded in the greatest numbers, and with the greatest diversity (n=6 species), in the LC MPA as compared to NAFO area Div. 3P (DFO 2010a). Through kernel density analysis of coral distribution, higher concentrations of sea pens within the LC and to the west of the LC MPA were identified (Kenchington et al. 2010). Corals provide important structural habitat for many species; they can create unique habitats (e.g. isolated islands); provide structure (e.g. thickets); add complexity to a featureless seabeds (e.g. sea pen fields in soft mud environments); and provide resting, feeding, and nursery areas (e.g. sea pens are nurseries for redfish (Baillon et al 2012)), as well as refuge from predation across various life stages. Data on corals are collected primarily by annual DFO research trawl surveys, and the catchability of various coral species likely varies considerably (DFO 2010a). The establishment of the LC MPA will contribute to the mitigation of the main threats to resident coral species, which include habitat destruction, biomass removal, and potential loss of biodiversity (from bottom trawling), as well as habitat contamination resulting from waste and increased sedimentation due to oil and gas exploratory drilling.

Several identified information gaps for sea pens include:

- Catchability in trawl gear and incidence of harm.
- Incidence/likelihood of re-attachment of sea pens when disturbed by bottom contact gear.
- Changes in abundance and diversity of sea pens and other coral and sponge taxa in MPA over time.
- Faunal (fish and invertebrate) associations with sea pens, such as redfish (Baillon et al. 2012).
- Effects of sedimentation on sea pens resulting from exploratory drilling.
- Incidence of bycatch of sea pens and other coral and sponge taxa in longlines and crab pots. To achieve this goal, increased at-sea Canadian Fisheries Observer coverage is needed for most Div. 3P fisheries, especially in some fisheries where there is no coverage.
- Effects of changes in pH and water temperature on sea pen growth/ physiology/ survival.
- Feeding ecology, growth rates, longevities, and recruitment of sea pens.

Black Dogfish

Black Dogfish distribution appears to be influenced by water temperature and depth (>3.8°C and >350 m), as well as body size and sex (Kulka 2006). Highest concentrations have been nearly all within the LC but were also found to a lesser extent on the Grand Banks (Kulka 2006). Boag (2014) conducted a study in Subdiv. 3Ps and found 423 sharks (184 females and 239 males) where Black Dogfish ranged from 170 to 720 mm.

This species is ovoviviparous (litter size around 4-40 live young), and slow growing with late sexual maturity and low fecundity. Over time, abundance in Div. 3P has fluctuated from low levels during the 1970s and early 1980s, followed by rapid increases and stabilization up to the mid-1990s. The shallow portion of LC is a known area for Black Dogfish pupping, as indicated by the occurrence of a substantial proportion of mature females and young-of-the-year (YOY=15-30 cm TL; Kulka 2006; Boag 2014). Black Dogfish feed on or near the seafloor consuming mainly crustaceans, squids, cephalopods, jellyfish, and bony fishes. Establishment of the LC MPA will contribute to the mitigation of the main threats to spawning female Black Dogfish and their pups, which include bycatch in a number of deep water fisheries (DFO 2010a).

- Identified information gaps for Black Dogfish include:
- Incidence of bycatch and discards in all fisheries in 3P.
- Accurate estimates and timing of significant bycatch of Black Dogfish in all fisheries in NL waters which capture dogfish require reporting of catch and discards by species.
- Timing of annual pupping through seasonal sampling of Black Dogfish populations.
- Information on specific habitat requirements for YOY, immature and mature Black Dogfish.
- Effects of seismic surveys on all life stages of Black Dogfish.
- Information on Black Dogfish movements and migrations by age and maturity stage.
- Trophic role of Black Dogfish and their associations with other organisms.

Smooth Skate

Smooth Skate distribution appears to be influenced by water temperature and depth (greatest densities at 5-6°C and 400-500 m), and potentially prey availability (Simpson et al. 2012). Study of 3P trawl survey data indicates Smooth Skate are present throughout the LC MPA. Abundance of immature and mature Smooth Skate fluctuated from the early 1970s to 2005 in Div. 3NOPs (Simpson et al. 2012). Between 2007 and 2010, immature abundance declined and adult abundance increased. Without knowledge of the effect of research trawl changes on catchability of Smooth Skate (especially at smaller sizes), abundance estimates from pre- and post-1995 spring surveys are not directly comparable (Simpson et al. 2012). Smooth Skate are selective feeders, consuming primarily small crustaceans through most of their lives, and eating fish only upon attaining their largest body sizes. Establishment of the LC MPA will contribute to the mitigation of the main threats to Smooth Skate, which include bycatch from bottom trawling, and habitat contamination resulting from oil and gas exploratory drilling.

Identified information gaps for Smooth Skate include:

- Accurate estimates of significant bycatch of Smooth Skate in all fisheries.
- Specific habitat requirements for YOY, immature and mature Smooth Skate.
- Life history parameters and reproductive cycle (especially timing of skate egg extrusions by spawning females on nursery grounds) for this area of the species' range. Information regarding size at maturity and growth patterns is also required.
- Effects of seismic surveys on all life stages of Smooth Skate.

- Trophic role of Smooth Skate (<30 cm TL) and their associations with other organisms.
- Distribution and abundance in Subdiv. 3Ps and the LC MPA along with movements of Smooth Skate within the area.

Porbeagle Shark

Porbeagle Sharks are distributed from Newfoundland and Labrador to the Sargasso Sea in the Western Atlantic, and from Iceland and western Barents Sea to Morocco in the Eastern Atlantic, and appear to be influenced by water depth and temperature (Campana et al. 2013). Porbeagle moves into the Gulf of Maine, Georges Bank, and southern Scotian Shelf in January-February, travel northeast along the Scotian Shelf through the spring, and then appears off the south coast of Newfoundland and Labrador and in the Gulf of St. Lawrence in the summer and fall (Campana et al. 2013). Campana et al. (2013) reported that long term abundance has declined compared to estimates in 1961, although recent values were 4-22% higher than estimates in 2001. Spawner abundance in 2009 was 83-103% of its 2001 value (Campana et al. 2013). Porbeagles have low fecundity and a late age of sexual maturation. Research indicated that Porbeagle mating grounds in the western North Atlantic are off southern Newfoundland and at the entrance of the Gulf of St. Lawrence (Campana et al. 2013). Porbeagle is primarily an opportunistic piscivore, i.e. its diet is composed of a wide variety of species (groundfish and cephalopods being important prey items), and depends on shark body size and season (Joyce et al. 2002). Porbeagle bycatch in longline and gillnet fisheries is a major threat to the Northwest Atlantic population (Simpson and Miri 2014). Establishment of the LC MPA will enhance research and conservation efforts in and around those waters. In April 2014, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) upheld its designation of the Porbeagle Shark as “Endangered”. DFO will conduct a recovery potential assessment of the Porbeagle in 2015 through a *SARA* assessment process.

Identified information gaps for Porbeagle Shark include:

- Accurate estimates of commercial longline and gillnet bycatch of Porbeagle (Simpson and Miri 2014).
- Post-release mortality rates of Porbeagle bycatch from particular fishing gears (especially gillnets, longlines, and weirs).
- Effects of seismic surveys on all life stages of sharks.
- Movements within the LC MPA (especially of pregnant females), and presence of YOY and immature Porbeagle.
- Seasonal estimates of Porbeagle abundance.

Northern Wolffish

Three wolffish species are widely distributed in Canadian Atlantic and Arctic waters: Northern Wolffish (*Anarhichas denticulatus*), Spotted Wolffish (*A. minor*), and Atlantic Wolffish (*A. lupus*). Distribution appears to be influenced by water temperature (preferably 1.6 -4°C; DFO 2010a). Northern Wolffish are generally distributed from the Davis Strait/west Greenland to the Grand Banks and Laurentian Channel. Spotted Wolffish are rarely caught sampled in Div. 3LNO and Subdiv. 3Ps during spring research surveys, while Atlantic Wolffish is found in Div. 3LNO and shallower parts of Subdiv. 3Ps (DFO 2013b).

The Northern Wolffish has been specifically identified as one of the species of interest based on estimates of higher abundances compared to the other wolffish species in the LC MPA (Kulka and Templeman 2013). Based on morphometric and meristic characteristics, Northern Wolffish appear to comprise two distinguishable groups in NL waters: one group centered on the northern and southeastern Grand Bank (Div. 3LN), and another scattered over much of the northeast Newfoundland and Labrador shelves (Div. 2J3K); no data were available for Subdiv. 3Ps (Simpson et al. 2013a). Further studies on distribution and abundance of all three wolffish species are ongoing (DFO 2013b). Regarding diet, the two most important prey groups for Northern Wolffish are pelagic and benthic fishes; shrimp and echinoderms for Spotted Wolffish; and crabs and echinoderms for Atlantic Wolffish (Simpson et al. 2013b). In 2012, COSEWIC re-evaluated the status of wolffish in Atlantic Canada and concluded that, despite signs of population recovery; Northern Wolffish and Spotted Wolffish remain designated as “Threatened” (DFO 2013b). Atlantic Wolffish also remains listed and is designated of “Special Concern”. Establishment of the LC MPA will contribute to the mitigation of threats to resident Northern Wolffish, which include bycatch and habitat destruction by bottom trawling and other fisheries.

Identified information gaps for Northern Wolffish include:

- Timing and location of spawning activity.
- Survival rates after release from various commercial fishing gear types and depths hauled (DFO 2013b).
- Biological Reference Points for comparative analysis of effectiveness measures (DFO 2013c).
- Age and growth, reproduction, mortality, movements, and stock structure; especially in Subdiv. 3Ps (DFO 2013b; DFO 2013c; Simpson et al. 2013a).
- Temporal and spatial variability of prey organisms (DFO 2013c).
- Effects of hypoxia on Northern Wolffish survival (DFO 2013c).
- Accurate estimates of speciated commercial wolffish landings and discards at sea (only collected by Canadian at-sea Fisheries Observers), and data on fishing locations and wolffish species caught, which are all necessary to evaluate the contribution of commercial fisheries to wolffish mortality (DFO 2013c).

Leatherback Sea Turtle

During summer and fall Leatherback Sea Turtles occur frequently in Div. 3P. The largest concentrations occur on the continental shelf and slope but also further offshore (DFO 2010a). Leatherback Sea Turtles undergo an annual migration between breeding areas at low latitudes (South and Central America, the Caribbean, and continental US) and foraging habitat in temperate waters, where they aggregate to consume jellyfish (Atlantic Leatherback Turtle Recovery Team 2006). Based on satellite tracking and aerial survey studies in Canada, Leatherback Sea Turtles travel and feed along the southeast coast of Newfoundland and in the Gulf of St. Lawrence (Atlantic Leatherback Turtle Recovery Team 2006; Dodge et al 2014). Regular sightings of Leatherback Sea Turtles in Canadian waters extend from July through September, with the majority present in August until they decrease markedly in late September and October (DFO 2012a). Evidence suggests that the LC MPA represents a migration pathway for this species between these areas (DFO 2012b). Leatherback Sea Turtles are listed as “Endangered” under *SARA*. The establishment of the LC MPA could contribute to mitigation of the main threats to Leatherback Sea Turtle, which include injury and mortality due to entanglement in lines of fixed fishing gear and vessel strikes (DFO 2012a). Behavioural responses to noise (e.g. seismic surveys) have also been observed in marine turtles (DFO 2010a).

Information gaps associated with Leatherback Sea Turtles include:

- Information about population size and trends in Atlantic Canadian waters and beyond (Atlantic Leatherback Turtle Recovery Team 2006).
- Frequency of incidental capture by fixed fishing gears, mortality, and post-release survival in Canadian waters (DFO 2012a).
- Contribution of vessel strikes to injury and mortality (Atlantic Leatherback Turtle Recovery Team 2006).
- Contribution of marine pollution (e.g., debris and contaminants) to injury and mortality (Atlantic Leatherback Turtle Recovery Team 2006).
- Better understanding of negative effects of man-made noise on this species' behaviour (Atlantic Leatherback Turtle Recovery Team 2006).

Research Objectives

It has been recognized that, besides the COs, there are several important components of the LC MPA ecosystem that may merit conservation but where further baseline data is needed. The following Research Objectives (ROs) are proposed by DFO-NL Oceans Division to promote focused scientific objectives that could lead to a better understanding of these components and potentially new COs through an adaptive management approach.

1. Advance the understanding of the distribution, biodiversity, health and integrity of **cold water corals and sponges** in the LC MPA.
2. Identify important as well as **sensitive marine benthic areas and habitats** in the LC 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 LC MPA.
5. Advance the understanding of the spatial and temporal distribution of **sharks** and shark by catch, and quantify shark by catch across all fisheries for species frequenting the LC MPA.
6. Advance scientific studies contributing to the identification and understanding of significant or critical habitat for ***SARA*-listed species** found in the LC MPA.

There are significant linkages between the COs and ROs which are depicted in Figure 3. Specifically, RO 1 (location, health, and integrity of cold water corals and sponges) and RO 2 (identify important and sensitive marine benthic areas and habitats) are closely linked to CO 1 (protection of sea pens) and each other; RO 3 (plankton variability) is not directly linked to any CO, but has been included as a potential indirect indicator below; RO 4 (cetacean distribution, abundance, and migration) can be addressed along with CO 6 (protection of Leatherback Sea Turtles); and RO 5 (spatial and temporal distribution of sharks and shark by catch with respect to their life stages) is intrinsically linked to COs 2 and 4 (protection of Black Dogfish and Porbeagle Shark, respectively). RO 6 refers to significant or critical habitat for *SARA*-listed species found in the LC MPA. According to the Species at Risk Public Registry (visited April 11, 2014), currently-listed species relevant to the LC MPA include Spotted Wolffish and Atlantic Wolffish (linked to CO 5 protection of Northern Wolffish), Great White Shark (linked to RO 5 and CO 2), and Fin Whale, Blue Whale, Beluga Whale, and North Atlantic Right Whale (linked to CO 6 protection of Leatherback Turtles). The main objective of this report, however, is to provide monitoring indicators, protocols, and strategies for the primary COs, and the ROs will be addressed when applicable and appropriate; therefore, further work may be required to identify specific, directed monitoring programmes.

MONITORING FRAMEWORK

The proposed monitoring framework involves an overall strategy that is recommended as an optimal means of monitoring the LC MPA. There are several overarching principles and approaches that are recommended to enhance the overall framework as described here.

SCIENTIFIC STEERING COMMITTEE

It is recommended that a Scientific Steering Committee be established to assist in the overall development, implementation and maintenance of the Monitoring Plan. The committee should include MPA managers and be represented by the following research groups/areas of the DFO Science Branch: HOTO, MPAs, oceanography, benthic ecology (including corals), ecosystem research, marine species at risk, and marine mammals. Each represents a component of the COs and ROs that together will be able to provide advice on an integrated approach to the scientific direction of the LC MPA.

