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Review of the indicators and recommendations for an Ecological Monitoring Plan for the Banc-des-Américains Marine Protected Area

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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

In 2011, the surrounding area of American Bank has been identified as an Area of Interest (AOI) since a wide diversity of habitats is present, which generates a biological hot spot for several pelagic, demersal and benthic species. In March 2019, Canada and Québec governments signed the *Canada-Quebec joint project agreement regarding the Banc-des-Américains marine protected area (MPA)* allowing the establishment of a MPA at this site to promote long term biological productivity and diversity of the fishery resources as well as the recovery of species at risk.

As part of this MPA, the science sector has identified features of the ecosystem, anthropogenic pressures and related indicators to monitor adequately and to ensure conservation objectives are met. Following the expert review, 33 indicators were selected: 11 indirect indicators for physical and chemical oceanography and the pelagic ecosystem, 9 direct indicators for the benthic and demersal ecosystem, 4 indicators relating to species at risk (whales and Atlantic wolffish) and 9 indicators for monitoring anthropogenic pressures. The review of existing surveys and the data they provide has identified several programs, such as the AZMP program and multispecies surveys, that can be used to monitor many indicators. In some case, these surveys could be enhanced to improve the spatial coverage in or near the MPA. However, for 10 indicators, 6 new surveys woud be needed to monitor them. To review and validate some ecosystem features, pressures and indicators and to specify all the protocols needed for monitoring, it is recommended to set up a scientific committee that will propose a comprehensive monitoring plan and work on its implementation.

INTRODUCTION

In 2011, the Banc-des-Américains was identified as an Area of Interest (AOI) for the creation of a 1,000 km² Marine Protected Area (MPA) (Figure 1). In June 2018, the Canadian and Quebec governments announced the *Canada-Quebec Collaborative Agreement for the Establishment of a Network of Marine Protected Areas in Quebec*. The Banc-des-Américains MPA is the first joint project carried out under this *Canada-Quebec Agreement,* and it is intended to promote the productivity and diversity of fisheries resources and the recovery of species at risk. It will have dual status: an aquatic reserve under Quebec law, and a marine protected area (MPA) under Canada's *Oceans Act*. The *Canada-Quebec joint project agreement regarding the Banc-des-Américains MPA* was signed in March 2019. The Banc-des-Américains was designated as an MPA under the *Oceans Act* on March 6, 2019, with the publication of *Regulation (SOR/2019-50)* in the *Canada Gazette*, Part II.

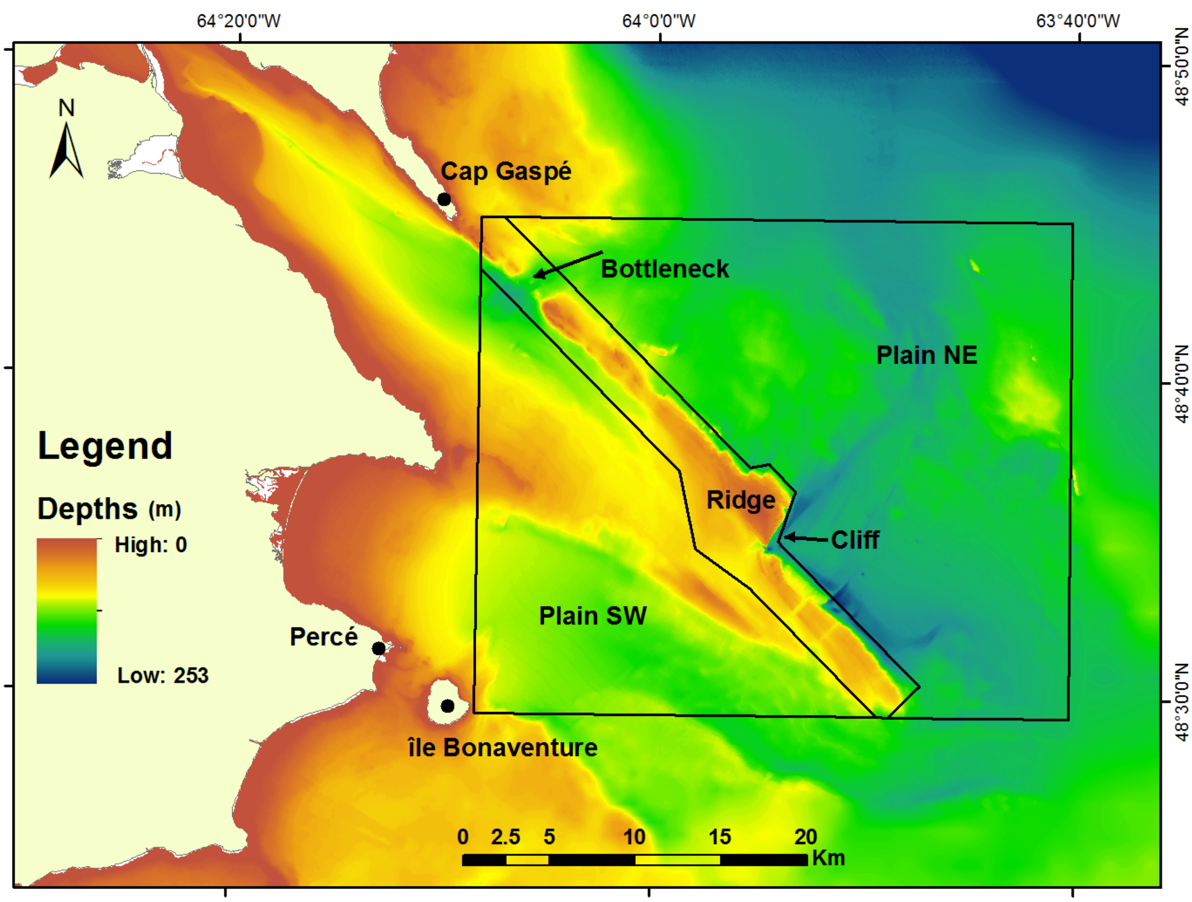

Figure 1. Banc-des-Américains Marine Protected Area: rocky ridge and adjacent plains.

Once a site has been designated a MPA under the *Oceans Act*, a monitoring program must be developed and implemented to assess the extent to which conservation goals and objectives are being achieved as well as the overall effectiveness of the management measures. DFO Science is responsible for developing indicators, protocols and strategies for monitoring the individual conservation objectives (CO) of established MPAs. This monitoring also provides information that helps managers better understand and respond to changes in this ecosystem.

The purpose of this document is to propose a preliminary list of potential indicators, protocols and strategies for the Banc-des-Américains MPA. The recommendations provided are related to ecosystem monitoring, including indicators associated with current pressures. Socio-economic considerations, as well as the potential effects that the creation of an MPA would have on them, should also be assessed in a management plan; they are beyond the scope of this report, however, and consequently will not be discussed. It should be noted that this document is not the final monitoring plan which will be implemented. The final monitoring plan will be developed by the managers of the MPA, based on these recommendations, in collaboration with the Government of Quebec, partners, stakeholders and DFO Science.

BANC-DES-AMÉRICAINS MARINE PROTECTED AREA

This section briefly describes the COs, the ecosystem of the Banc-des-Américains MPA, the human activities carried out in the area and the existing management measures. After the site was selected, a comprehensive review of biophysical and socio-economic information on the area was conducted (AECOM Tecsult Inc. 2010; Gauthier et al. 2013). Three documents may be consulted for a more detailed description. The first is the report by Gauthier et al. (2013) resulting from the Intersectoral Consultation Workshop on the Banc-des-Américains Area of Interest held in Mont-Joli, Quebec, in June 2010. The second is the report by Savenkoff et al. (2017) describing the habitats and epibenthic communities of the American Bank. Last is the report by Gendreau et al. (2018) outlining the human activities that could compromise the achievement of the COs for the Banc-des-Américains MPA. Little is known about the MPA’s ecosystem. Available scientific knowledge has been used as a basis for developing a monitoring program for the ecosystem features, but some knowledge gaps have been identified which point to the need for additional characterization studies.

CONSERVATION OBJECTIVES (COs)

The goal and COs of the Banc-des-Américains MPA were developed based on the results of an intersectoral workshop which brought together various DFO experts held at the Maurice Lamontagne Institute in Mont-Joli in 2010 (Gauthier et al. 2013). This information is presented here as the basis for the recommendations related to monitoring set out in this document. No refinement or modification of their formulation is proposed, as these would be outside the scope of this work.

The main goal of the Banc-des-Américains MPA is to promote the productivity and diversity of fisheries resources (species fished) associated with the American Bank and the adjacent plains, and to promote the recovery of species at risk.

The conservation objectives of the Banc-des-Américains MPA are as follows (cited in no particular order of priority):

1. To conserve and protect benthic (seabed) habitats;
2. To conserve and protect pelagic (water column) habitats and forage species (prey);
3. To promote the recovery of whale and wolffish species at risk.

DESCRIPTION OF THE ECOSYSTEM

Physical description

The American Bank is a submerged rocky ridge which begins about 6 km off Cap Gaspé. It extends some 34 km offshore from the Forillon Peninsula along a northwest-southeast axis. Its highest peak is located nearly 12 m below the water surface; four other peaks are found at depths between 24 and 35 m (Service Hydrographique du Canada [SHC] 2000). The ridge is located at depths between 40 and 60 m below the surface. There are a few trenches about 2 km in width around the bank; the three deepest are located at depths of 157, 166 and 187 m. The average depth of the plains on either side of the bank ("the adjacent plains") is 90 m in the southwestern sector and 140 m in the northeastern sector. Overall, the water depth throughout the MPA varies between 12 and 207 m (Gauthier et al. 2013).

A 100 m rocky cliff at the southeast end of the ridge is a unique feature of the Banc-des-Américains MPA. This underwater cliff, which is visible on bathymetric surveys, was described during a mission carried out in the summer of 2017 using a remotely operated vehicle called the ROPOS (Remotely Operated Platform for Ocean Science). The images captured by this equipment revealed a rock face with step-like relief alternating with vertical walls (G. Côté, DFO, unpublished data).

Sediment grain size gradually decreases with increasing depth for the three geographic structures (ridge, southwestern plain and northeastern plain) located in the area. The top of the ridge (> 20 m) consists of a hard substrate, then cobbles dominate up to a depth of 50 m, and at greater depths, fine sediments account for the highest proportion of substrate cover (Savenkoff *et al.* 2017). Although the plains are dominated by fine substrates, large boulders are also present and are colonized by species associated with hard substrate (G. Côté, DFO, unpublished data).

This physical configuration, which is unique to the Banc-des-Américains MPA, creates a wide variety of benthic habitats and influences the movement of water masses, producing unusual hydrodynamic conditions.

Physical and chemical oceanography

One important characteristic of the Banc-des-Américains MPA is that it is directly affected by the Gaspé Current, the most important current in the Gulf of St. Lawrence. Its waters, which come from the Estuary, occupy the upper part of the water column (0–40 m deep) and flow in the coastal band (10–15 km wide) along the north side of the Gaspé Peninsula (Benoit et al. 1985). This current carries nutrient-rich waters and a diversity of planktonic organisms, especially during the summer months (Koutitonsky and Bugden 1991; Levasseur et al. 1992; Plourde and Runge 1993). The Gaspé Current can therefore affect the availability of food for certain ecological features in the MPA (e.g. krill, copepods, capelin, herring, mackerel and marine mammals) and also influence pressures by transporting contaminants, wastewater etc. into the area.

Taking into account the influx of nutrients, the special dynamics around the American Bank make it a potentially productive site, a possibility that remains to be validated through further studies. An oceanographic mooring system was deployed opposite the American Bank cliff from June 2016 to August 2017, allowing rare physical phenomena to be observed which are likely to induce mixing of the water layers and upwelling of water to the surface (P. Galbraith, DFO, pers. com.). High-frequency internal wave trains with oscillations about 10 m in amplitude that reached a depth of 60 m were observed. These waves usually induce mixing, and in the area around the MPA, they interact with the nutrient-rich waters of the cold intermediate layer. An internal tide was also observed with vertical oscillations reaching 50 m at a depth of 100 m. The mooring system also recorded the renewal of deep water masses over the 14-day spring-neap tidal cycle, with inflows of dense waters possibly coming from areas 50 m deeper and farther offshore in the Gulf. Taken together, all these factors make the Banc-des-Americains MPA a unique site in the Gulf of St. Lawrence. Further research is required to increase understanding of the patterns of particle accumulation and dispersion influenced by local hydrodynamic conditions.

Pelagic Ecosystem

The species composition and abundance of the pelagic biomass (meso- and macro-zooplankton and small pelagic fish) off the eastern tip of the Gaspé Peninsula vary a lot through the seasons. Planktonic and nektonic organisms are transported by the Gaspé Current from the St. Lawrence Estuary to the southern Gulf, passing by the eastern tip of the Gaspé Peninsula. The Banc-des-Américains MPA is a complex assemblage of shallow basins and longitudinal ridges (Figure 1) which contributes to a temporary concentration of planktonic biomass in and around the site. In addition, the continuous transport of zooplankton, combined with the unique topography, promotes significant accumulations of macrozooplankton biomass—mainly northern krill (*Meganyctiphanes norvegica*) and Arctic krill (*Thysanoessa raschii*) (Figure 2)—at different times of the year, making the site very attractive to zooplanktophagous animals, such as baleen whales and small pelagic fish (McQuinn et al. 2016). It has been suggested, however, that local krill production is probably limited, even though krill are likely to feed there during the summer owing to the accumulations of phytoplankton and mesozooplankton (copepods, etc.). Further studies are required to better describe krill dispersion and retention as well as the spatial and temporal distribution of krill in the area.

In addition to zooplankton, small pelagic fish (capelin, herring and mackerel) concentrate in this area during spawning and feeding periods. Although these concentrations may be transitory and therefore difficult to quantify, accumulations of small pelagic fish such as capelin during the spawning period may result in spectacular short-lived predatory displays by marine mammals and birds. Schools of small pelagic fish were acoustically detected along the Gaspé Peninsula coast and around the Baie des Chaleurs on either side of the American Bank during the annual herring acoustic survey (McQuinn et al. 2012) and during the southern Gulf ecosystem survey in September, as well as the Atlantic Zone Monitoring Program (AZMP) oceanographic survey in June. The Banc-des-Américains MPA is located at the northern edge of the mackerel spawning area (Grégoire et al. 2013). The water temperature is colder in the MPA than in the species' preferred spawning grounds farther south (Grégoire et al. 2013). As the climate warms, however, mackerel may be observed to spawn more often in this region. Little information is available on the precise distribution of sand lance.

Benthic and demersal ecosystem

The rich and diversified benthic invertebrate communities in the area are linked to the variety of bottom types (substrate, depth, slope) and the prevailing current dynamics in the Banc-des-Américains MPA. Benthic imagery surveys conducted between 2012 and 2016 over a depth gradient from 14 m to 204 m identified 131 taxa of epifauna belonging to 11 phyla (Savenkoff et al. 2017). Gastropod and bivalve molluscs accounted for the highest number of taxa (n=31), followed by arthropods (n=24), chordates (n=23; fish and tunicates), echinoderms (n=19; mainly starfish and brittle stars), cnidarians (n=14; mainly anemones) and annelids (n=9; mainly polychaetes). Plumose anemones (*Metridum senile*), which are present only at depths under 50 m, may form dense colonies. Brittle stars, especially daisy brittle stars (*Ophiopholis aculeata*) and spiny brittle stars (*Ophiacanthas bidentata*), are predominantly found at depths of less than 100 m, while at greater depths, shrimp (*Pandalus* spp.) and other arthropods are more abundant (Savenkoff et al. 2017).