Following the commencement of the monitoring programme, the proposed Committee would likely have a reporting structure similar to DFO's Atlantic Zonal Monitoring Program (AZMP) that meets annually to discuss results and provide advice for future directions and collaborations where appropriate. Given the wide range of species and numerous factors involved in the overall LC MPA management, it will be valuable to regularly compare results, identify gaps and discuss new areas of potential the research. Furthermore, it may be beneficial to assist MPA managers in developing and promoting research questions in academia and the scientific community that can inform the ROs through collaborations beyond the specific monitoring requirements. Stakeholders and academia could be involved in subcommittees where appropriate to ensure engagement and potential collaboration opportunities are being maximized.

Also, a robust data management system will be required to ensure that the Committee, as well as MPA Managers, can easily access the data, given the large spatial scale of this MPA and many factors recommended in the monitoring framework. Details regarding the establishment and maintenance of the data management system should be discussed following the formation of the Science Steering Committee in collaboration with MPA managers.

BASELINE MONITORING

The LC MPA is not a well-studied ecosystem to date. There are many unknowns and data gaps that require supplementary research to gain a better understanding of the ecosystem's function, structure, and processes. Therefore, critical to any monitoring programme within the LC MPA would be the establishment of baseline or reference points from which further comparisons through status and trend monitoring are possible. Baseline monitoring is required to build a foundation that is critical to the determination of any future changes that may or may not be related to management measures. It is also important to determine initial conditions in order to effectively gauge natural variability in potential monitoring indicators, as compared to actual changes in the system resulting from the MPA measures.

Adaptive Management Considerations

Adaptive management should be inherent in MPA planning as a guiding principle and be adopted in the LC MPA. Adaptive management refers to “the systematic acquisition and application of reliable information to improve natural resource management over time” (Wilhere 2002). This definition implies that the monitoring framework and subsequent management and monitoring plans are treated as experiments designed with the best knowledge and technology at the time. However, based on potential results found through extensive monitoring, MPA managers can adapt to meet the changes that occur within the MPA as more information becomes available.

The proposed monitoring framework and plan for the LC MPA should also be hypothesis-driven, and based on a rudimentary understanding of the ecosystem and thus involves uncertainty. Hypothesis driven monitoring enables the detection of changes related to MPA management through a scientifically defensible framework. Therefore, adaptive management should be used to experimentally test the implicit hypotheses of monitoring plans (Wilhere 2002).

Dealing with uncertainty also implies that decision makers and stakeholders, in general, are aware that actions have uncertain outcomes (Wilhere 2002) and that those actions, if necessary, can be modified in order to pursue the desired outcomes. This process can only occur with close coordination and agreement between stakeholders, flexible regulations, and integration of management actions and monitoring activities from the beginning of the process (Wilhere 2002; Sale et al. 2005; Morris and Green 2014). DFO Oceans Division is responsible for managing the MPA to meet objectives, and the evaluation of effectiveness of the management and monitoring plans. This requires collaboration with DFO Science, other sectors within DFO, other government departments, academia, Aboriginal groups and stakeholders.

Monitoring Framework

The framework is based on literature relevant to MPA development and input through review and consultations and involves the identification of a set of potential indicators and suggested protocols and strategies based on the ecological, environmental, and human (key threats) components.

Canada’s national MPA programme has several examples where monitoring has taken different approaches to the establishment of a monitoring framework. There are advantages and disadvantages to any approach, given the goals of each MPA as well as geographic location, species of interest, and threats to the ecosystem. Indicators and monitoring protocols are fairly straightforward when there are one or two conservation objectives for a specific CO, such as the coastal Eastport MPA where the main CO is the maintenance of a viable lobster fishery (DFO 2014a). Larger, more dynamic MPAs may use ecosystem-based approaches with keystone species and variables providing a basis for further investigation, such as the Gully MPA (Kenchington 2010). Alternatively, threats to the ecosystem can be considered as a basis for monitoring, how they can be reduced, and their effects on particular species, such as the St. Lawrence Estuary MPA (Provencher et al. 2012). Offshore MPAs also provide a unique challenge to the creation of a monitoring programme whereby costs of monitoring can be prohibitive and limit the scale and types of monitoring possible. Furthermore, forming a programme encompassing a wide range of species, such as the case of the LC MPA, amplifies the scope of work required to ensure coverage of all COs in addition to informing the ROs.

In developing a framework for the LC MPA, a review of relevant indicator frameworks was conducted. Shin et al. (2010) described an ecosystem approach that aimed to evaluate the effects of fishing on the health of marine ecosystems in a global context, based on eighteen MPAs worldwide. Kenchington (2014) developed a framework for the monitoring of coral and sponge megafauna in the Eastern Arctic. DFO (2014b) proposed a monitoring framework for the St. Anns Bank AOI, which is located in the southwestern portion of the Laurentian Channel and aims to protect fish and fishery resources, benthic environments, and marine reptiles.

Regardless of the type of MPA and goals, a selection process for indicators should be based on the following general criteria (Rochet and Rice 2005; Shin et al. 2010; DFO 2014b):

- **Theoretical basis/ecological significance**: indicators should be solidly based on scientific knowledge.
- **Sensitivity**: indicators should be sensitive to management actions, with responses specific to known causes and providing a signal independent of natural variability.
- **Measurability**: indicators should consider cost efficiency, historical data criteria, and the use of simple, existing, proven and analytical instruments (including non-invasive, non-destructive methods). Indicators need to be measurable or estimated on a routine basis, and data time-series should be available.
- **Tractability**: the set of indicators must remain small and redundancy should be avoided as much as possible. Indicators must be informative of the states and trends of ecosystems.
- **Researchers and stakeholders support**: indicators should be supported by scientists who (potentially) will conduct field research and analysis, and by stakeholders.
- **General public awareness**: indicators must be widely and intuitively understood by the general public.

MONITORING INDICATORS

A proposed list of indicators for assessing management effectiveness of the LC MPA is presented. DFO (2013a) defines *indicators* as variables, pointers or indices, whose fluctuations reveal key elements of a system; *protocols* as specific methodologies required for monitoring indicators (equipment, techniques, quality control, etc.); and *strategies* as avenues employed to undertake the monitoring protocols (government agencies, academia, community groups, etc.).

In this framework, indicators are grouped into three categories:

1. *direct* indicators which will provide information on the status and trends of the specific species of interest related to the COs;
2. *indirect* indicators which will provide information on key ecosystem drivers or indicators environment that can inform changes in the COs; and
3. *anthropogenic pressure indicators* which will assess human activities inside and outside of the LC MPA that may affect the COs

Some of the indicators, protocols and strategies can also be used opportunistically as basis to address the ROs given the relationship between COs and ROs.

Direct Indicators

These indicators provide specific information on the status and trends of COs (and ROs). These values are essential in the determination of whether change is occurring with respect to the species of interest. Regulation of human activities within the MPA (e.g. fisheries, oil and gas activities) may induce changes to the properties of COs (production of biomass, stability over time, etc.) in the long term. A summary of the indicators as they apply to the species of interest are represented in Table 2 along with the associated hypotheses.

Biodiversity

The overarching goal of the MPA is to conserve biodiversity through the protection of key species and habitats, ecosystem structure and function; therefore, it is important to provide a measure of its effectiveness towards attaining that goal. The Convention of Biological Diversity (CBD) uses the definition of biological diversity as “the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems”. As such, the indicators used to assess if the MPA is working effectively to meet its goal must reflect that challenge.

- *Species richness*. This measurement takes into account the number of species per number of individual animals present in an ecological community or region. The observed species richness is affected by not only the number of individuals but also the heterogeneity of the sample. Species richness is a count of species, and it does not take into account the abundances of each species or their relative abundance distributions (Stachowicz et al. 2007).
- *Diversity.* This is a quantitative measure that reflects how many different species are in a dataset, and simultaneously accounts for the evenness of how the species are distributed among those types. It represents information about both the number of species and their relative abundance (evenness) (Stachowicz et al. 2007).

Sea Pens

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

- *Biomass*. This indicator is useful to detect changes in estimated abundance over time. By mitigating human threats, total biomass of corals is expected to change (Pomeroy et al. 2004; Shin et al. 2010; Kenchington 2014).
- *Abundance and density*. For the sea pens, this indicator can be estimated based on scientific surveys and catch rates in the Zone 2.
- *Size distribution*. Size distribution of sea pens will be informative regarding the structure of corals populations, i.e. the proportion of smaller (immature) to larger (mature) individuals. By restricting fisheries, it is expected that individuals of all size classes will have an opportunity to increase in abundance over time in the MPA, including larger size classes. This indicator could also provide insight on recruitment success by detecting changes in the proportion of larger individuals (Pomeroy et al. 2004).
- *Geospatial indicators (including patch stability, connectivity)*. Corals and sponges patch area, density, and field size (proposed by Kenchington et al. 2012) measure habitat area occupied by corals and number of patches by area respective to a broader area. Changes in spatial properties and arrangement, position, or orientation of habitat patches in the broader survey area assist in the interpretation of ecological phenomena, in addition to health, function, and structure (Kenchington et al. 2012). The connectivity of corals and sponges patches indicator measures the distance between patches (isolation or proximity) and interactions between them, based on gamete or larval dispersal range (when available) (Kenchington et al. 2012). Dispersion of corals and sponges patches is a measure of the pattern of distribution of patches (regular or clumped) with respect to each other (Kenchington et al. 2012).
- *Taxonomic diversity and richness.* There are data gaps regarding the taxonomy of sea pens and this indicator will help to inform this knowledge gap and assist in the long term management.

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; however, the longevity of sea pens is still considered a data gap for certain species.

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.* This indicator is useful to detect changes in estimated abundance over time. By mitigating human threats, total biomass of these fish species is expected to change (Pomeroy et al. 2004; Shin et al. 2010; Kenchington 2014).
- *Size distribution*. Size distribution of the fish species of interest will be informative regarding the structure of their populations; i.e. the proportion of smaller (immature) to larger (mature) individuals. By restricting fisheries, it is expected that individuals of all size classes will have an opportunity to increase over time in the MPA, including larger size classes. This indicator could also provide insight on recruitment success by detecting changes in the proportion of larger individuals (Pomeroy et al. 2004).
- *Frequency.* The frequency of encounters can be a proxy to the abundance within the LC MPA and the reference area.
- *Occurrence.* The Northern Wolffish is an endangered species and is rare within the entire region; therefore, occurrence in any quantity can provide information on the status of the species.

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*. The commercial bycatch of the fish species of interest is valuable information as it can provide insight into the use of the adjacent areas as potential spillover from the MPA. Also, if a shift in habitat utilization occurs, it would be in these adjacent areas.

Porbeagle Shark

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

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

- *Frequency.* The frequency of encounters can be a proxy to the abundance within the LC MPA and the reference area to gain a better understanding of the number of individuals present.
- *Occurrence.* The Porbeagle is rare within the entire region; therefore, occurrence in any quantity can provide information on the status of the species.

By reducing the risk of human-induced mortality due to fishing such as 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*. The commercial bycatch of sharks is valuable information as it can provide insight into the use of the adjacent areas as potential spillover from the MPA.
- *Numbers of lethal encounters and non-lethal entanglements*. This indicator should decrease as a result of the designation of the MPA due to lack of fishing in the MPA.

These data can also inform ROs 5 and 6 related to shark and shark bycatch as well as *SARA* listed species.

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 at this time; however, the design of the aerial surveys could provide an abundance estimate for the MPA and/or the NL south coast, and by sampling the MPA and adjacent areas to provide a measure of the relative importance of the LC MPA for leatherbacks at different times. The estimate may not be very precise if there are few sightings, or the distributions of leatherbacks are clumped.

Using adaptive management, incoming data will inform MPA managers over time regarding any additional indicators or necessary alterations to the programme.

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

- *Numbers of lethal encounters and non-lethal entanglements*. This indicator should decrease as a result of the designation of the MPA due to reduced traffic and no fishing in the MPA.
- *Frequency.* The frequency of encounters can be a proxy to the abundance within the LC MPA and the reference area to gain a better understanding of the amount of individuals.
- *Occurrence.* The utilization of the LC MPA by Leatherback Sea Turtle is not well understood; therefore, occurrence in any quantity can provide information on the status of the species.

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 MP*A. Although the specific methods of measurement remain undetermined, it may also be useful in determining habitat requirements and predictors on locations of turtles.

Indirect Indicators

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). They may be helpful in further understanding 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 programme will be weakened. Both trends and anomalies in the data should be analyzed as summarized in Table 3.

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, chlorophyll) of the water column, and in areas adjacent to the MPA*. These parameters affect different processes for organisms (e.g. growth, metabolism), populations (e.g. productivity) and habitats (overall health) present in the MPA (DFO 2014b).
- *Bottom oceanographic properties near the seafloor inside and in adjacent waters to the MPA.* Information on the oceanographic bottom parameters will be useful in understanding the habitat of sea pens and bottom dwelling species.
- *Water mass movements.* This can be useful to inform any shifts in the populations of interest, or those of their prey, resulting from changing conditions.
- *Wave height.* This indicator is useful in the interpretation of changes in surface conditions that may impact water conditions. Further, wave heights can significantly influence ambient noise measurements and influence detectability of Leatherback Turtles and other near-surface species during aerial surveys.
- *Extent of ice cover inside and in adjacent to the MPA*. Sea ice is infrequent in the LC MPA (DFO 2010a); however, it can affect primary production and influence fishing effort adjacent to the MPA (stressor indicator, see next section) (DFO 2014b). Ice cover also has strong influence on pinnipeds (to some extent if ice drifts out of Gulf carrying breeding harps and or hoods) and relates strongly to cetacean presence.
- *Speed of sound, as a proxy for seawater pH (i.e. level of acidity).* This could be particularly valuable for sea pens and the RO3.

Ecosystem Indicators

Ecosystem indicators (e.g. trophic interactions and cascades) are important because they assist in the quantification of processes that may be occurring on a greater scale than the habitats of single species. These indicators are usually assessed at a scale of the larger system, i.e. both inside the MPA and in adjacent reference area(s). They will also assist in the assessment of the overarching goal associated with biodiversity.

- *Animal/plant/bacterial community composition.* These set of indicators are the basic measure of the species composition (diversity, richness, evenness) and structure (distribution, relative abundance) within the MPA. These indices should be used to collect information on the COs as well as other species occurring within the MPA including presence/absence and/or abundance of apex predators (Pomeroy et al. 2004; DFO 2014b).
- *Infaunal and epifaunal composition.* This is important for determining which communities on the seafloor will interact with the species of interest to provide structure and function. These species can also represent prey for some of the species of interest.
- *Species distribution.* This will provide information in determination of the overarching goal of biodiversity and habitat utilization of the different regions of the MPA.
- *Trophic structure* LC MPA species of interest occupy different trophic levels in the food web (primary producers, different levels of predators). Monitoring trophic relationships between these species over time can provide insight into changes in the structure and function of the ecosystem in the MPA, and possible connections across its boundaries (Shin et al. 2010).