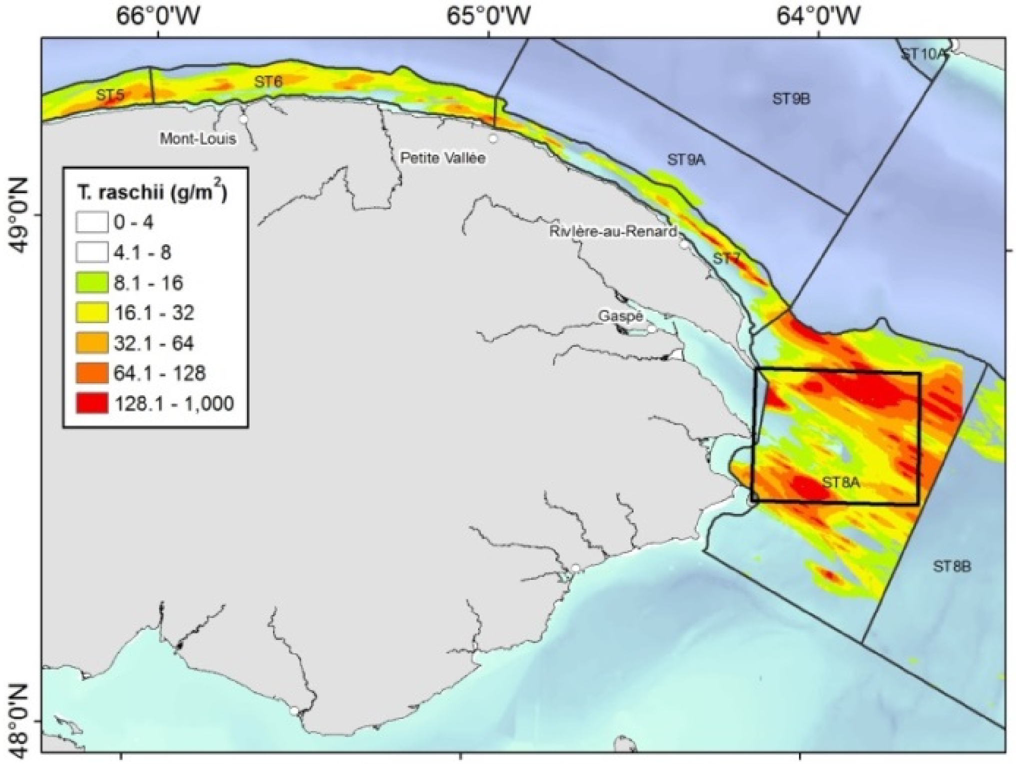

Figure 2. Biomass (g · m²) of Arctic krill accumulated along the Gaspé Peninsula from 2009 to 2014 (data for strata along the Gaspé Peninsula only).

Data collected through imagery projects (Savenkoff et al. 2017; G. Côté, DFO, unpublished data) also made it possible to observe different species assemblages in different sections of the Banc-des-Américains MPA. Some images of the ridge show a rather dense cover of red algae or bushy hydrozoans (Savenkoff et al. 2017; G. Côté, DFO, unpublished data) which may provide shelter for demersal fish or small crustaceans (Fontaine 2006; Martinez 2010). The geological configuration of the cliff promotes zonation of species, including a wide variety of sponges, anemones and starfish (G. Côté, DFO, unpublished data). The many rock crevices also provide shelter for small redfish (*Sebastes* sp.). The plains are characterized by a diversity of substrates ranging from fine sediments in which shrimp (*Pandalus* sp.) burrow, to seafloor areas dotted with boulders which have been colonized by sponges and anemones (G. Côté, DFO, unpublished data).

Corals and sponges have also been observed in the Banc-des-Américains MPA. Soft corals, which are found throughout the area, have been only identified to the family level (Nephteidae), since the species identified, specifically sea strawberry (*Gersemia rubiformis*) and sea cauliflower *Drifa glomerata*, can be easily confused in photos (Nozères et al. 2014). They have mainly been observed on the northeastern plain at depths greater than 50 m. Sponges are also found at depths greater than 20 m throughout the MPA, with more observations made on the ridge (Savenkoff et al. 2017) and high densities found on the cliff (G. Côté, DFO, unpublished data). Recent analyses have identified seven morphological groups of sponges in the area, including some large sponges belonging to the genus *Plicatellopsis* (G. Côté, DFO, unpublished data; C. Dinn, DFO, unpublished data). Genetic analyses are under way to try to more accurately identify these sponges, and further work is required to better characterize these organisms in the Gulf of St. Lawrence about which little is known.

Colonial tunicates possibly belonging to an invasive species, the golden star tunicate (*Bottrylus schlosseri*), have been seen on some images. To date, scientists have not been able to confirm the presence of the invasive species from the images (Savenkoff et al. 2017).

Benthic imagery has made it possible to describe the epibenthos present in the area fairly well. Nonetheless, little is known about the endobenthic and suprabenthic communities. Work began in the summer of 2018 to help fill these gaps.

The MPA is included in the multispecies survey of the southern Gulf of St. Lawrence, which uses a bottom trawl. The data collected show that, although once dominated by large demersal fish species (like Atlantic cod), the southern Gulf community now comprises a greater proportion of small pelagic fish, like Atlantic herring. Slight increases in biomass have been observed for only a few demersal species (e.g. redfish and Atlantic halibut) since 1990 (R. Bernier, DFO, unpublished data).

The southern Gulf of St. Lawrence is also home to a wide variety of epibenthic invertebrates. This includes commercial species like snow crab and American lobster. Despite significant fluctuations since the 1990s, total invertebrate biomass has remained fairly stable overall; however, a slight increase in biomass has been recorded for snow crab and American lobster populations.

Target species

About 20 species at risk are likely to be found in the Banc-des-Américains MPA (Table 1). In terms of the development of MPA monitoring, the focus is on species at risk listed in the *Species at Risk Act* (SARA), which includes whales and certain species of wolfish, mainly Atlantic Wolfish, as mentioned in CO #3. While some information is available on these species, for both wolffish species and whales alike, further studies are needed to determine how they use the area and its importance to them, in order to assess the existing level of protection in the area.

Species at risk:

- Wolffish (*Anarhichas sp.):* Three species of wolffish are present in the Gulf of St. Lawrence. Atlantic wolffish is listed as Special Concern under SARA, while Spotted wolffish (*Anarhichas minor*) and Northern wolffish (*Anarhichas denticulatus*) are listed as Threatened. In the Banc-des-Américains MPA, only the presence of Atlantic wolffish has been confirmed; Spotted wolffish are likely present, but it is not known whether Northern wolffish occur there (Larocque et al. 2010; Savenkoff et al. 2017). Although all three species have been caught in DFO's multispecies surveys in this area, these catches are sporadic and small, and do not indicate that the MPA is a preferred area for wolffish (Collins et al. 2015). Cracks and cavities that could serve as shelter for wolffish (Keats et al. 1985) have been identified amidst rocks on the ridge (Savenkoff et al. 2017). Atlantic wolffish are mainly found on hard, rocky substrates that are inaccessible to bottom trawls and are rarely found on sandy or silty bottoms (Horsman and Shackell 2009; Larocque et al. 2010). In 2014, divers confirmed the presence of Atlantic wolffish on the ridge at four stations located at depths between 15 and 30 m.
- Fin Whale (*Balaenoptera physalus*): Special Concern. During the ice-free period, fin whales can be observed regularly in the waters of the Laurentian Channel as far upstream as Tadoussac. According to a study by Lesage et al. (2007), the fin whale occurs in the Ecologically and Biologically Significant Area (EBSA) off the Gaspé Peninsula, including the Baie des Chaleurs channel. The MPA is part of this EBSA, and fin whales have been observed in the northeast and southeast sectors of the Banc-des-Américains MPA by the

Marine Mammal Observation Network (MMON), among others (ROMM 2016). It should be noted that these data include a bias related to tour boat operators' ability to travel to offshore waters.

- Blue Whale (*Balaenoptera musculus*): Endangered. Blue whales feed in Canadian waters and their distribution is linked to aggregations of krill, particularly Arctic krill and northern krill (their two main prey species). Important habitats for the blue whale have been identified by combining information on their distribution with information on krill aggregation areas (Lesage et al. 2018). Four areas have been identified as important for blue whale foraging, feeding and social interactions, including an area encompassing the Lower Estuary of the St. Lawrence and northwestern Gulf of St. Lawrence (Lesage et al. 2018). The Banc-des-Américains MPA is located in this sector, and blue whales have been observed both there and in the adjacent region mainly during whale-watching excursions (ROMM 2016) as well as via satellite telemetry (Lesage et al. 2017). A larger number of sightings have been made in the northeast and southeast part of the area (ROMM 2016), but these data include a bias related to tour boat operators' ability to travel to offshore waters.
- Humpback Whale (*Megaptera novaeangliae*): Special Concern. Humpback whales regularly visit the Estuary and the Gulf of St. Lawrence during the ice-free period and seem to congregate mainly in the northern Gulf (Doniol-Valcroze et al. 2007). According to a study by Lesage et al. (2017), this species may occur in the EBSA off the Gaspé Peninsula, including the Baie des Chaleurs channel. The MPA is part of this EBSA, and humpback whales have been observed in the northeast sector by the MMON, among others (ROMM 2016). It should be noted that these data include a bias related to tour boat operators' ability to travel to offshore waters.
- North Atlantic Right Whale (*Eubalaena glacialis*): Endangered. Very little is known about the distribution of right whales in the Gulf of St. Lawrence or how they use this habitat. Until very recently, only a few annual sightings had been recorded and most were random since virtually no surveys were being conducted on this species (Daoust et al. 2018). Since 2015, surveys have been established in the southern Gulf in addition to those carried out in the north, allowing more sightings of right whales to be made (> 40 individuals in 2015 and 2016, > 100 individuals in 2017). Research is still being carried out to determine what appears to be driving this species' increased use of the Gulf of St. Lawrence. Initial sightings suggest that right whales feed there. Their main prey, copepod species (*Calanus* spp.), may be present in several potential feeding areas in the Gulf (Daoust et al. 2018). The Banc-des-Américains is one of these potential feeding areas, and since surveys first began in 2015, a few individuals have been observed there along with several more to the south and east of the site.

COs also focus on forage species, since that they are important prey, particularly for marine mammals and predatory fish.

Forage species :

- Euphausiids (krill): the two most important krill species in this region are northern krill and Arctic krill (McQuinn et al. 2015). In the Gulf of St. Lawrence, krill is the major prey item in the marine food web (Savenkoff et al. 2013). The distribution of krill aggregations makes this region a significant feeding area for marine mammals, including minke whales, fin whales, humpback whales and blue whales. Krill is also the primary food source for juveniles and adults of a number of fish species, including capelin, herring, mackerel, cod and redfish.
- Copepods: the different copepod species found in the area include the following: *Pseudocalanus* sp., *Oithona* sp., *Centropages* sp. and *Acartia* sp. (smaller organisms), as

well as *Calanus finmarchicus*, *C. glacialis* and *C. hyperboreus* (larger ones). Young copepods (nauplii) are the principal prey of young fish while older stages (copepodites) are eaten by larger fish, such as capelin.

- Pelagic fish (herring, capelin, mackerel): group of fish that supports significant predation by the upper trophic levels in the Gulf of St. Lawrence. These species move or feed in the area, and many of them spawn there.

HUMAN ACTIVITIES AND IMPACTS

Human activities

Commercial activities related to fishing, shipping and marine mammal watching activities are the main human activities that currently occur in the Banc-des-Américains MPA (Table 2). In the longer term, other non-recurrent (e.g. industrial) activities may be carried out, some with negative impacts on the environment.

Fishing

The Banc-des-Américains MPA is relatively close to the coast, and some commercial fisheries are carried out there. At present, the predominant commercial fishing activity in the area is the snow crab fishery which is carried out using traps (approximately 94% of all fishing income). Bottom longlines are used to catch Atlantic halibut, and gillnet fishing for Greenland halibut is carried out sporadically. Gillnets and longline gear are used very little, however (< 1 % of catches), while other types of fishing gear (handline, Danish seine, traps) are used infrequently. Northern shrimp is also occasionally harvested using a bottom trawl. The American Bank has historically been known for cod fishing. Unfortunately, owing to a sharp decline in the southern Gulf cod stock, a moratorium on commercial cod fishing was imposed from 1993 to 1997, in 2003 and from 2009 to the present. In summary, the species currently fished in the MPA are:

- snow crab (mostly);
- Atlantic halibut;
- Greenland halibut;
- in smaller numbers: Atlantic cod, American plaice, witch flounder, white hake, redfish, shrimp and mackerel (Gendreau et al. 2018).

Bottom trawling is considered to be the most damaging commercial fishing gear for the seabed (Fuller et al. 2008). It can alter the composition of habitats and species that live on the sea floor, and even destroy them. In addition, this gear catches many non-target species (bycatch), including species at risk, such as the Atlantic wolffish or cod. The risks associated with bottom trawling were therefore assessed as very high in relation to the COs for the MPA (Gendreau et al. 2018), even though this type of gear is not used in the MPA at present, owing to the existing moratoria on groundfish fishing (MPO 2017a). Gillnets are also recognized as fishing gear that can damage the seabed and present a high risk of entanglement for certain whale species (Fuller et al. 2008; Brown et al. 2015; Baumgartner et al. 2017). Fishing with traps causes disturbance to the seabed, especially when the traps are deposited on the bottom and hauled to the surface. There is also a risk that mammals will become entangled in the lines (Fuller et al. 2008; MPO 2010). It should be noted, however, that the crab fishing season generally runs from mid-April to early June, which is before whales are regularly present in the area. Given how rare recreational fishing is in the area, it would have little impact on the attainment of the COs.

Shipping transport

Some commercial vessels—including tankers, cargo ships, chemical carriers and cruise ships carrying up to 400 passengers—cross the MPA to enter and leave the Baie des Chaleurs or the Port of Gaspé. Summer is the busiest period.

Transportation of petroleum and chemical products by tankers presents the greatest risks in the event of spills. However, this type of vessel traffic is very limited in the MPA, which reduces the risk. Marine traffic can also cause collisions with marine mammals, environmental disruptions (noise, spread of invasive species) and pollution.

Tourism activities

Tourism activities in the Banc-des-Américains MPA are seasonal and mainly consist of marine mammals watching. Three companies are likely to visit the MPA as part of their activities (cruises and boat tours). The operating season generally extends from early June to mid-October. Target species and the observation sites vary depending on the distribution of marine mammals in the area (ROMM 2016).

The main threats related to these activities are disturbances caused by vessel noise and the risk of collision with the marine mammals. Relatively small craft can get very close to the animals, which may disturb them. The recent amendment to the *Marine Mammal Regulations* imposes new approach distances on vehicles (approach distance of 100 m at all times for whales, dolphins and porpoises, and 200 m if an individual is resting or with a calf), which help to limit disturbances to cetaceans in the area.

Other potential activities

No company holds oil, gas, or mining exploration or operating licences in or near the area (Gendreau et al. 2018). In addition, there are no underwater cables in the MPA, and no project proposals for the establishment of underwater generators or other marine infrastructures are being considered.

Anthropogenic pressures

The human activities listed above are likely to have a negative impact on the ecological features covered by the MPA (Table 3). These potential negative impacts are listed as existing or potential ecosystem pressures.

Entanglement and collisions

Entanglement (active gear and ghost fishing gear) and collisions between ships and marine mammals can cause fairly serious injuries and even kill animals. In the Banc-des-Américains MPA, collisions are likely to occur in connection with marine transportation, fishing, recreational tourism, and scientific and monitoring activities (Gendreau et al. 2018). These pressures are likely to affect marine mammals to the greatest extent, and according to the Réseau québécois d'urgences pour les mammifères marins (RQUMM), about 60 reports of injured or dead cetaceans and seals were received in the Gaspé Peninsula (Gaspé sector) region between 2004 and 2015 (ROMM 2016).