- *Energy flows.* The information provided can be useful in the ecosystem community context in terms of understanding the structure and function of the ecosystem in the MPA.
- *Biomass of predator/prey species.* These relationships are valuable to understand the larger ecosystem processes in a broader context instead of individual species.
- *Primary production*. Primary production in terms of carbon fixed per unit area per year and timing and intensity of the spring bloom; and composition of the phytoplankton community in the MPA and in adjacent waters to the MPA (DFO 2014b). This is valuable information as it provides the basis for lower level production for a variety of species and prey.
- *Zooplankton variability*. Within the LC MPA, calanoid copepods and macrozooplankton are an important link to higher trophic levels (such as RO6 endangered Blue Whales and Northern Right Whales (*Eubalaena glacialis*)). Gaining a better understanding on shorter time scales is necessary in order to understand the linkages between physical, chemical and biological properties and to forecast changes over time (DFO 2010a). Further, the enumeration/identification of selected zooplankton could be used to provide better assessment of rare or ephemeral taxa. This is also part of RO 3 and RO6.
- *Jellyfish aggregations inside and adjacent to the MPA.* Monitoring jellyfish can provide insight into the spatial relationship between predator (Leatherback Sea Turtles and Sunfish (*Mola mola*)) and prey (Houghton et al. 2006a, Houghton et al. 2006b). These aggregations can indicate potential foraging areas for leatherbacks areas of significant primary productivity since marine current advection and other processes result in jellyfish blooms.

Habitat Characterization Indicators

Habitat characterization is an important component of any monitoring programme, 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)*. It is important to understand the habitat available within the MPA to gain a better understanding of the species' requirements and that the reference areas are appropriate.
- *Sediment composition (e.g. sediment grain size) and chemistry.* Important to understand as this information can provide insight into the structure and function to the community ecosystem.
- *Natural gas seeps and pockmarks.* The community around these structures can rely heavily on these features for energy input, and thus need to be better understood.
- *Nutrient flux (i.e. sediment and water)*. Several species of interest rely on the layer between the sediment and water and a better understanding is required.

Other Indicators

- *Underwater sound (i.e. natural and anthropogenic)*. Sound monitoring allows for the identification of sound-producing species and provides insights into how cetaceans might be using the LC MPA. It also characterizes the acoustic environment of the study area by identifying sound sources and estimating sound propagation properties. This can inform the anthropogenic stressor indicator of shipping and petroleum exploration activities.

Anthropogenic Pressure Indicators

The underlying principal of six COs for the LC MPA includes 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 the CSAS is mandated to provide scientific advice, it does not provide socio-economic advice. However, there are certain anthropogenic stressor indicators that can provide critical information that influence the biological and ecological components of the system, and are required to understand changes in the status and trends for the direct and indirect indicators (Table 4).

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

- *Regulatory compliance inside the MPA (regarding commercial fishing, oil and gas activities, vessel ballast water, etc.).* It is important to ensure the MPA regulations are enforced effectively when assessing if it is meeting its goals and objectives.
- *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.* Since the MPA will displace fisheries, this indicator will inform the effect of management measures in terms of spatial extent and patterns (i.e. aggregation) of fishing activity adjacent to the MPA after closure. It will be necessary to examine pre-closure fisheries data in order to assess the effects of the MPA on fishing effort distribution post-designation (Kenchington et al. 2012). This indicator will measure the consequences of fishing effort occurring outside the boundaries of the MPA i.e., threat to species that move outside the MPA (DFO 2014b). Fishing bycatch and mortality is a major risk factor to all the species of interest. RO 5 refers to the bycatch of sharks in adjacent areas.
- *Commercial infrastructure development activities*. It is important to continually acquire and update information on large-scale marine infrastructure that could have impacts on the species of interest to account for potential stressors to the COs and ROs inside and adjacent to the MPA (Park et al. 2011; DFO 2014b). For example, factors related to petrochemical exploration and extraction could impact the MPA and need to be quantified if they occur.
- *Vessel ballast water exchanges*. Similar to the previous indicator, it is important to gather updated information on ballast-water exchange activities in order to account for potential impacts of discharges on the performance of COs and ROs. Ballast water exchanges can affect water quality and enhance invasive species proliferation. Reports can further inform details of shipping traffic in the area (threat to turtles) (DFO 2014b).
- *Oil spills and longer-term leaks from marine vessels.* Spills and leaks can have long-lasting effects to the ecosystem and must be accurately identified and quantified. Oil spills can occur at various scales throughout Atlantic Canada that are monitored by dedicated Transport Canada surveillance flights. These threats should be monitored and quantified in the LC MPA.
- *Oil and gas exploration/production discharges.* Biologically-toxic discharges can have unintended consequences to the species of interest and their prey (i.e. turtles and their jellyfish prey); therefore, an accurate estimate of these quantities will be valuable. Drilling wastes may also modify benthic habitat and adversely affect sessile species (sea pens) and benthic fauna (prey species).

- *Seismic surveys*. Research is ongoing to determine the effects of seismic surveys on a wide range of species, including sharks. Therefore, it will be valuable to obtain accurate data on any ongoing seismic activities. It would be interesting to determine any effects of seismic noise on marine species such as sharks given the regulatory timing restrictions for seismic activity as proposed for the MPA.
- *Anthropogenic debris and other marine pollution inside and adjacent to the MPA.* Monitoring these activities will provide information on the intensity of the different threats to Leatherback Sea Turtles (and cetaceans) inside and in adjacent waters to the MPA. More information is required to assess threats to the Atlantic population. Regarding marine debris, the Recovery Action Plan (Atlantic Leatherback Turtle Recovery Team 2006) states that there is little information on how it affects Leatherbacks and that it would be useful to conduct studies on this topic. The Plan focuses on reducing the amount of marine debris through studies on the origin of manmade debris that might impact Leatherbacks and waste management. Education programmes can also be useful in reducing this threat.
- *Ship strikes (i.e. on marine mammals, leatherback turtles) in and adjacent to the MPA*. There is a direct link to mortalities as a result of ship strikes; therefore, quantification of the frequency and speeds of vessel passages, and the resultant vessel strike risks would be valuable information given the lack of restrictions for vessel passage in the proposed regulatory intent of the MPA. The Atlantic Leatherback Turtle Recovery Team (2006) states that it is necessary to identify areas where turtles and traffic overlap to assess the risk posed to turtles from this threat. In high-risk areas, work should be done with mariners, fishers and recreational boaters to identify and implement measures that will reduce this source of risk of harm and mortality to Leatherbacks (Atlantic Leatherback Turtle Recovery Team 2006).
- *Vessel transits (other than pleasure craft) by mercantile, surface, naval, and commercial fishing vessels steaming to fishing grounds*. Similar to the ship strikes, it would be valuable to determine the volume of traffic within the MPA as many ship strikes are not recorded as the ship may not be aware of their occurrence. Therefore, proxy or estimated ratio could be developed to determine their potential. Further, data collected from other vessels such as sightings when available can be informative. The vessel transit rate and type can be used to estimate risk via species density strike estimation techniques.
- *Anthropogenic sound*. Sound has been proven to effect marine mammals, sea turtles, and fish and therefore studying the characteristics of this stressor in the MPA would be valuable.
- *Biomass removal by research surveys conducted in the MPA.* This information is valuable to collect to determine the potential impact the research surveys are having on the MPA and the species of interest in particular.
- *Seabed area swept by bottom mobile research and monitoring gear (i.e. total and subdivided by seabed habitat type) in the MPA.* Given that bottom gear is a known risk factor for several species such as corals, it will be valuable to determine potential impacts on these potential vulnerable marine ecosystems.

MONITORING PROTOCOLS AND STRATEGIES

The following potential protocols (equipment, techniques, etc.) can be used the collection of data to inform the direct, indirect, and anthropogenic pressure indicators of the LC MPA. Protocols and strategies that could be useful for monitoring the LC MPA are provided. It should be noted that they are based upon best available knowledge and technologies at the time of publication of this Research Document and this list is not exhaustive. It is possible that other techniques could be used as the monitoring programme and technology evolves.

Direct Indicators Protocols and Strategies

Trawl surveys

Trawl surveys are fishery-independent, multi-species programmes conducted by DFO to assess commercial and non-commercial stocks in Canadian waters. In addition, distribution and abundance for corals and sponges have also been included in assessments in recent years.

In the NL Region, the surveys are conducted yearly in April-May for 3P using a stratified random sampling design. Strata are indicated in Figure 4 for the LC MPA region. A Campelen 1800 Shrimp Trawl has been used since spring 1996 for these surveys when it was switched from an Engel 145 High Lift Otter (demersal) Trawl (McCallum and Walsh 1995). Comparative fishing experiments to derive conversion factors for both gear types have shown that the Campelen catches a greater size range of most commercial species and a wider range of species than the Engel 145 otter trawl (Warren 1997). However, while comparative studies were conducted for major commercial species; the exercise was not completed for “minor” species which include the LC MPA species of interest. As a result, the indices of biomass and abundance obtained from Campelen surveys cannot be directly compared to Engel surveys, due to differences in catchability between the two gear types.

It should be noted that the fisheries located on other side of the LC, specifically 4Vns, are managed by DFO Maritimes Region. These trawl surveys are conducted in June-July using a Western IIA trawl on the Scotian Shelf, Bay of Fundy and Georges Bank (1985 to present) (Swain et al. 2012). A comparative study was conducted between the Campelen and Western IIA gear types in 2005 for Witch Flounder in 4RST (Swain and Morrin 2006); however, no major studies have been completed for the LC species of interest. Therefore, it may be more meaningful to compare the rates of change instead of the absolute values of indices derived from both regions, if required. Other differences between the surveys include fishing procedures, whereby 30-minute tows at 3.5 knots are performed for the Western IIA gear and 15-minute tows at 3 knots are conducted using the Campelen gear.

The NL multispecies survey represents a valuable source of data in the MPA area given its longevity (DFO has been collecting data in the LC area since 1972 by DFO NL Region) (Kenchington et al. 2012). However, historical data does not exist on the other side of the LC where there has been no consistent sampling deeper than 270 m to present (D. Clark, pers. comm., 2014). New strata have been added and will be sampled starting in 2014.

Advantages to the multispecies survey include the longevity of the data, pre-existing protocol that can be utilized with minimal adaptations required providing synergies and cost savings, and focuses on multispecies. Some of the disadvantages of deploying trawl surveys in the LC MPA include: the destructive nature of trawling to corals; the potential underestimation of abundance due to species (or sizes) with low catchability (e.g. Smooth Skate); the low level of confidence in data related to biomass, specific location and diversity of corals; and the large scale of the existing survey which requires adjustment to operate at the scale of the MPA. Another possible disadvantage of the trawl survey is that full coverage of the MPA may be interrupted due to weather, ice cover, and ship reliability. Vessel allocation is tightly-scheduled and can be subject to change due to breakdowns and repairs.

Modifications to the trawl survey approach are possible to reduce the overall impact to corals including reduction of bottom time, and changing the frequency of sampling within specific areas of the MPA (such as Zones 1a/b from yearly to biannual). Also, enhanced encounter protocols to ensure large coral patches are avoided in subsequent surveys and samples are retained for further analysis. Also, with regards to the fish species of interest, the main focus of the trawl surveys has traditionally been more commercial species (i.e. Atlantic Cod, American Plaice and redfish). The non-commercial/non-forage fish species are not studied as thoroughly as the "major" species. Therefore, it is recommended that enhanced sampling protocols be put in place for all the species of interest within 3P to obtain at a minimum length, weight and sex to enable future study and research on these species where possible. Retention of stomachs would provide additional useful data for studies of ecosystem indicators.

Shark pelagic longline survey

This type of fishery-independent survey can be conducted to provide status of the population health and abundance estimates and habitat use (e.g. Porbeagle mating grounds) of Porbeagle and other sharks found off of Atlantic Canada. Shark surveys were conducted in 2007 and 2009 by DFO Maritimes in conjunction with Atlantic Canadian fishermen from the Canada-US border to northern NL (Campana et al. 2013). The surveys were conducted in June, not a common fishing period in the LC MPA. Comparison of the survey abundance indices with previous commercial catch rates were difficult, however, population models predicted that survey catch rates were roughly comparable with 2000-06 commercial catches (Campana et al. 2013). There are no new planned surveys in the near term for the Maritimes Region; however, shark surveys in LC MPA could coincide with Maritimes Region on the other side of the LC to obtain a better zonal understanding of the shark population (S. Campana, pers. comm., 2014). It is recommended that a survey be conducted every five years following baseline establishment of abundance indices of sharks in the LC MPA among other indicators for the shark CO and RO.

Tagging surveys (pop-up archival transmission tags (PATs))

Tagging can be a useful tool to inform MPA managers and scientists on the movement of individuals in the LC MPA. The tags have been used in the past to track migration patterns and habitat use (e.g. pupping grounds) of wolffish, Porbeagle and other sharks and turtles in the Atlantic Ocean by DFO and other researchers (Campana et al. 2010; Simpson et al. 2014; Dodge et al. 2014). Some limitations of tagging include negative effects on tagged animals, failure to transmit data due to mechanical failure, tag destruction or loss, environmental effects, depth limitations and cost.

PATs have been used in Atlantic Canada by DFO Maritimes for sharks (Kerstetter et al. 2004; Pade et al. 2009; Campana et al. 2010). In 2013, the NL Region deployed a series of satellite tags on shark species in the NL Region. Tags were deployed on four Blue Sharks and one Porbeagle shark with plans to deploy more tags in 2014 (M.R. Simpson, pers. comm., 2014). Information gathered from an individual shark tag can include depth, water temperature and light intensity of the shark's path. In conjunction with the tagging, testing of baited underwater cameras is being conducted to establish a standardized biweekly estimate of shark encounters from which an abundance index could be developed over time (M.R. Simpson, pers. comm., 2014). This work can be extended for a more directed effort into the south coast of NL and the LC MPA.

Tagging is a tool that can be used to define movement patterns for Leatherback Sea Turtles in Atlantic Canada as well. Tagging for satellite telemetry enables remote tracking over broad spatial and temporal scales, and the collection of location, environmental, and dive data depending on the deployed tags. Dodge et al. (2014) identified limitations in previous studies to include:

1. Small sample size due to cost of tags and availability of turtles;
2. Daily tag locations are estimates (satellite tracking data contain errors in the observed locations of tagged animals, so data are treated in order to get estimates);

3. Tagging location and timing may result in underestimation of habitat use in some areas; and
4. Physical and behavioural effects of the tagging on the individual following capture and release from excessive handling of individuals while deploying the tag.

One current method of tagging turtles involves drilling small holes in the dorsal ridge of the shell of the turtle and attaching the tag (J. Lawson, pers. comm., 2014). A study conducted by researchers from Dalhousie University, the Canadian Sea Turtle Network (Halifax, Nova Scotia) and commercial fishermen in Nova Scotia found this protocol useful (DFO 2012b). The method could be applied in the LC MPA by deploying tags in the area between June and September when the turtles are migrating through the LC MPA. A collaborative arrangement between regions would be advisable to ensure consistent methods across the Atlantic region given the potentially large migration patterns. However, this type of survey has limitations depending upon the type of research questions asked and the expected goals of the programme should be carefully considered.

Passive acoustic receivers

Two main approaches could be implemented in the LC MPA depending on the requirement: one type of receiver records sound in the of animals in their proximity which uniquely-coded transmitters that have been previously attached; and the second approach employs a type of receiver that records the sounds emitted naturally by most marine animals or human activities.

The installation of acoustic receivers on the seafloor can be used to record signals of animals equipped with acoustic tags as they swim within the vicinity of a recorder depending on the range (could be between 800-1,000 m radius). This technique has been successfully used for a variety of species in Atlantic Canada including shark species, Atlantic Salmon, Atlantic Cod and wolffish (Ocean Tracking Network (OTN) 2014; Simpson et al. 2014), and has been proposed for monitoring cetacean presence and anthropogenic sound in the Gully (DFO 2010b). An existing network of receivers known as the OTN is depicted in Figure 5 It should be noted that there are other receivers not part of this Network that are deployed throughout Atlantic Canada, i.e. the map does not represent all monitoring efforts possible, just those linked to the OTN.

Research on migratory species could potentially benefit from this protocol, given that individuals are tagged and there is sufficient receiver coverage. Uploading data requires a vessel equipped with a hydrophone within range of the system or alternatively, the unit could be recovered using an acoustically tethered anchor. Batteries require changing on a continual basis, but some systems can be deployed for six months to six years prior to recovery. Given the large scale of the LC MPA, the quantity and placement of the receivers would require careful consideration to ensure effective and meaningful results (i.e. to ensure the receivers are available to the tagged species and in areas most frequented by species of interest).

A disadvantage of using these transmitters includes the effect on the animal during the tagging process whereby the animal, such as the Porbeagle, needs to be drugged to conduct a procedure to implant the tag putting the animal at potential risk (M.R. Simpson, pers. comm., 2014). However, other species, such as Atlantic cod are less affected by the procedure. Substantial investment of receivers and tags would be required to adequately cover the entire region which would require continual maintenance of the system given the large size of the LC. Further, the potential low return in data volume should be considered prior to installation of this type of system.

A second acoustic approach involves using a series of autonomous acoustic recorders (such as AURAL devices) that are deployed in the marine sound channel (approximately 50 m depth) at multiple locations throughout the LC MPA. These would record the underwater sounds emitted by many marine species (cetaceans, seals, fish, crustaceans, as well as anthropogenic sounds (seismic shots, vessel noise, underwater construction), and ambient noise (itself a function of biotic and abiotic sources). These recorders have the advantage that they can record sounds for prolonged periods independent of weather conditions or time of day. Computer processing techniques are available to analyse the large quantity of data these recorders collect.

Sea turtle (and cetacean) aerial surveys

Large-scale aerial surveys in offshore waters have the potential to be a useful component of a larger strategy for monitoring marine megafauna such as cetaceans, pinnipeds, sea turtles, seabirds, and fish that spend some time near the sea surface (e.g. sharks, sunfish, schooling fish such as capelin and mackerel). A systematic aerial survey in collaboration with other regions and governments (e.g. United States and France) could identify and quantify turtles and cetaceans in the LC MPA and adjacent areas.

An example of a large aerial survey occurred in 2007. DFO's Trans North Atlantic Sightings Survey (TNASS) collected data on the distribution and abundance of a variety of marine megafauna at the ocean surface in Atlantic Canada including Newfoundland and Labrador, Cape Breton, Gulf of St. Lawrence, and Scotian Shelf areas (Lawson and Gosselin 2009). These data were integrated with the European and American surveys to provide coverage for virtually all of the North Atlantic. Some of the limitations (which were addressed by the crew) included range limitations of the aircraft, platform- and observer-based differences in fauna detectability, and weather conditions (although for this survey, conditions were generally good).

Other aerial surveys have been employed to identify populations and distribution of Leatherbacks and cetaceans in the French territory of St. Pierre and Miquelon off the Newfoundland south coast (DFO 2012a). Such a survey could be conducted in collaboration with DFO NL and Maritimes Regions to benefit both regions. The next large-scale aerial survey is planned for 2017 in conjunction with an international effort, although currently funding to support this effort has not been allocated.

Other potential surveys are possible from different platforms that are designed for aerial surveillance, such as the Provincial Airlines Beechcraft King Air aircraft, which is used in the DFO Conservation and Protection (DFO Conservation and Protection (C&P)) aerial surveillance programme, although the fast aircraft speed and non-bubble windows of this platform make it less ideal for visual survey work than slower aircraft such as the Twin Otter aircraft (J. Lawson, pers. comm., 2014). Test flights would be advisable prior to incorporation into any large-scale programme. Cost of this type of survey is a major limitation. It could be conducted yearly, or every 5 years for updates and support of other monitoring and research efforts, with the possibility of aligning it with the planned 10-year interval for the Atlantic cetacean surveys proposed by DFO's Centre of Expertise in Marine Mammalogy (CEMAM).

Remotely Operated Vehicles (ROVs)

ROVs can be used to study the status and structure of coral and sponge assemblages for the following indicators: abundance, distribution, richness, and associated biodiversity. Sensitive benthic habitat indicators could be addressed from this non-invasive, “soft touch” protocol. ROVs allow for controlled sampling and detailed observation of specific deep-water habitats with the ability to retain samples when necessary. These can be equipped with depth sensors, compass, sub bottom profilers and multibeam sonars and laser beams providing a scale for measuring the size of the sampled bottom areas (Bo et al. 2012).

One specific example of a specialized research ROV is the Remotely Operated Platform for Ocean Science (ROPOS), operated by the Canadian Scientific Submersible Facility (CSSF) and designed for scientific/research purposes. The ROPOS has been deployed in Atlantic Canada to study deep-water gorgonian corals (Mortensen and Buhl-Mortensen 2004), and on the southwest Grand Banks to study deep-sea fish-habitat associations (Baker et al. 2012a) and coral assemblages (Baker et al. 2012b). ROPOS has also been used in Pacific waters to study glass sponge reefs (Cook et al. 2008). Recruitment trays have been deployed in study areas to determine the rate of recovery/change in a selected habitat. Other ROV platforms are available on the East Coast through contracts; however, since cost, platform availability and vessel time are limiting factors, planning needs to begin well in advance of any potential work. Consideration also needs to be given to the depth rating and capability of the system and operators prior to the selection of a particular ROV platform.

Benthic/habitat mapping studies

Benthic mapping studies are conducted to characterize the biotic and abiotic components of benthic assemblages within a specific area. Utilizing various technologies would enable the collection of data on corals and sponges as well as on sensitive marine benthic areas and habitats in the LC MPA (ROs 1 and 2). Provencher and Nozères (2011) used a variety of sampling methods to assess the benthic assemblages in the Manicouagan MPA.

From July 2010 to November 2013, DFO NL Oceans Division contracted the collection of multibeam bathymetry data with backscatter and sub-bottom profiles in the LC MPA (Figure 6). These surveys were conducted to a standard of 100% bottom coverage, in contrast to the 200% coverage that the Canadian Hydrographic Service (CHS) employs to produce navigational charts. The dataset covers approximately 10,900 km^2 of the LC MPA. Besides the multibeam data, the related backscatter was analysed to produce a number of associated data products including a backscatter mosaics, slope maps, curvature and aspect. A ground-truthing survey over the entire LC MPA was still in progress as of April 2014 (Figure 7). The data collected in the ground-truthing exercise includes grab samples, video and still imagery. The contract also included infauna collection for future analysis. Multibeam studies will provide information on suitable physical habitat for benthos, including corals and sponges (K. Gilkinson, pers. comm., 2014). The ground-truthing is required to determine smaller resolution changes in the habitat since the multibeam data does not provide the scale of resolution to track changes in the fine scale.

Other studies involve the use of multiple, usually simultaneous, tools to determine benthic assemblages and habitat features. The videograb, towcam, and campod described in Gordon et al. (2000) were designed and constructed at the Bedford Institute of Oceanography (BIO). This equipment has a small footprint when taking grab samples (K. Gilkinson, pers. comm., 2014); it is suitable for making time series observations at a given location and offers an alternative to more destructive methods.

Some of the tools are:

- *Towcam:* These underwater video recording units are useful for surveys on the scale of kilometres; towcams provide continuous imagery with which to discern major habitat features, and can be used over any kind of seabed as long as the relief is relatively low and the water is not turbid (Gordon et al. 2000). DFO NL has recently acquired a deep sea drop camera that can be used for this type of work, utilizing a dual camera system to provide photographic and video imagery of coral and sensitive benthic habitats up to 900 m.
- *Sidescan sonar and QTC-View Systems*: Based on acoustic class and sediment types, these techniques together produce a physical habitat map (texture and substrate characteristics), which provides a useful basis for designing subsequent biological surveys. Survey limitations include difficulty defining habitat boundaries with the sonar

when changes in the surface texture are gradual (Brown et al. 2000; Freitas et al. 2003; Brown and Collier 2008).

- *Benthic grabs*: These grabs are useful to sample infaunal and epifaunal organisms. Sample size and depth (e.g. amount of sediment and depth of the grab sample on each station) will depend on the surface area of the grab e.g. 0.1 m^2 (Hamon Grab, Van Veen, Smith-McIntyre grabs) or 1.5 m^2 (IKU grab), and on penetration depths e.g. 20 cm (Smith-McIntyre grabs) or 50 cm (IKU grab). Some of the limitations of benthic grabs include difficulty to sample rarer megafauna components, limited sampling sites, not allowing for detailed benthic maps, and costs and time (Brown et al. 2000; Gilkinson 2013).
- *Box core:* The box corer is used to collect sediment samples and biota at sea-floor features as a complimentary tool. Box corers are a common tool used in many types of marine surveys to determine habitat types, utilization and sediment quality (Majewski et al. 2009). Limitations of the box core include the destructive nature of sampling and limited sample size possible. Box corers can also be limited if the seabed type is coarse to boulder; however, the LC MPA is known to be mainly mud, based on previous seabed mapping exercises.
- *Video grab:* A more specialized benthic grab is the BIO videograb, which has an associated video imagery that provides information on the undisturbed habitat from which the sample is collected as well as information on the quality of the sample (Gordon et al. 2000).
- *Campod:* The Campod system provides a high-resolution video and photographic imagery of benthic habitat and epibenthic organisms. The Campod system can have different resolution settings and can be used over any kind of seabed regardless of relief, including steep walls of submarine canyons. The Campod can be towed just above the seabed during slow drifts, as well as set down on the seabed to take video and photos (K. Gilkinson, pers. comm., 2014).

Local Ecological Knowledge (LEK)

The use and collection of LEK can have significant benefits for monitoring programmes depending on how it is collected, used and the type of indicator being informed. LEK is particularly useful in generating baseline information in poor-data situations and can be used conjointly with scientific knowledge to provide a larger picture (Neis et al. 1999; Colpron et al. 2009; Dawe 2010). Additionally, integrating LEK and science allows for meaningful participation of fishers (Colpron et al. 2009). Even though the LC MPA is an offshore area, fishers can “have a ‘user-social’ attachment and a significant knowledge base relating to the offshore environment” as shown in the Gully MPA (Charles and Wilson 2009).

The main limitation of LEK is the potential to be perceived as anecdotal, and consequently its use in science and management has been limited (Dawe 2010). However, the use of fishers’ LEK is increasing. Examples include two studies conducted in the Northern Gulf of St. Lawrence where fishers’ LEK was integrated with scientific knowledge, one of which was a study on the biology, biogeography, and population trends of three species of wolffish (along with analysis of stock assessment data and on-board observations) (Dawe 2010). The other study collected data on the distribution of deep-sea corals (Colpron et al. 2009). In the Maritimes, LEK has also contributed to the location of corals, descriptions and samples of different species (DFO 2006). Fisher participation has allowed for the identification of potential locations for scientific surveys and a better understanding of preferred coral habitat (DFO 2006).

Locally, a survey of fishers on the south coast of Newfoundland was conducted in 2013 to ascertain the level of shark bycatch experienced by fishers from the LC area which will continue in the 2014 season (M.R. Simpson, pers. comm., 2014). The aim of this survey is to record catch of sharks in the inshore fleet where there is no observer coverage. LEK surveys could also be extended to include sea turtles and cetaceans, among others species; similar surveys were conducted to ascertain pinniped and cetacean bycatch in lumpfish and similar gillnet fisheries in the late-1990s. Inclusion of non-governmental organizations (NGO) sightings into the occurrence data base would be valuable information to gain a better understanding of the migration patterns of these species.

Indirect Indicator Protocols and Strategies

Atlantic Zone Monitoring Program

The AZMP provides regional and zonal monitoring of a broad suite of oceanographic variables. In the proposed LC MPA, the Cabot Strait and St. Pierre Bank lines of the AZMP (Figure 8*)* can provide the necessary oceanographic information for the indirect indicators related to physical and biological oceanography (P. Pepin, pers. comm., 2014). When taken together, current protocols acquire data from upstream and downstream in all directions although the sampling is not simultaneous, it is likely sufficient coverage for use as a protocol to inform the indirect indicators. The existing programme has occurred in the spring and fall every year since 1998 from DFO CCG vessels, although the St. Pierre line commenced in 2010. The AZMP aims to collect and analyse the biological, chemical, and physical field data that are necessary to:

1. Characterize and understand the causes of oceanic variability at the seasonal, inter-annual, and decadal scales,
2. Provide multidisciplinary data sets that can be used to establish relationships among the biological, chemical, and physical variables, and
3. Provide adequate data to support the sound development of ocean activities.

Standard AZMP stations collect data on temperature, salinity, pH, nutrients, and phytoplankton among others. In 2014, calcium carbonate chemistry will also be collected and analysed which would potentially be useful for informing the sea pen CO and sensitive benthic habitats RO. Further, during the survey, profilers obtain current data through the continual use of an acoustic Doppler current profiler (ADCP). Zooplankton collection, enumeration and identification can also be conducted as a component of AZMP surveys.