Noise and disturbance

Noise generated by human activities (mainly due to navigation in the area) is likely to disturb or modify animal behaviour, especially the behaviour of marine mammals (Gendreau et al. 2018). Disturbances can also be caused by the proximity of boats and human activities in the MPA.

Wastewater discharges

Wastewater discharges consist of organic or inorganic matter released from land-based (municipal, industrial and agricultural) or navigation-based (fishing, science, marine transportation and recreational tourism) activities which may contaminate the environments where it is discharged. The main pressure in the area consists of untreated wastewater and ballast water releases from navigation-related activities, since there are no known local land-based sources (Gendreau et al. 2018).

Biomass harvesting

Biomass harvesting involves removing a portion of the total mass of an animal or plant stock or population in its natural environment. The commercial snow crab fishery is the main harvesting activity in the MPA by landed weight (Gendreau et al. 2018).

Physical substrate disturbance and turbidity

Altering the natural physical environment can directly affect benthic habitats and the species found there. Disturbances can be anthropogenic or natural (e.g. storms). Turbidity is generally caused by suspended matter generated by natural processes (e.g. flooding) or by human activities (e.g. resuspension of sediments by bottom trawl) which absorbs, diffuses and/or reflects light. In the Banc-des-Américains MPA, anthropogenic disturbances like fishing and scientific activities using bottom-contact fishing gear are considered the main pressures that can disturb the substrate and cause turbidity.

Climate change

Climate change is a threat in the MPA just as it is throughout the entire Gulf of St. Lawrence. Potential impacts include an increase in water temperature and a decrease in pH level relative to historical values recorded for the area, as well as a change in the flow of the Gaspé Current. Such impacts can cause changes in species distribution; for example, certain species may disappear, while new species may appear in the area (Gendreau et al. 2018).

Aquatic Invasive Species (AIS)

The arrival of aquatic invasive species (AIS) is a potential pressure in the MPA. Around the world there is an increasing trend in the number of AIS recorded, which is mainly attributable to human activities and climate change (Carlton and Geller 1993). Climate change increases the ability of non-native species to establish themselves by providing favourable environmental conditions and by disrupting the conditions required by native species (Landry and Locke 2012, in Benoît et al. 2012). AIS are often associated with ballast water and therefore present a high risk of being introduced into Canada (Transports Canada 2010). Some aquatic invasive species have been detected in the southern Gulf by a DFO AIS monitoring network that uses collectors deployed in coastal areas and aquaculture sites. Invasive tunicates (*B. schlosseri, B. violaceus* and *Ciona intestinalis)* have been detected in the Magdalen Islands, while the bryozoan *Membranipora membranacea*, which forms encrusting colonies, has been observed near the Gaspé Peninsula (Simard et al. 2013). The potential for these species to establish themselves in the various Banc-des-Américains habitats should be studied in greater depth to determine whether they need to be monitored.

Oil spills

No oil and gas development activities have been identified in the vicinity of the MPA, and the *Regulations* prohibit all such activities within its boundaries. Nonetheless, oil spills associated with marine transportation represent a potential threat that may lead to pollution.

MANAGEMENT MEASURES

The *Banc-des-Américains MPA Regulations*, made under the *Oceans Act*, prohibit any activity that disturbs, damages, destroys or removes from the MPA any living marine organism or any part of its habitat or is likely to do so. Exceptions to this general prohibition allow certain activities that do not compromise the achievement of the MPA's conservation objectives to be carried out therein (Table 4).

The Banc-des-Américains MPA is divided into two management zones (Figure 3). More stringent restrictions apply in the Core Protection Zone, the most sensitive part (Zone 1 including the entire ridge), while an Adaptive Management Area (Zones 2a and 2b including part of the adjacent plains) allows activities deemed compatible with the COs to be carried out under certain conditions.

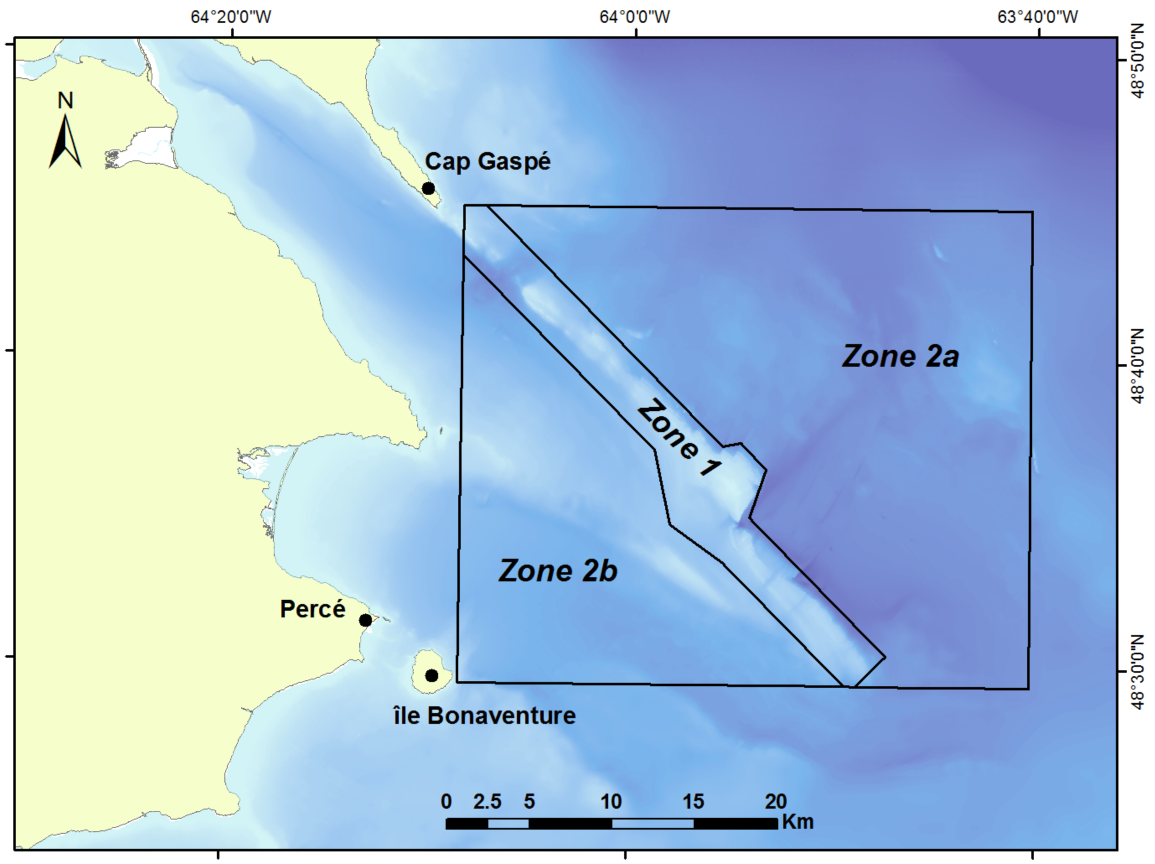

Figure 3. Management areas for the Banc-des-Américains MPA.

As a result, some activities may continue to take place in the MPA, such as approved tourism or scientific activities (Table 4), and certain commercial or recreational fishing activities in Zone 2. The main activities that are prohibited in the MPA are:

- Trawl and gillnet fishing;
- Directed commercial fishing of forage species (capelin, herring, mackerel, sand lance, krill and copepods);
- Anchoring of vessels in Zone 1;
- The discharge of sewage and grey water from large vessels;
- Activities related to oil and gas development and mining.