Satellite (SST, chlorophyll, ice)

Satellite information can be compiled to provide sea surface temperature (SST), chlorophyll a and sea ice distribution data that will be useful in the interpretation of other monitoring results. This data can be obtained through DFO, Environment Canada and National Oceanographic and Atmospheric Administration (NOAA) among other sources. Limitations in this information include a limited spatial resolution, restrictions due to cloud cover, and a degree of specialized training to interpret the data. However, no specialized sampling equipment would be required.

Ocean observatory/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. Satellite phone links from these moorings can be used to transmit data to a base station if they are surface moorings. Subsurface moorings require retrieval through the use of an acoustic release and surface vessels. There is a substantial cost in maintenance and battery replacement which would include tending (depending on length of deployments) and vessel time to retrieve the equipment on a regular, ongoing basis.

Similarly, acoustic recorders can be installed on the oceanographic moorings, with bottom-mounted anchoring systems to record soundings of anthropogenic activities, and natural sound sources such as weather and marine megafauna such as cetaceans (see above). By recording the sounds of the animals in the area, RO4 can be informed to gain a better understanding the species complement of the study area. As described for the receivers of the OTN, deployment and placement of the moorings require careful consideration to ensure the best possible location. Several moorings throughout the MPA could yield better data coverage, and accommodate the variable sound propagation previously observed in the LC (J. Lawson, DFO, pers. comm., 2014). Cost and deployment/retrieval are limitations of the acoustic moorings, although the time and costs to analyze the recordings can also be relatively high as it requires specialized equipment and expertise. These types of systems and data analyses could be conducted by DFO or through contracting services as required.

Underwater vehicles (gliders)

Underwater vehicles, such as gliders are used as a remote sensing tool to observe changes throughout the water column and can be a useful given the appropriate research question. They have been used by the OTN to collect acoustic tagging data from moored recording stations (OTN 2014). Dependent on the payload, the glider can be useful tools for collection of data from CTDs, sonar and/or current meters. Limitations of underwater gliders include cost, the requirement for hands-on deployment and continual maintenance. The battery life is dependent upon the type of payload package, but likely lasting several days to one month. The Canadian Center for Ocean Gliders is a national non-profit organization that houses and maintains four gliders which can be deployed at a cost dependent on the purpose and research question being proposed.

Anthropogenic Pressure Indicator Protocols and Strategies

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 MPA and adjacent waters before and after the inception of the MPA. This information could be valuable to determine the level of activity in the MPA and in adjacent waters due to fishing and other uses such as transiting. The schedule of vessels required to have a VMS is available through DFO Fisheries Management and can change depending on the vessel size and type of fishery. Data has been collected since 2004 when there were < 1500 vessels equipped with VMS throughout Canada. As of 2012, more than 2,800 vessels were equipped with VMS (N. Barbour. pers. comm., 2014). Information on vessels that do not carry a VMS unit could be collected via fishers' organizations. As of 2014, a DFO has compiled a series of three reports on vessel movements within 100 km of Atlantic Canadian coasts (for Canada's east coast see Simard et al. 2014).

Commercial landings and logbook data

This information is collected by DFO as part of fishery license requirements. This information will be valuable for establishment of the type of fish being caught areas adjacent to the MPA which could be benefiting from conservation activities within. The main limitation is the accuracy of the information reported by fishers as the species of interest would be considered as bycatch and thus may not be accurately recorded. Specific projects could be designed to collect missing details or complimentary information on fishing trips as required. At-sea observer coverage and dockside monitoring could also be enhanced to provide better information for this region given the Department's commitment to the LC MPA.

Infrastructure development

Developments such as number and types of seabed cables, offshore-petroleum exploration and development activities, etc. should be monitored and documented. Information is collected by various agencies that are also members of the LC Advisory Committee, including CHS)and Canada-Newfoundland and Labrador and Canada-Nova Scotia Offshore Petroleum Board (C-NLOPB and C-NSOPB, respectively). MPA managers could request data on the development of infrastructure within the LC MPA on a regular basis. Human activities that could potentially affect the resources in the MPA should be accurately maintained for baseline information in case an event could occur that could impact the MPA, such as oil spills, etc. Further, updated information from partners could be useful within DFO (i.e., Fisheries Protection Program) and other governmental organizations (i.e., Transport Canada and the NL provincial government) which could be input into the overall data management system for the MPA.

Ballast-water reports

These reports must be submitted by vessels and pleasure crafts as part of the Ballast Water Management Plan (*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.

Research on sea turtle-human activities

Research on entanglements in fishing gears, ingestion of marine debris, and ship strikes can be developed in conjunction with DFO, fishing industry, NGOs, and academia. Other groups could be observers from the Canadian Wildlife Service and the Sea Watch Program. This is no existing data collection protocol for this particular project (although it exists for national sightings and other types of biological data in DFO) and the logistics and feasibility of acquiring this type of information needs to be explored potentially through the LC Advisory Committee.

PROPOSED EXPERIMENTAL DESIGN

A potential approach to assist MPA managers in assessing outcomes of the MPA using the identified indicators, protocols and strategies is proposed. It should be noted that the LC MPA species of interest are long-lived and it may take an extended period of time, (i.e. lag time) before substantial changes in their status (if any) occur. Another consideration is the range and diversity of the species of interest. Given the migratory nature of some species, it may be difficult to detect noticeable changes in a relatively small region of the species range. It is important to be aware of potential expectations prior to any assessment of the MPA.

Types of Experimental Design

Several types of experimental designs have been used to determine the effects of management measures of MPAs. Common designs are highlighted in Table 9 and the problems that may arise in drawing conclusions from the resulting data.

In any type of experiment, a critical aspect of design includes the provision of a control or reference site to demonstrate if change has occurred resulting from a change at the treatment site (Botsford et al. 2003). Further, the appropriate selection and use of a control area in the assessment of MPAs provides scientific defensibility to any type of comparative experiment. Reference area(s) should be selected to represent similar habitats, species representation and conditions to the treatment area (i.e., inside the MPA). The LC MPA is no exception and the delineation of such control area(s) can be complex, due to its size and diverse species of interest that have specific habitat requirements. As a result, it may be necessary to select different areas as appropriate for different species.

In some cases, the lack of specific LC MPA data prior to designation can hinder the statistical power and assessment. While it is recognized that MPAs are designated based on a range of factors, planning is required to ensure the science does not come after the social-economic considerations. It would be useful to identify and monitor more potential control sites at the beginning of a programme then omit ones that do not track the progress or are not relevant to the overall programme in consultation with the Science Steering Committee and stakeholders after a suitable time (Osenberg et al. 2011). It is recommended that a study on the statistical power of the number and location of appropriate treatment and reference sites inside and outside the MPA be conducted. A study of this nature would ensure the scientific defensibility of the monitoring programme.

A model programme is presented as an ideal means to monitor the LC MPA using the identified indicators above. However, it is recognized that due to the availability of resources (i.e., vessel allocation schedules, budgets, etc.), that it may be not possible as detailed. Therefore, an alternative means of conducting the programme is also presented.

Ideal Programme

Non-Migratory Fish Species (Black Dogfish, Smooth Skate and Northern Wolffish)

An ideal programme for monitoring the non-migratory fish species of interest in the LC MPA would involve using a CCG vessel (such as the *Alfred Needler* or *Teleost*) to ensure data comparability with historic values from the multispecies survey for gear types, crews, etc.

The programme would likely require approximately six days per year to complete, depending on weather and other extenuating circumstances, starting as soon as possible to obtain pre-designation data to build a historical data set or “before” condition. Current trawl surveys allow for 6-10 sets per day in the NL Region (D. Power, pers. comm). It is proposed to conduct a series of fixed station trawl sets (in the same duration, speed and conditions as the existing multispecies survey protocols) in Zone 2 a/b using the Campelen 1800 shrimp trawl gear as used in current NL multispecies surveys. The ideal approach would be to conduct a minimum of two fixed-location sets within each strata of the LC MPA every year.

The other side of the LC represents a possible control site given the similar habitat, depth and oceanographic conditions as the LC MPA. Similar sampling effort would need to be conducted in the control sites as in the MPA. However, the adjacent side of the LC resides in the Maritimes Region, and as described above, regular trawl surveys in 4Vns use Western IIA gear type during the summer. For this reason, to enable good data comparability it is recommended that sampling be conducted in that area in the same trip and using the same gear type. The strata adjacent to LC MPA (558 and 559; Figure 4) are two very large strata; therefore, it is recommended that they be subdivided into two sections each, with two sets in fixed location conducted in each sub-area. The total fixed sets for the programme would be a minimum of 24 total sets (i.e. 16 within the MPA and 8 in the reference area). It should be noted that the ongoing trawl surveys in 3P and 4V should continue to be conducted as usual; however, not inside Zones 1a/b, due to the invaluable data they acquire for other DFO programmes.

Corals (Sea Pens)

Zones 1a/b should be excluded from the yearly trawl survey monitoring regime. Instead, sampling would occur in those areas using “soft touch” methods such as deep sea camera/imager or ROV that would be on board the Canadian Coast Guard (CCG) vessel as part of the larger monitoring mission as described above. The sampling protocols within each zone and the exact locations will depend upon initial baseline monitoring and results from the ongoing habitat mapping exercise currently being conducted by DFO NL Oceans, in consultation with Kenchington (2014).

Similar efforts should be conducted on a habitat with sea pen aggregations where no management measures are in place, such as in the aggregation of sea pens in Strata 559 in 4Vs as identified in Kenchington (2010) and along the slope of the LC. For comparison purposes, reference areas should include “highly trawled areas” to compare to Zone 1a/b that are considered “no-trawl areas”. It is important to keep in mind that trawling is not the only stressor influencing the abundance of sea pens. A gradient could be considered i.e. sampling inside the MPA to middle and heavy fished areas. It is warned that the conclusions regarding reference areas for corals should not be drawn only from the study by Kenchington et al. (2010) on coral density areas since it is based on a few sets and further decisions on specific sampling locations within Zones 1a/ b should be following results from the ongoing ground-truthing and baseline surveys.

If it is expected to measure spillover effects to adjacent areas, the distance from the boundary must be considered as a variable. Ideally, monitoring of sediments, epifaunal, and infaunal organisms should be conducted yearly or even seasonally. It is advisable to conduct an initial baseline groundtruthing exercise in the proposed sampling areas (treatment and reference) prior to the final selection of long term monitoring locations to ensure appropriate areas are considered. Coral work would likely need to occur every five years after the initial baseline monitoring and establishment of optimal station locations (based on initial survey results).

Migratory Species (Porbeagle, Leatherback Sea Turtle)

A traditional reference area may not be possible for the migratory species of interest (i.e., Porbeagle Shark and Leatherback Sea Turtle). For the Porbeagle, a shark longline survey centred in the LC could be completed in the early stages of the designation process to establish a baseline of relative abundances. Given the Porbeagle and other shark species’ migratory nature, the programme would be ideally coordinated with Maritimes to incorporate with St. Anns Bank AOI for a zonal programme and focus. The Porbeagle shark has a low rate of recovery; therefore, it is likely that a five-year survey cycle would provide ample feedback (S. Campana, pers. comm., 2014).

Turtle and cetacean monitoring could be conducted annually using aerial surveys to update the 10-year time frame of the repeated surveys through CEMAM. The next large-scale Atlantic survey is scheduled in 2017 to assess the population and status of the various megafauna traversing the region. The aerial surveys could also be conducted in the same zonal arrangement as described for the Porbeagle.

Tagging surveys for both species would also be useful on a yearly basis to monitor the occurrence, use and movement patterns within the LC MPA and should be conducted as part of this programme. However, due to the behaviour effects and potential risk posed to turtles during tagging, it is not recommended at this time.

Finally, ongoing LEK monitoring of bycatch and sightings would be extremely valuable to continue for both sharks and turtles to provide hands-on information from the local fishers along the south coast of NL.

Indirect indices

The AZMP suite of measurement parameters could be completed while sampling is on-going on the main research survey including enhanced zooplankton and calcium carbonate measurements. It would be relatively straightforward to integrate certain components of the oceanographic monitoring programme into the overall mission plan while other components of the survey are on-going.

Moorings or fixed stations for acoustic receivers and oceanographic sensors could also be deployed and maintained during these missions. It would be recommended to mount a series of bottom mounted subsurface oceanographic moorings with temperature, salinity and dissolved oxygen sensors along with current profilers in the LC MPA, inside Zones 1a/ b. Work should be completed to determine the efficacy of coupling these systems to acoustic monitoring equipment (i.e. AURAL recorders) deployed for the cetacean and ambient noise studies.

Anthropogenic indices

All the described anthropogenic indicators should be collected and analyzed by the necessary means to inform the indicators and also make the information available to the Science Steering Committee as part of a database established to maintain all relevant MPA data. The integration of the information will be useful for analysis and assessment of the effectiveness of the MPA for managers on a continual basis as part of the adaptive management approach.

Alternative Monitoring Programme

There can be many extenuating factors involved in planning and executing a complex programme such as the LC MPA monitoring programme, namely the lack of reliable ship time on a vessel that is already fully tasked, logistical challenges of surveying an area outside the NL Region's management, and quantity of historical data. As a result, alternative means must be considered.

The existing multispecies surveys should be used given the longevity of the data source from the MPA and potential reference areas should be selected on the NL side of the LC. A reference area for deep water could include the area along the NL/NS Oil and Gas Regulatory Tribunal Line, not part of the MPA. However, it is warned that adjacency does not necessarily mean similarity between areas. Suggested reference areas based on the DFO NL multispecies stratum (See Figure 4) include: 319 and 711 (based on similarities; although 319 is the slope), the outside portion of 706, outside 713, north and south of 714, the south east of the LC extending into the French zone (collaboration is possible), 715, 716 and 310 (Burgeo Bank). Areas 712-714 towards St. Pierre may be suitable for the Black Dogfish and Wolffish. It is not recommended to use contractors or outside sources to conduct trawl surveys in the MPA. The long-standing existing data set would not be comparable to a new trawl, ship, and sampling protocols to acquire this data.

It should be noted that the statistical power of the number of sampling sites and locations should be considered prior to the final design of the long term monitoring plan.

Sharks, turtle and cetacean protocols are not a component of the trawl survey programme, therefore relies on other means. These would represent new components to monitoring directed specifically at the LC MPA, with the exception of the collection of LEK. Components of these surveys are possible to conduct through contracts from outside sources such as chartering vessels and some equipment deployments. For turtles, an estimated reference area could be towards the easterly end of the LC study region including St. Pierre and the Burin "turtle box", strata 314 if looking for density of prey, and strata 308 for sound surveys.

Aerial surveys in collaboration with C&P are ongoing, but not conducted specifically for LC MPA monitoring at this time. They are focused on reconnaissance work, rather than surveying for abundance and distribution, therefore caution must be taken in using this type of strategy. Chartering this service to other groups may be advisable for better data quality and applicability. Also, data processing of sound recordings would be a component that could be outsourced due to the nature of the work and expertise required.

Coral surveys would need to be conducted on a separate platform from the trawl surveys as the multispecies surveys are tightly scheduled and would not be available for separate coral work. Separate vessel surveys for coral studies, such as those of the CCG *Hudson*, could be undertaken as part of other ongoing coral surveys supported by DFO Science Maritimes, through their support for directed LC MPA work. Other vessels can also be used for ROV deployment depending on their capability and availability. Collaborations with other organizations within academia may be an ideal outsourcing avenue.

Limitations in the proposed framework

There are several limitations in this framework. Prior to committing to a final course of action, much more baseline data is required for all the species of interest. Generally, these are not well-studied species; therefore, many questions are outstanding that need to be answered before qualified advice can be provided. For example, coral distribution is based on a kernel density model (Kenchington et al. 2010) and a groundtruthing data set is necessary to support any final decisions on the best locations within the MPA for long-term monitoring. Information on the seasonality and life history of species such as black dogfish remains largely unclear, therefore more sampling is required.

While it was specified that a regular interval for the aerial surveys should be considered, no specification of the scope of each of these surveys was provided. Effectiveness (and costs) rise with increased coverage obtained through decreasing transect spacing or undertaking replicates. The coefficient of variation for estimates from the 2007 TNASS coverage, while good compared with other aerial surveys for marine megafauna, are large enough to make anything but quite large changes in megafauna local abundance undetectable. This is a limitation of most aerial surveys – thus studies are usually replicated over time (Taylor et al. 2007).

(Final) Recommendations for Monitoring

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 LC 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 programme and the provision of oversight on advancing Research Objectives in cooperation with MPA managers.

It is recommended that once MPA monitoring has been initiated, long-term maintenance of the programme be established given that most indicators are slow to respond and short-term changes may be difficult to detect. Flexibility in the programme is required based on many factors, but the core programme is important and should be maintained once established.

OTHER CONSIDERATIONS

Considerations for enhancing the value of MPA monitoring activities include ensuring adequate baselines have been established; understanding lag times; and establishing protocols for data management, storage, and accessibility. Coordination of monitoring with similar activities in other Departmental programmes 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 species 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 following establishment of an MPA should be considered carefully when assessing monitoring results to determine MPA success against objectives.

Development of a data management system is an integral component to a monitoring programme, 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. Initiatives exist within DFO for managing sightings data, biological data, and imagery.

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.

CONCLUSIONS

The LC MPA is a large, complex ecosystem for which there are many data gaps that need to be addressed through baseline monitoring prior to the establishment of a large-scale and long-term monitoring programme. Appropriate experimental design with reference areas and baseline data will assist MPA managers in demonstrating the long-term effects of management measures. The proposed indicators in this framework will together form a basis to provide context and understanding for this study of the LC MPA ecosystem.

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

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

Overall, 11 direct indicators, 25 indirect indicators and 14 anthropogenic indicators have been identified to monitor the proposed LC MPA. Analysis of the status and trends of these indicators will provide MPA managers with the information necessary to assess effects resulting from the establishment of the LC MPA where appropriate. They will also allow the assessment of direct effects of the management measures enacted through the establishment of the MPA, in the context of overall variation or change within the ecosystem. The assessment of the effects of the MPA on the COs requires the appropriate selection and use of reference areas, to be determined in conjunction with a scientific steering committee. These areas, outside of the MPA, should be selected to represent similar habitat, species representation and conditions to the treatment area (i.e. inside the MPA), and should consider the ability to detect changes among these areas. Hypothesis driven assessment of MPAs provides scientific defensibility for the monitoring program.

Strategies for the collection of indicator data include incorporating and/or extending 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 events), and following existing standardized protocols for those undertakings. However, where collaborative or contractual agreements are necessary to acquire indicator data, it is important that data collection protocols are standardized if not conducted by DFO personnel – 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 programme if using contracted services.

There remain knowledge gaps in the understanding of specific aspects of many of the species of interest within the LC MPA, as well as gaps in knowledge related to the overall functioning of the LC ecosystem. Data gaps exist in our understanding of the life histories of all species of interest in the LC MPA; and baseline distributions and detailed taxonomy for corals and sponges are particularly limited. Research is required to address data gaps 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 programme for the LC MPA. Through an adaptive management process, this committee would also be responsible for interpreting the scientific results of the monitoring programme and the provision of oversight on advancing Research Objectives. And, if necessary, the Committee could recommend modifications to data collection or analysis protocols to ensure maximum utility of the data in support of the LC MPA.

It is recommended that once MPA monitoring has been initiated, long-term maintenance of the programme be established given that most indicators are slow to change and short-term changes are unlikely.

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APPENDIX I - ACRONYMS

Acronym	Definition
ADCP	acoustic Doppler current profiler
AOI	area of interest
AURAL	Autonomous Underwater Recorder for Acoustic Listening
AZMP	Atlantic Zonal Monitoring Program
BIO	Bedford Institute of Oceanography
CBD	Convention of Biological Diversity
CCG	Canadian Coast Guard
CEMAM	Centre of Expertise in Marine Mammalogy
CHS	Canadian Hydrographic Service
CNLOPB	Canada Newfoundland and Labrador Offshore Petroleum Board
CNSOPB	Canada Nova Scotia Offshore Petroleum Board
CO	conservation objective
CSAS	Canadian Science Advisory Secretariat
CSSF	Canadian Scientific Submersible Facility
CTD	conductivity, temperature and depth sensor
DFO	Fisheries and Oceans Canada
DFO C&P	Fisheries and Oceans Canada Conservation and Protection
DFO FAM	Fisheries and Oceans Canada Fisheries and Aquaculture Management
DFO FPP	Fisheries and Oceans Canada Fisheries Protection Program
HOTO	Health of the Oceans
LC	Laurentian Channel
LEK	local ecological knowledge
MPA	marine protected area
NAFO	Northwest Atlantic Fisheries Organization
NGO	non-governmental organization
NL	Newfoundland and Labrador
NOAA	National Oceanographic and Atmospheric Administration
OTN	Ocean Tracking Network
PAT	Passive acoustic tag
RO	research objective
ROPOS	Remotely Operated Platform for Ocean Sciences
ROV	remotely operated vehicle
SARA	*Species at Risk Act*
SST	sea surface temperature
TNASS	Trans North Atlantic Sightings Survey
VMS	Vessel Monitoring System
YOY	year of young

APPENDIX II - FIGURES

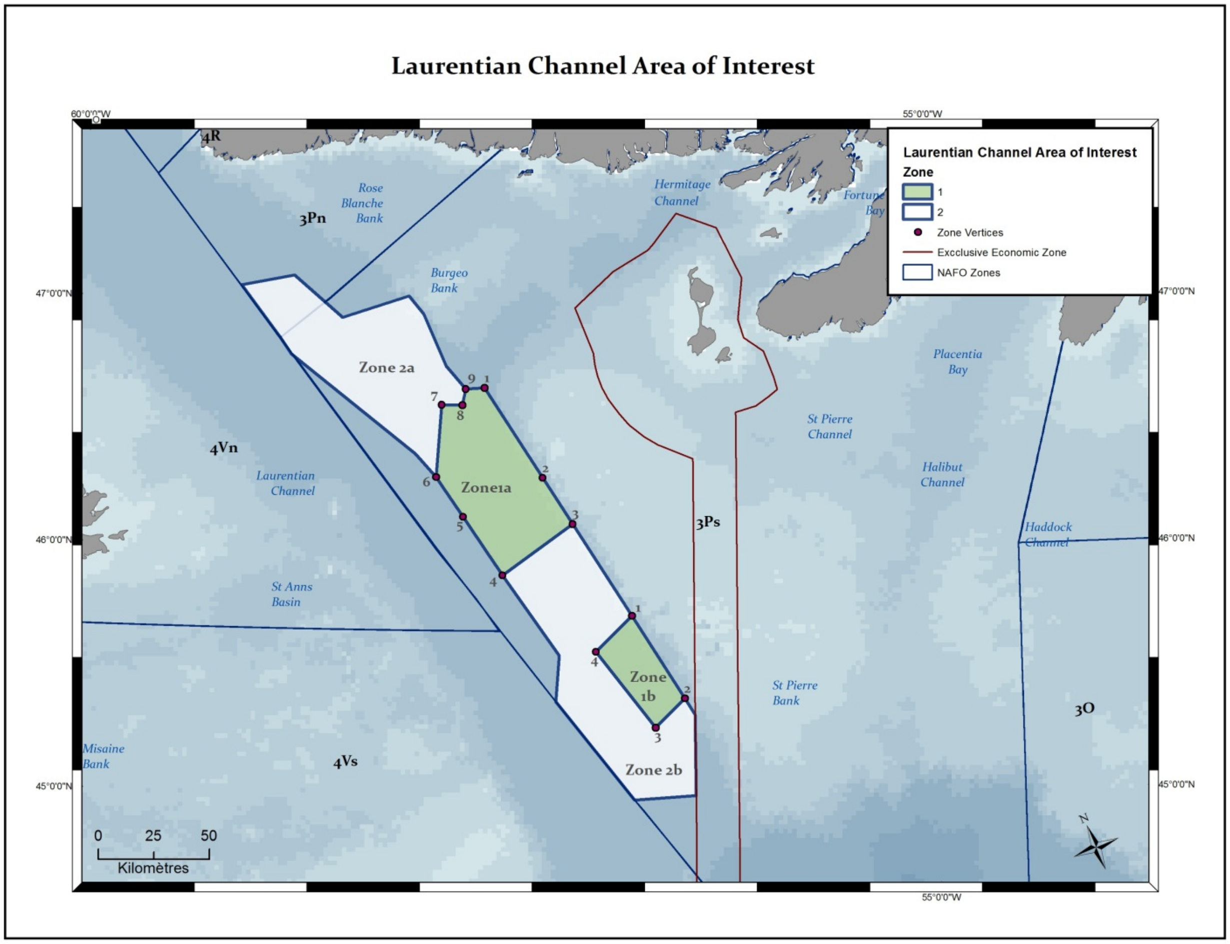

Figure 1. Boundaries and zoning scheme of the proposed LC MPA (June 2014). Total proposed MPA area covers approximately 11,908 km^2. Green areas (30% of the MPA): Zone 1a (ca. 2,722 km^2) and 1b (902 km^2). Zones 1a/b offers the highest level of protection within the MPA. White areas: Zone 2a (ca. 3,941 km^2) and 2b (ca. 4,343 km^2). Zones 2a/b will accommodate activities compatible with the conservation objectives.

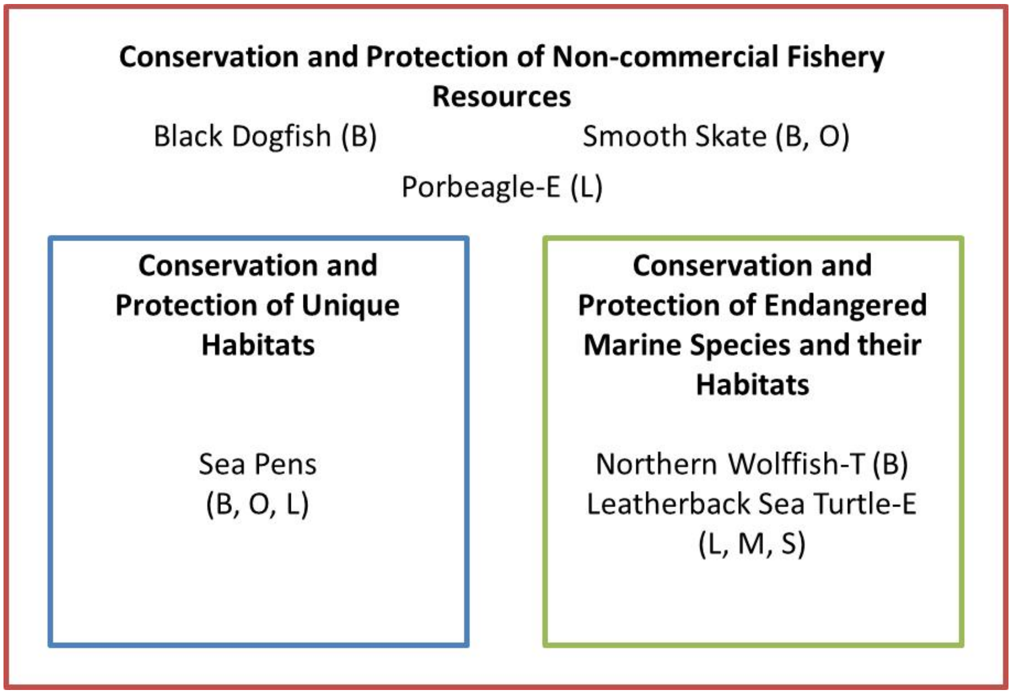

Figure 2. LC MPA contributions to the ecosystem. It will contribute specifically to the conservation and protection of non-commercial fishery resources, unique habitats, and Endangered (E) or Threatened (T) marine species (Oceans Act) by regulating human activities that pose threats to COs such as bottom trawling (B), longlines (L), and oil and gas activities (O). Non-regulatory measures and an agreement towards best practices are being pursued to address marine debris (M) and ship strikes (S).

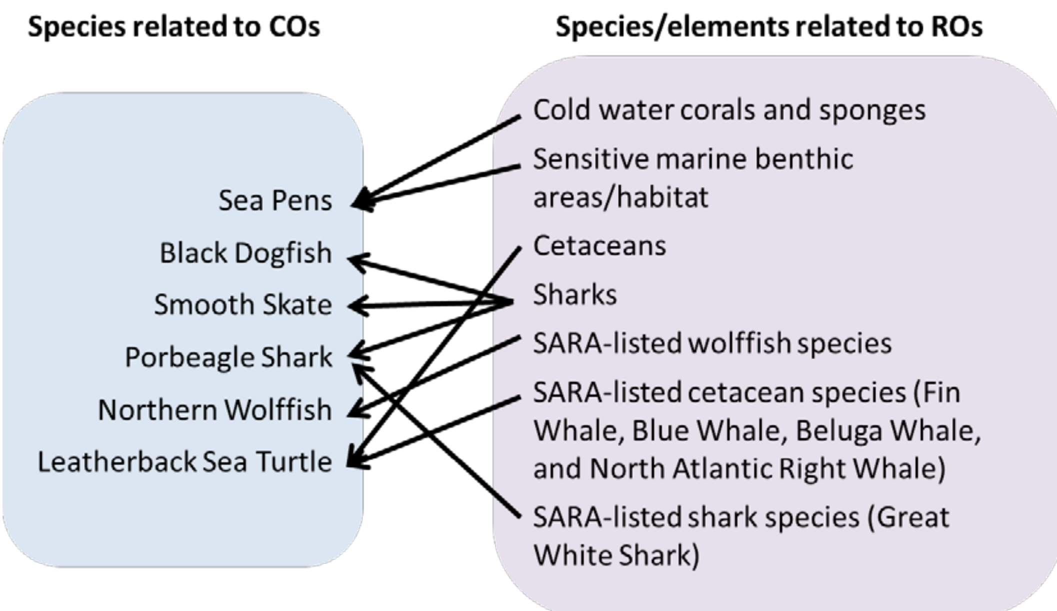

Figure 3. Links between the species of interest considered as COs and the species or elements considered as ROs in the proposed LC MPA. Plankton variability (RO 3, excluded from this figure) is not directly linked to any CO but it is included as an indirect indicator. SARA-listed species refer to RO 6.