RECOMMANDATION FOR AN ECOLOGICAL MONITORING PLAN

A monitoring plan is essential to provide information necessary for effective management of the MPA, i.e. management adapted to the conditions and trends of protected ecosystems as well as the anthropogenic pressures and other threats to ecosystems (Kenchington 2010). An effective monitoring plan must be designed according to the objectives of the MPA, the structures and functions of the ecosystems within it, and the types of pressures acting on these ecosystems. Other factors, including budgetary constraints and technical capacity, must be considered in order to develop a realistic plan and ensure its optimal implementation.

The recommendations are based on the literature related to the development of a monitoring plan which involves identifying a set of potential indicators along with protocols and strategies based on ecological, environmental and human (pressures) features (MPO 2013). Several monitoring plan proposals for MPA projects were consulted to develop this monitoring plan for the Banc-des-Américains MPA, including the Gully MPA (Kenchington 2010), St. Anns Bank MPA (MPO 2014a), the Estuary (Provencher et al. 2012) MPA project, and more recently the Laurentian Channel MPA (Lewis et al. 2016), in addition to guidelines from the IUCN's Programme on Protected Areas (Pomeroy et al. 2004).

IMPLEMENTATION OF A MONITORING PLAN

Steps

Monitoring programs should include four key steps (Kenchington 2014):

- Identify a set of indicators and their associated protocols, including details related to monitoring frequency and the indices and parameters that will be calculated;
- Collect data or extract relevant data already compiled by other, existing implemented programs or surveys;
- Archive the collected data in an appropriate manner;
- Analyze and interpret the data collected to provide concise information to MPA managers who will be able to adjust the management plan as necessary.

Scientific committee

As suggested by Lewis et al. (2016), it is recommended that a scientific steering committee be established to assist in developing, implementing and updating the monitoring plan. The committee should include MPA managers and DFO Science Branch representatives responsible for the different aspects covered by the COs. For the Banc-des-Américains MPA, representatives from the fields of oceanography, pelagic ecosystems, benthic ecology, marine species at risk, marine mammals and conservation should be included on the committee.

The scientific committee should draw on the St. Lawrence Action Plan (SLAP) and AZMP models. The committee could meet annually to discuss indicator results and publish a monitoring report at a frequency to be determined by the committee (e.g. 3 or 5 years).

The committee's objectives would be to specify the indices and parameters to be calculated for the different indicators selected, to plan the protocols to be implemented or modified, as well as to periodically compare the results obtained, identify gaps and adapt the monitoring plan accordingly. The committee could also help MPA managers develop collaborations and promote research on specific issues in the academic and scientific community to help fill knowledge gaps. The committee may also consider using a data management and sharing system to ensure that all participants in the monitoring program as well as MPA managers can easily access the data collected.

Spatial and temporal scale

Spatial and temporal scales must be taken into consideration when selecting indicators and their associated features (Stanley et al. 2015). For example, Stanley et al. (2015) reviewed a large number of studies that indicated the length time it took after MPA establishment to detect positive effects from the protection accorded . The time frame for the detection of changes ranged from two years to several decades, indicating that the response time may be long, particularly for long-lived and late-maturing species as opposed to faster-growing taxa.

Similarly, the residence time of an organism in the MPA has an effect on the degree of protection it can potentially provide. MPAs offer less protection to species whose range extends beyond their boundaries than to sessile species or those with small home ranges (Stanley et al. 2015). For this reason, an MPA must be designed and monitored by taking into account the distribution and movement models for the target species. These two spatial and temporal considerations should therefore be considered when selecting key species or indicator species for maximizing an indicator's potential to detect changes.

Indicators

In the context of an MPA monitoring plan, Kenchington (2010) suggests using the term "indicator" in a broader sense than that ascribed to the word "index". Indicators are elements to be measured rather than parameters or scales of measurement. For example, *epibenthic community composition* could be an indicator for benthic communities and *species richness* and the *Shannon diversity index* are examples of indices that could be used for this indicator. In the present exercise, only a list of indicators is proposed; specific indices and parameters associated with indicators will have to be determined at a later stage.

Criteria

According to the review by Lewis et al. (2016), an indicator selection process should be based on the following general criteria (Pomeroy et al. 2004; Rochet and Rice 2005; Shin et al. 2010; MPO 2014b):

- **Theoretical basis/ecological significance:** Indicators must be based on sound scientific knowledge.
- **Sensitivity:** Indicators must be sensitive to management actions; the magnitude of change in an indicator corresponds to a degree of variation in pressure (e.g. fishing, pollution).
- **Interpretable:** Indicators must show specific responses to known causes and allow for the signal to be interpreted in a way that distinguishes natural variability from anthropogenic variability.
- **Measurable:** Indicators should take into account cost-effectiveness, the presence of historical data as well as the use of simple and proven methods and equipment (including non-invasive and non-destructive methods). Indicators should be able to be measured or estimated on a regular basis, and time series of data should be available.
- **Easy to manage:** The number of indicators should remain small, and redundancy should be avoided as much as possible. Indicators should provide information on ecosystem conditions and trends.
- **Researcher and stakeholder support:** Indicators should be supported by the scientists who are likely to conduct research and analysis in the field, as well as by MPA managers and stakeholders.

- **Public awareness:** Indicators must be widely and intuitively understood by the general public.

It has been acknowledged that no single indicator can fully satisfy all these criteria and that these are therefore desirable attributes rather than strict requirements.

The focus should be on indicator effectiveness, with preference given to indicators that are inexpensive, easy to implement and sustainable. In addition, the selection of indicators should focus on the features and associated indicators with a strong capacity to detect changes, such as a component or aspect of an ecosystem that is particularly sensitive to a given class of anthropogenic pressures (Kenchington 2010). It has similarly been suggested that instead of developing new protocols, efforts be devoted to optimizing or enhancing monitoring activities.

Types of indicators

Four categories of ecosystem features have been selected with the aim of achieving the three COs: 1) physical and chemical oceanography; 2) pelagic ecosystem (including forage species); 3) benthic and demersal ecosystem; and 4) species at risk. Indicators have been developed for all component categories. Based on the different types of indicators described by DFO (2011) and Lewis et al. (2016), the proposed indicators for the Banc-des-Américains MPA have been grouped into two types.

1. **Direct indicators** that can be used to assess the state of the MPA and its performance in terms of achieving the conservation objectives as well as the effectiveness of the management measures. These indicators focus on communities, populations, species (permanent residents of the MPA) and habitats of interest specifically related to the COs (e. g. epibenthic community on the ridge).
2. **Indirect indicators** that assess the state of the MPA ecosystem, but that do not allow changes to be directly linked it management. These indicators will provide information on key ecosystem and environmental factors that can influence observed changes in the sector. The spatial distribution of these indirect indicators extends well beyond the boundaries of the MPA (e. g. surface water temperature, total copepod biomass);

Ecosystem features can be subject to various anthropogenic pressures that can affect the attainment of COs. **Anthropogenic pressures indicators** have also been developed to assess the impact of human activities on the environment.

Monitoring protocols

Effective monitoring of the ecosystem features identified cannot be achieved through occasional observations or a series of disjointed research projects. Monitoring of trends to detect temporal changes (or a lack thereof) must be based on the repeated measurement of the same variables using the same methods, in order to maximize the signal measured (Kenchington 2010).

Different methods can be used in a monitoring plan, such as the control-impact method, which uses sampling stations located in the protected area and in reference areas outside of it (Stanley et al. 2015). However, according to a comprehensive review by Stanley et al. (2015), most studies recommend using the experimental Before-After Control-Impact (BACI) approach. This approach is characterized by monitoring sites inside and outside of the MPA as well as the availability of data gathered before management measures were implemented. The BACI approach is the preferred option since it alone makes it possible to distinguish between management impacts and natural variability, and thus to determine in a robust manner whether changes observed in the MPA are the result of management measures.

International recommendations for MPA monitoring emphasize the need to develop monitoring programs that are robust in terms of separating out natural variability, operate on reasonable time scales and, most importantly, that use sound statistical design principles (Stanley et al. 2015). The protocols selected for the monitoring plan should therefore follow the BACI approach when possible.