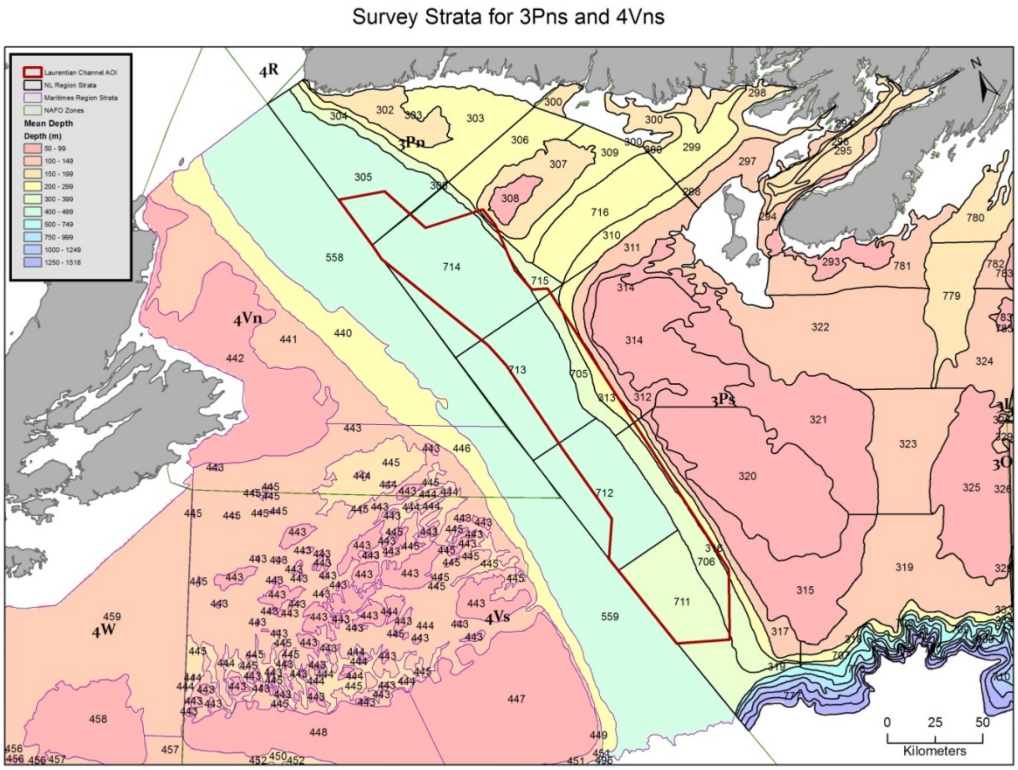

Figure 4. Multispecies survey strata in the LC MPA region. The boundaries of the LC MPA (circa 2014) are outlined in red.

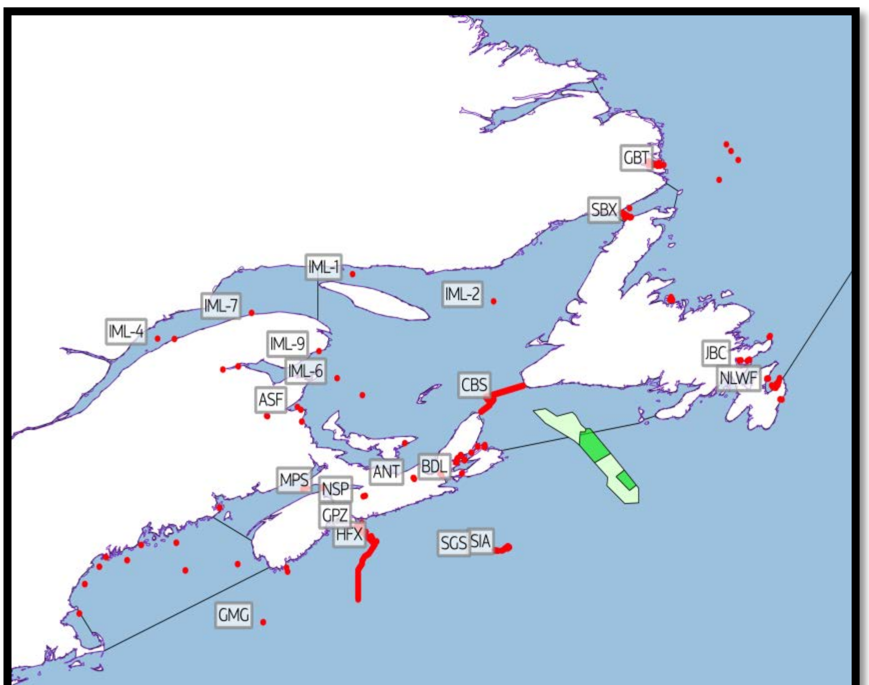

Figure 5. Ocean Tracking Network (OTN) current acoustic receivers (red) in Atlantic Canada with reference to the LC MPA (green) (Source: Ocean Tracking Network).

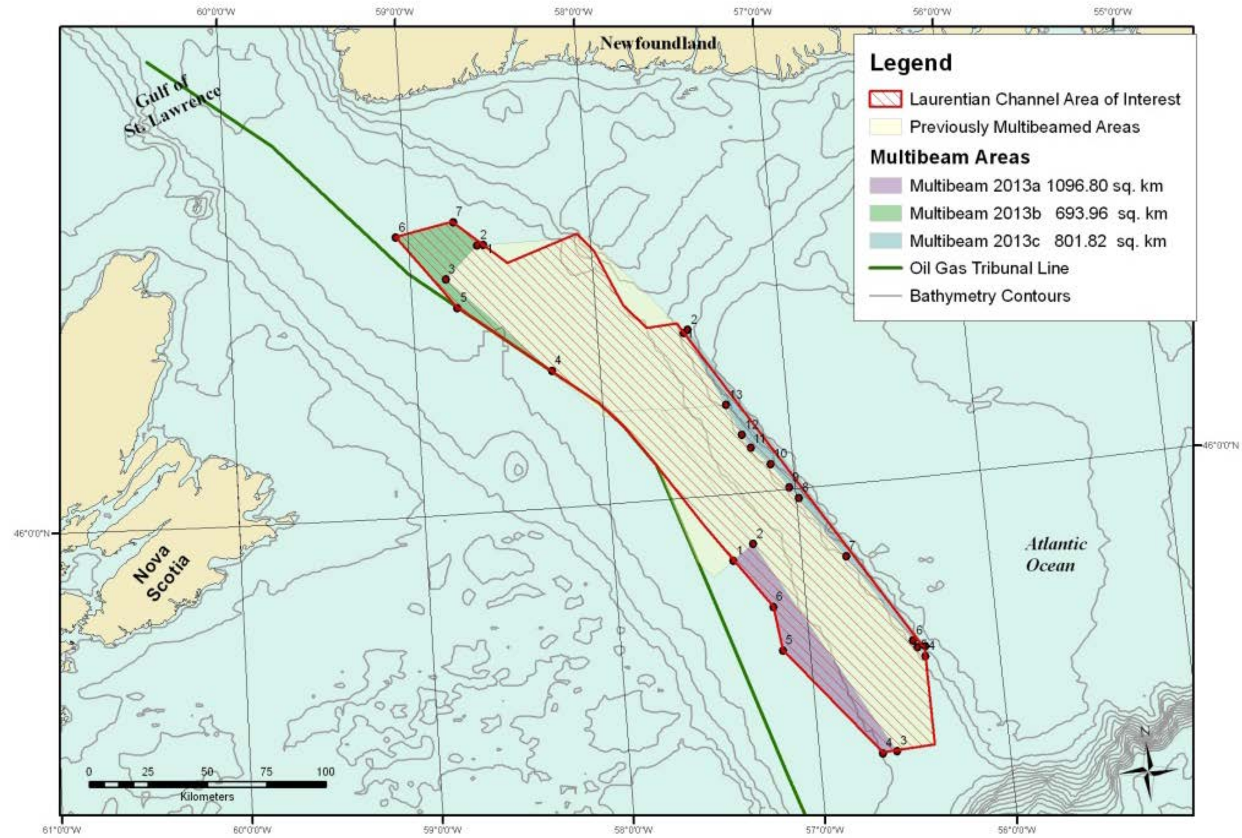

Figure 6. Areas covered by the 2010-2013 multibeam survey in the LC MPA.

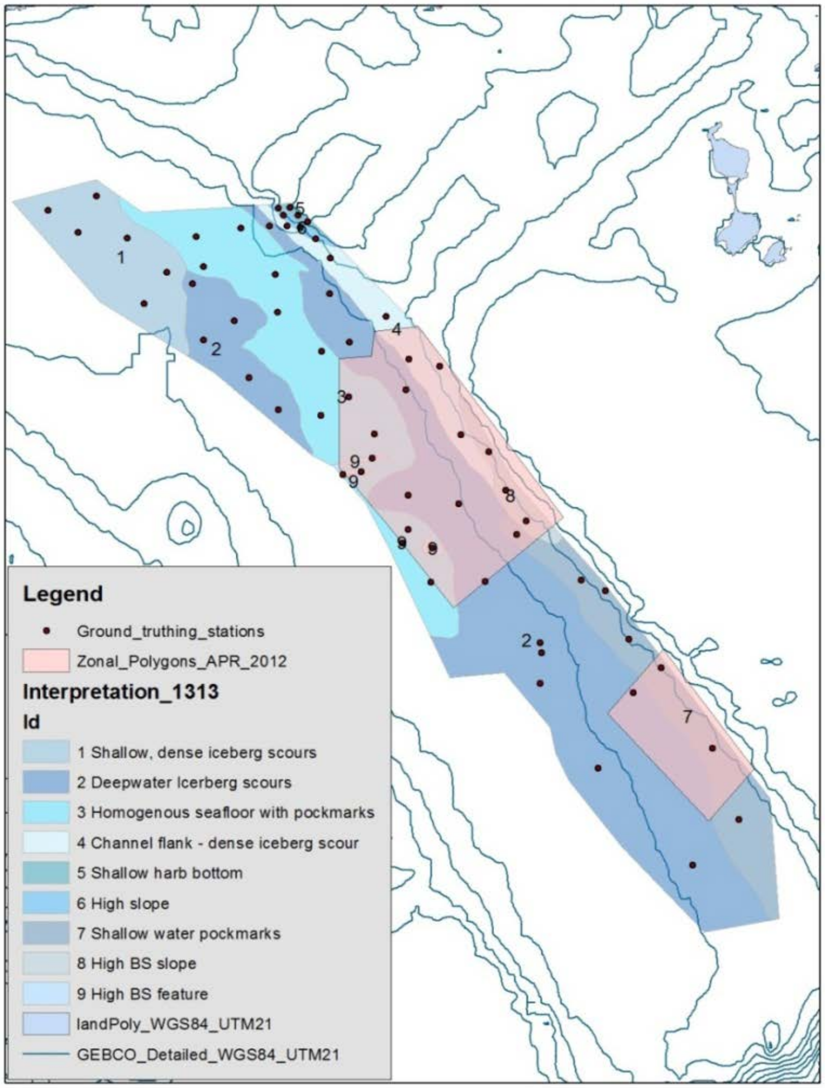

Figure 7. Ground-truth stations and initial interpretation of habitat classes in the LC MPA. Note the interpreted classes depicted were based on acoustic segmentation classes developed as part of the ground-truth survey contract.

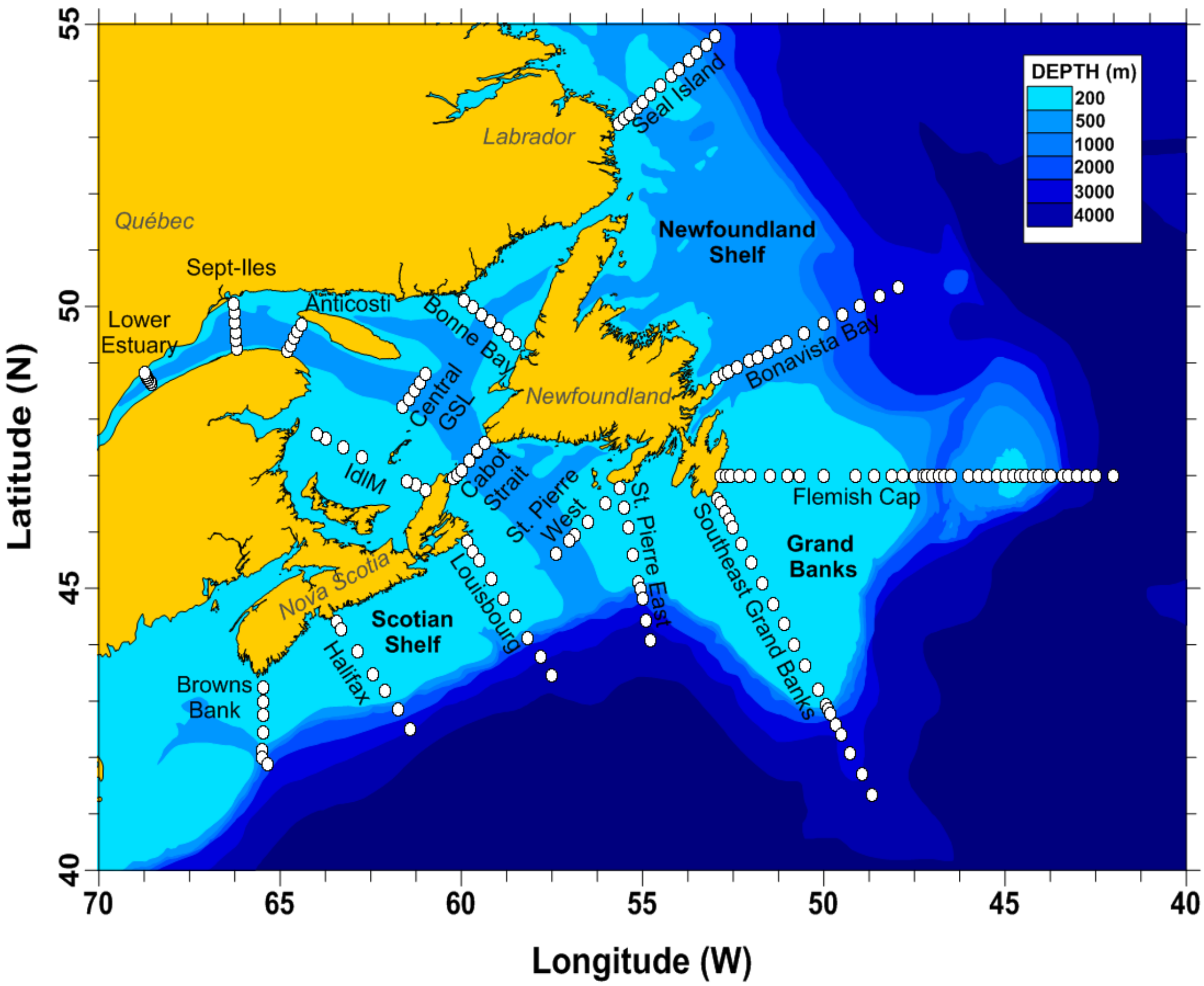

Figure 8. AZMP proposed fall survey plan, 2014. White dots represent monitoring stations.