PROPOSED ECOSYSTEM FEATURES AND MONITORING INDICATORS

Two in-house workshops involving Science experts were held at the Maurice Lamontagne Institute (MLI) in February 2018 to review the ecosystem features and prepare a list of indicators for pelagic and benthic habitats of Banc-des-Américains. Based on this information, a list of potential indicators for assessing the effectiveness of DFO's regulatory measures management and for describing trends in species and communities in the MPA has been developed and is presented here. These indicators should be reviewed in light of the various criteria presented in the previous section. The monitoring indicators are described in relation to the ecosystem features and anthropogenic pressures that have been identified with a view to achieving the COs for the MPA (Table 5, Table 6).

Physical and chemical oceanography (O)

All of the proposed oceanographic indicators are *indirect* indicators which are essential for describing the environmental conditions influencing the ecosystem. Monitoring of local and regional variability of oceanographic conditions makes it possible to assess their impacts on the ecological features, and consequently, to identify and better understand anthropogenic variations.

Physico-chemical characteristics of water

Measured in the MPA as well as over a larger region that is representative of oceanographic conditions:

O1) Temperature, salinity, nutrients, dissolved oxygen, pH, turbidity, in the different water layers (surface, cold intermediate water layer, bottom, etc.)

These oceanographic properties affect various processes related to organisms (e.g. growth, metabolism), populations (e.g. productivity) and habitats (overall health) present in the area (MPO 2014b). Key parameters and specific parameters should be selected in relation to the species and communities targeted by monitoring activities, such as water temperature in spring, which can influence primary and secondary production. Key parameters should also be used to monitor the potential effects of climate change on ecosystem features (pH, temperature and dissolved oxygen threshold) and optimal levels for the habitats of key species like the Atlantic wolffish.

O2) Dynamics of currents, waves and internal tides

Hydrodynamic conditions can induce mixing of water masses, cause nutrients inputs into the surface layer and promote increased primary productivity. Vertical migrations associated with the internal tide can contribute to zooplankton aggregations and their availability to predator species (Maps et al. 2015; McQuinn et al. 2016). Modelling would be useful for clarifying the prevailing dynamics. Further characterization is required to validate the indicator's relevance as well as to specify the parameters to be measured and the scale that should be recommended.

O3) Ice cover

The extent and thickness of ice cover vary considerably from year to year depending on winter weather conditions. Ice is transported into the area from the northern Gulf by the Gaspé Current or drifts in under the action of the prevailing winds (Galbraith et al. 2017). The direct effect of ice cover on marine ecosystems in the area is unknown, but it could influence the timing of phytoplankton blooms in spring and the use of the area by seals and cetaceans as well as fishers.

Pelagic ecosystem (P)

The CO #2 of the MPA is related to the conservation of pelagic habitats and forage species. All of the indicators developed are *indirect* indicators, since the pelagic habitat is very dynamic and the ecosystem features identified are not confined to the Banc-des-Américains MPA. For example, the capelin found in the area are not an isolated population that uses only this habitat. It is suggested that the indicators be measured using two spatial scales to distinguish local biomass from biomass from upstream of the MPA since organisms (phytoplankton, zooplankton, etc.) are transported by the Gaspé Current from the Estuary along the Gaspé coast.

Phytoplankton

Phytoplankton are at the base of the food chain and therefore essential for understanding the entire pelagic ecosystem and even the benthic ecosystem (pelagic-benthic coupling).

Measured in the MPA and across a larger region that is representative of oceanographic conditions:

P1) Chlorophyll a biomass

P2) Species abundance/taxonomy

Zooplankton

Zooplankton is a primary part of the diet of several biotic features (herring, capelin, mackerel, whales, etc.) related to COs and is therefore an important element to monitor to explain ecosystem variations. Its important link with higher trophic levels could explain observed variations in several other indicators selected.

Measured in the MPA and across a larger area:

P3) Total biomass

P4) Abundance of different dominant/key species: Calanus *spp.,* Pseudocalanus *spp.* and Temora *spp.*

To clarify the relevance of monitoring dominant species, a detailed characterization should be carried out to examine the relationship between the different zooplankton species and the predatory species found in the MPA. If some species are in fact the preferred prey items for key species in the area, the indicator should be retained.

Forage species

Krill, herring and mackerel were identified as key forage species in the MPA (Gauthier et al. 2013). Like zooplankton, these species play an important role in the diet of some whales and demersal fish species.

Measured in the MPA and nearby acoustic survey strata:

P5) Krill biomass

P6) Biomass from the herring stock assessment for Area 4T

P7) Biomass and abundance from the mackerel stock assessment

P8) Abundance of mackerel eggs, monitoring of spawning habitat quality

For the time being, no indicators have been identified for capelin, although it is understood that this species is very important for ecosystem functioning.

Benthic and demersal ecosystem (BD)

CO #1 for the MPA is aimed directly at the conservation of benthic habitats. Therefore, monitoring the communities found in such habitats or associated with them can provide information on the condition and evolution of this environment. According to Pomeroy et al. (2004), community composition is a very important indicator. Maintaining or restoring the composition and structure of a community that is a naturally component of an MPA is advantageous to ensure the integrity of the ecosystem, including its health, functions and resistance to disturbance. Community composition is represented by the diversity, species richness, and the relative abundance and dominance of the species found there (Pomeroy et al. 2004). Diversity measures provide a useful summary of community conditions and trends, but there is always a risk that species will disappear without any detectable change in diversity. The composition of the community therefore is an important factor (Stanley et al. 2015).

Monitoring of benthic habitats makes it possible to develop *direct indicators*. Three broad categories of benthic invertebrates (divided according to their position in relation to the substrate) are targeted for MPA monitoring: endobenthos, epibenthos and suprabenthos. The benthic invertebrates in each category include a wide diversity of species that perform a variety of ecosystem functions. However, little or no data are available for the endobenthic and suprabenthic groups, so no indicators have been proposed to date. One of the main reasons for monitoring benthic invertebrates is that many of them are important forage species for the young life stages and adults of several fish species that have commercial value (e.g. cod) or a conservation status (e.g. wolffish). Only macro- and megafauna would be considered, as monitoring micro- and meiofauna would not be realistic in terms of time and costs.

Epibenthic communities

Epibenthos monitoring focuses mainly on megafauna: echinoderms (starfish, brittle stars, basket stars, sea urchins, sea cucumbers), cnidarians (anemones, hydrozoans, soft corals), sponges, decapod crustaceans (crabs, lobster, shrimp), molluscs (gastropods, nudibranchs, scallops) and sea squirts.

Measured at fixed monitoring sites in the MPA, at control sites outside of it and in the strata of the nearby survey:

BD1) Presence / Relative abundance or percent coverage / Size structure of fixed, erect organisms (sponges, etc.)

Fixed, erect species including sponges, soft corals, algae and anemones (Table 7) are likely more vulnerable to pressures such as bottom-contact fishing gear (Fuller et al. 2008). These organisms can also serve as biogenic habitat for other demersal and benthic organisms (Campbell and Simms 2009; Hogg et al. 2010). It is therefore appropriate to monitor them. Further analysis should be carried out to select a few indicator species from the epibenthic communities.

BD2) Composition of demersal communities: species richness, diversity, abundance, density, biomass of species or taxa

BD3) Biomass, abundance and size structure of indicator/dominant species

It is recommended that key species be monitored, possibly cold-water stenothermal[1] species (e.g. snow crab), which are good indicators of temperature-related changes. Starfish should also be monitored since some species have very specific thermal preferences and are important benthic predators (Franz et al. 1981; Barkhouse et al. 2007). It is also easy to inventory them, given that species present in the Gulf of St. Lawrence are well known.

Demersal communities

This component is related mainly to the overall objective of the MPA, which is to promote the biological productivity and diversity of fisheries resources (harvested species). A number of demersal fish species are also dependent on benthos as a food source.