APPENDIX III - TABLES

Table 1. General description of the proposed Regulatory Intent for the LC MPA according to the zoning scheme (June 2014). Allowed activities will be regulated by specific acts and regulation programs (see text for detail).

Activities	Regulatory Intent
Commercial, Aboriginal and Recreational Fishing	Commercial fishing **will not be** allowed within the MPA Recreational fishing **will not be** allowed within the MPA Aboriginal fishing (food, social and ceremonial fisheries) **will be** allowed within the MPA
Oil and Gas Exploration and Production	Seismic surveys **will be** allowed within the MPA from December 1 to May 31 Oil and gas drilling **will be** allowed only within, or from, Zone 2 a/b
Marine Transportation	Commercial, non-commercial, foreign, and recreational vessel activities associated with navigation **will be** allowed within the MPA Ballast exchange in the Alternate Ballast Water Exchange Zone **will be** allowed within the MPA between November and May
Subsea Cables	The laying of cables and their subsequent use and repair **will be** allowed only within Zone 2 a/b
Emergency, Safety, Security and Sovereignty	Any activity for the purpose of public safety, national defence, national security, or law enforcement or in response to an emergency **will be** allowed within the MPA
Scientific Research, Scientific Monitoring, and Education Activities	Scientific research, scientific monitoring, and education activities **will be** allowed within the MPA

Table 2. Proposed direct indicators useful to measure the effectiveness of the LC MPA.

Species	**Direct Indicator**	**Hypothesis**
Overarching Goal	Biodiversity	Biodiversity will be maintained or increased within the LC MPA relative to the reference areas
Sea pens	Biomass	Biomass is expected to increase or be maintained with the reduction of harm inside the MPA as compared relative to a reference areas
Sea pens	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
Sea pens	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
Sea pens	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

Table 3. Continued.

Species	**Direct Indicator**	**Hypothesis**
Sea pens	Abundance and density	Number of individuals should increase or be maintained relative to reference areas
Black Dogfish	Biomass	Biomass is expected to increase or be maintained with the reduction of harm inside the MPA relative to a reference area
Black Dogfish	Size distribution	Size distribution should increase or be maintained with reduction in harm, in particular pups, and larger individuals relative to a reference area
Black Dogfish	Abundance	Number of individuals should increase or be maintained relative to reference areas
Black Dogfish	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
Smooth Skate	Biomass	Protection measures should increase or maintain biomass of smooth skate within the MPA relative to the reference areas
Smooth Skate	Size distribution	Proportions of YOY and reproductive females should increase or be maintained from protection of the MPA relative to reference areas
Smooth Skate	Abundance	Number of individuals should increase or be maintained relative to reference areas
Smooth Skate	Mean life span	The mean life span should increase or maintained if there is a reduction in harm to smooth skate from fishing
Porbeagle Shark	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 Increase number of sightings of porbeagle
Northern Wolffish	Biomass	Biomass of Northern Wolffish should increase or be maintained over the long term resulting from protection of the MPA area relative to reference areas
Northern Wolffish	Size distribution	The range in size should increase or be maintained with reduction in harm relative to reference areas
Northern Wolffish	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
Northern Wolffish	Occurrence and frequency	Number of individuals should increase or be maintained relative to reference areas
Leatherback Sea Turtle	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 4. Proposed Indirect Indicators in the LC MPA.

Type and #	**Oceanographic Indicators**
Ocean-1	Temperature, salinity, oxygen concentration, alkalinity, light levels, chlorophyll, pigments, nutrients, currents, and pH inside and in adjacent waters to the MPA
Ocean-2	Bottom oceanographic properties near the seafloor inside and in adjacent waters to the MPA
Ocean-3	Water mass movements
Ocean-4	Wave height
Ocean-5	Extent of ice cover inside and in adjacent waters to the MPA
Ocean-6	Sound speed as a proxy for pH
Ecosystem-1	Animal/plant/bacterial community composition
Ecosystem-2	Infaunal and epifaunal composition
Ecosystem-3	Energy flows
Ecosystem-4	Biomass of predator/prey species
Ecosystem-5	Primary production
Ecosystem-6	Zooplankton variability
Ecosystem-7	Jellyfish aggregations inside and in adjacent waters to the MPA. Species: *Cyanea capillata* and *Aurelia aurita*
Habitat-1	Habitat physical parameters (e.g., substrate type, 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)
Habitat-2	Sediment composition and chemistry
Habitat-3	Gas seeps and pockmarks
Habitat-4	Nutrient flux sediment and water
Habitat-5	Underwater sound produced by cetaceans, as well as the sources and propagation characteristics of other natural and anthropogenic sources
Habitat-6	Community (benthic and pelagic) function and structure (species distribution, trophic structure (predator/prey), energy flow, etc.)

Table 5. Proposed Anthropogenic Indicators in the LC MPA.

#	**Anthropogenic Stress Indicators**
1	Distribution of commercial fishing effort in adjacent waters to the MPA
2	Compliance inside MPA
3	Incidence of bycatch and discards of COs and ROs in adjacent waters to the MPA
4	Infrastructure such as number and types of seabed cables, offshore-petroleum exploration and development activities, etc. inside and in adjacent waters to the MPA
5	Number of ballast-water exchanges within or in proximity to the MPA and the quantities of ballast exchanged
6	Oil spills (vessel sources)
7	Oil and gas exploration and production discharges
8	Seismic survey activities
9	Quantity of anthropogenic debris inside and in adjacent waters to the MPA
10	Number of incidents of ship strikes in the MPA and in adjacent waters
11	Quantitative characteristics of anthropogenic sound within the MPA compared to adjacent waters
12	Number of transits of the MPA by vessels other than pleasure craft, broken down into mercantile vessels, surface naval vessels and fishing vessels not fishing in the area
13	Seabed area swept by bottom-tending mobile research and monitoring gear within the MPA, both as a total and subdivided by seabed habitat type
14	Biomass removed from research surveys within the MPA

Table 6. Summary of Proposed Protocols and Strategies in the LC MPA.

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/sharks/seabirds	Ongoing
Bottom Mooring (acoustic)	Cetaceans/other community species	Ongoing
Bottom Mooring (oceanographic)	Corals	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
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	Infrastructure and human activities	Accessible
Partner information (e.g., Transport Canada, Environment Canada, C-NLOPB)	Infrastructure; seismic surveys; sound; ship strikes	Accessible

Table 7. Summary of Proposed Direct Protocols and Strategies.

Species	**Direct Indicator**	**Protocol and/or strategy**
Overarching Goal	Biodiversity: species richness, evenness, diversity	Multispecies survey - 3P
Sea pens	Biomass Size distribution Geospatial indicators Taxonomic diversity and richness Abundance and density	Multispecies survey - 3P, Video Camera/ROV survey, academia research
Black Dogfish	Biomass Size distribution Abundance Mean life span	Multispecies survey - 3P, FFAW contracts
Smooth Skate	Biomass Size distribution Abundance Mean life span	Multispecies survey - 3P
Porbeagle Shark	Lethal encounters with fishing gear or vessels, immediately non-lethal entanglements Occurrence and frequency	Dockside monitoring, FFAW reporting Shark tagging survey, baited cameras
Northern Wolffish	Biomass Size distribution Mean life span Occurrence and frequency	Multispecies survey - 3P
Leatherback Turtle	Lethal encounters with fishing gear or vessels, immediately non-lethal entanglements Occurrence and frequency	dockside monitoring, FFAW reporting FFAW sightings (opportunistic)

Table 8. Summary of Proposed Indirect Protocols and Strategies.

#	Indirect Indicator	Protocol and/or strategy
Ocean-1	Temperature, salinity, oxygen concentration, alkalinity, light levels, chlorophyll, pigments, nutrients, currents, and pH inside and in adjacent waters to the MPA	AZMP, multispecies, moorings
Ocean-2	Bottom oceanographic properties near the seafloor inside and in adjacent waters to the MPA	AZMP, multispecies, moorings
Ocean-3	Water mass movements	Satellites
Ocean-4	Sea Surface temperature	Satellites
Ocean-5	Extent of ice cover inside and in adjacent waters to the MPA	Satellites/Environment Canada/NOAA
Ocean-6	Sound speed as a proxy for pH	Autonomous acoustic moorings
Ocean-7	Underwater sound produced by cetaceans, as well as the sources and propagation characteristics of other natural and anthropogenic sources	Autonomous acoustic moorings
Ecosystem-1	Animal/plant/bacterial community composition	Multispecies survey 3P, autonomous acoustic moorings, aerial surveys
Ecosystem-2	Infaunal and epifaunal composition	Box cores/grab samples
Ecosystem-3	Species distribution	Multispecies survey 3P, autonomous acoustic moorings, aerial surveys, AZMP
Ecosystem-4	Trophic structure	Multispecies survey 3P, AZMP
Ecosystem-5	Energy flows	Multispecies survey 3P, AZMP
Ecosystem-6	Biomass of predator/prey species	Multispecies survey 3P, AZMP
Ecosystem-7	Zooplankton variability	AZMP
Ecosystem-8	Primary production	AZMP
Habitat-1	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)	corals cruise/ongoing benthic work
Habitat-2	Gas seeps and pockmarks	corals cruise/ongoing benthic work
Habitat-3	Nutrient flux sediment and water	corals cruise/ongoing benthic work
Habitat-4	Sediment composition and chemistry	corals cruise/ongoing benthic work

Table 9.Summary of Proposed Anthropogenic Protocols and Strategies .

#	**Anthropogenic Indicator**	**Protocol and/or strategy**
1	Distribution of commercial fishing effort in adjacent waters to the MPA impacting the COs	DFO FAM
2	Compliance inside MPA	VMS, DFO C&P
3	Incidence of bycatch and discards of COs and ROs in adjacent waters to the MPA	Logbooks and landings, FFAW, LEK via interviews
4	Infrastructure such as number and types of seabed cables, offshore-petroleum exploration and development activities, etc. inside and in adjacent waters to the MPA	DFO FPP databases
5	Number of ballast-water exchanges within or in proximity to the MPA and the quantities of ballast exchanged	Transport Canada databases
6	Oil spills (vessel sources)	C-NLOPB/CNSOPB
7	Oil and gas exploration and production discharges	C-NLOPB/CNSOPB
8	Seismic survey activities	C-NLOPB/CNSOPB
9	Quantity of anthropogenic debris inside and in adjacent waters to the MPA	unknown
10	Number of incidents of ship strikes in the MPA and in adjacent waters	LEK via interviews
11	Quantitative characteristics of anthropogenic sound within the MPA compared to adjacent waters	Previous studies by DFO and Canadian Navy, autonomous acoustic moorings
12	Number of transits of the MPA by vessels other than pleasure craft, broken down into mercantile vessels, surface naval vessels and fishing vessels not fishing in the area	VMS
13	Seabed area swept by bottom-tending mobile research and monitoring gear within the MPA, both as a total and subdivided by seabed habitat type	DFO NL Multispecies and others
14	Biomass removed from research surveys within the MPA	DFO NL Multispecies, others

*Table 10. Types of Experimental Designs.**

Design	Frequency of occurrence	Requirements	Comments	Reference
Impact only	Uncommon	Samples taken only within MPA, post establishment	Very poor inferential ability	Claudet, 2011
Control-Impact (CI)	Very common	Samples taken both within MPA and “control” area, post-establishment	Poor inferential ability confounds spatial patterns with MPA effects	DFO 2014a (Eastport)
Before-After	Uncommon	Samples taken before and after MPA establishment, only within MPA	Poor inferential ability confounds natural temporal patterns/variability with MPA effects	Claudet, 2011
Before-After-Control-Impact (BACI)	Uncommon	Samples taken before and after MPA establishment, within MPA and “control” site(s)	If temporally replicated, strong design to make statements of effect of particular MPAs; weaker ability to make global statements of effectiveness; conditional on MPA and non-MPA sites having correlated dynamics	Pritcher et al. 2009
Impact vs References sites	Uncommon	Samples taken before and after MPA establishment, within multiple MPA and “control” site(s)	If replicated, strong design to make global statements of effectiveness; weak design to evaluate particular MPAs; conditional on MPA and non-MPA sites having uncorrelated dynamics and MPA “treatment” being allocated randomly to sites.	Claudet, 2011
BACI Paired Series	Uncommon	Sampled at same times (or nearly so) to remove temporal effects	Estimates the magnitude of difference between pairs before and after management measures	de Loma et al. 2008
Beyond BACI	N/A	Multiple control and MPA sites are sampled multiple times before and after, but sites are not sampled at the same points in time; assumes random sampling	-	Skitter et al. 2006

*Adapted: Claudet, 2011

Table 11. Proposed protocol schedule upon MPA designation.

Protocol/Year	1	2	3	4	5	6	7	8	9	10
Multispecies Trawl survey	X	X	X	X	X	X	X	X	X	X
Shark longline survey	X	-	-	-	X	-	-	-	-	X
Tagging (sharks)	X	X	X	X	X	X	X	X	X	X
Turtle and cetaceans survey (aerial surveys, acoustic recorders)	X	X	X	X	X	X	X	X	X	X
Benthic surveys (ROV)	X	X	-	-	-	X	-	-	-	-
LEK survey	X	X	X	X	X	X	X	X	X	X
AZMP	X	X	X	X	X	X	X	X	X	X
Satellite observations	X	-	X	-	X	-	X	-	X	-
Ocean observatory/Moorings	X	X	X	X	X	X	X	X	X	X
VMS data	X	X	X	X	X	X	X	X	X	X
Landings and logbooks	X	X	X	X	X	X	X	X	X	X
Databases (cables, oil activities)	X	-	X	-	X	-	X	-	X	X
Ballast-water reports	X	X	X	X	X	X	X	X	X	X
Entanglement/marine debris/ship strikes research	X	X	X	X	X	X	X	X	X	X