Measured in the MPA and the strata of the nearby multispecies survey:

BD4) Community composition: species richness, diversity, abundance, density, biomass of species or taxa

For this indicator, the parameters to be measured (diversity, abundance, richness, etc.) can be assessed for all species, or they can be assessed according to the functional groups of species present in these habitats. The preferred approach would be to define functional groups based on data from existing surveys.

Measured on the ridge:

BD5) Presence/size classes/abundance class of indicator species

It is recommended that demersal fish populations on the ridge be monitored, since historically this habitat has played an important role for cod and other fish. A number of demersal fish species are intimately linked to benthic habitats for food or shelter, for example. However, more specific knowledge on how these species use the ridge is required to validate the relevance of this indicator.

Benthic and demersal commercial species

This component is related to the overall objective of the MPA, which is to promote the biological productivity and diversity of fisheries resources. Information collected through existing (multispecies, sentinel, crab) surveys makes it possible to assess not only species abundance but also population structure, given that size, sex and age measurements are also recorded for commercial species.

Measured in the MPA and the strata of the nearby multispecies survey:

BD6) Biomass / abundance of commercial species

BD7) Size structure / sex / maturity

Measured on the ridge:

BD8) Abundance of lobster

Lobster populations around the Gaspé Peninsula are growing rapidly: catches per unit of effort and landings are increasing (MPO 2016), which may lead to an increase in lobster numbers in the MPA, especially to the west of the bank and on the ridge. The characteristics of the ridge—depth, temperature and substrate—are suitable for lobster. Lobster is a significant benthic

[1] Refers to organisms that can tolerate only a narrow range of temperature (Larousse).

predator (MPO 2014c) and could have impacts on the benthic and demersal communities of the MPA, including competition with other species that are usually present.

Substrate types

Substrate types directly influence associated benthic communities, mainly through the nature of the sediments and their grain size as well as the thickness of the oxygenated sediment layer. Properly characterizing substrates and monitoring their evolution ties into benthic monitoring and the broader CO of "conserving benthic habitats."

At monitoring sites in the MPA:

BD9) Type of sediment / grain size

It is recommended that sediment grain size be analyzed to properly characterize substrates.

Species at risk (EP)

A number of species at risk, including some fish species and marine mammals, are found in and around the MPA. This component is directly related to the third CO, and focuses on wolffish species and whale species at risk. There are no indicators related to other species as they are not directly targeted.

Atlantic Wolffish

The Atlantic wolffish is the only wolffish species whose presence in the MPA has been confirmed. Spotted wolffish are likely present, but it is not known whether Northern wolffish occur there. Monitoring will therefore be directed solely at Atlantic wolffish. Wolffish are generally sedentary: they use burrows and their movements are localized (Templeman 1984; Nelson and Ross 1992). It is necessary to provide a better description of how wolffish use the ridge, and to monitor the general trend of populations in the Gulf, in order to explain the evolution of the local population.

Measured on the ridge:

EP1) Presence / absence

EP2) Occupancy rate / availability of potential habitats (number of burrows) in the area

Measured in the MPA and the strata of the nearby multispecies survey:

EP3) Bycatch (commercial fisheries / scientific surveys)

Whales

The whales sighted in the Banc-des-Américains MPA have very large home ranges and use this area only at certain times of the year. Monitoring these species therefore requires an *indirect* indicator to evaluate the changes in the use of this area over time.

EP4) Presence of species at risk: fin whale, blue whale, humpback whale and North Atlantic right whale in and around the MPA

Ecosystem features to be considered

Three features should be included in the monitoring plan to ensure that it is complete and addresses all the conservation objectives. Owing to knowledge gaps, no indicators have been identified yet. However, this will be done as soon as more information becomes available.

Endobenthic communities

Monitoring of benthic habitats is directly related to CO #1. This includes the endobenthos, which consists of a diversity of species which perform a variety of ecosystem functions. There is no description of endobenthic community composition for the area. It is recommended that macrofauna (> 1 mm, caught with a 0.5 mm mesh) consisting mainly of polychaetes, priapulids, sipunculans, small bivalves, isopods, ostracods, cumaceans, amphipods, etc., be described initially. An analysis of the species sampled in the MPA along with a literature review would make it possible to target indicator species or groups of species. This knowledge of the endobenthos will allow the development of one or more indicators for use at fixed monitoring sites within the MPA and at control sites outside the MPA.

Suprabenthic communities

As with the endobenthos, monitoring of the suprabenthos is considered necessary to provide a comprehensive picture of the MPA's benthic habitats. The suprabenthos includes all invertebrates that live near the sea bottom or undertake vertical migrations in the water column, such as northern shrimp, gammarid amphipods and mysids. At most, only a scanty description exists of suprabenthic community composition in the MPA. Future sampling campaigns targeting this benthic component should describe its composition and contribute to the development of one or more monitoring indicators.

Capelin

Biomass is not measured during the stock assessment for capelin in the Estuary and Gulf of St. Lawrence, and data from multispecies surveys only indicate the presence of capelin, since pelagic fish are not targeted by this type of sampling. Accordingly, at present no survey data are available for assessing capelin abundance and biomass. However, a new monitoring activity is being developed at the MLI which could lead to an indicator in the future.

ANTHROPOGENIC PRESSURES (PA) AND PROPOSED MONITORING INDICATORS

In addition to ecosystem features, it is important to assess and quantify anthropogenic pressures in order to determine whether the adopted management measures are effective at reducing associated damage and potential impacts on species of interest and the MPA ecosystem.

Aquatic Invasive Species (AIS)

No AIS have been sighted in the MPA, but some encrusting AIS (e.g. *Membranipora* sp.) have been sighted in the Gaspé area. Invasive species can harm species that serve as biogenic habitat. *M. membranacea* is a bryozoan that attaches itself to algae (biogenic habitat), making it more likely that the algae will break apart during storms.

PA1) Presence/absence in the MPA

Noise and disturbance

In conjunction with CO #3 (to promote the recovery of whales at risk), monitoring of anthropogenic noise and disturbance in the MPA is recommended since these two aspects represent pressures for these species (Gendreau et al. 2018).

Measured in and around the MPA:

PA2) Anthropogenic noise

PA3) Commercial traffic intensity

PA4) Intensity of observation and recreational activities

The intensity and distribution of merchant shipping traffic (vessel type, tonnage, speed, etc.) are measured variables that do not directly measure noise but can provide information on the acoustic environment (Provencher et al. 2012). The parameters for the PA4 indicator could include the number of trips made by marine observation tour companies as well as the number of marinas, members and visitors in the area.

Collision

Collisions between ships and marine mammals pose a direct threat to the species targeted by CO #3. Since the proposed management measures for the MPA do not include restrictions on the passage of ships, the number of recorded accidents should be monitored along with accident trends over time. The vessel traffic indicator (PA3) and vessel speed can also provide information on the risk of collision.

Measured in and around the MPA:

PA5) Commercial vessel speed

PA6) Number of accidents (collisions)

Entanglement

Entanglement in active gear or ghost fishing gear can cause relatively severe injuries and even kill marine mammals. Monitoring of entanglements can help to detect trends for this pressure, which is directly related to CO #3 (the recovery of whales at risk).

PA6) Number of accidents (entanglements) reported in and around the MPA

Commercial fisheries

Some commercial fisheries continue to operate within the MPA, and several fisheries are carried out in the surrounding area. All biomass removed from and fishing intensity within the MPA itself should be accounted for to properly characterize changes in this pressure. Monitoring of fishing activities in the surrounding area may also be useful for assessing potential impacts of the MPA on landings made outside of the area.

Measured in and around the MPA:

PA8) Landings and commercial fishing effort for all fish and invertebrates

PA9) Distribution of fishing effort (data from the Vessel Monitoring System and logbooks)

Pollution

Pollution has been identified as a pressure that should be monitored because it can alter MPA ecosystems. However, no indicators have been identified yet due to the lack of available data. Since CO #1 focuses on the conservation of benthic habitats, sediment quality should be monitored in order to and track trends in the health of habitats. It is necessary to have baseline sediment quality data (presence and level of contaminants) before a decision can be made on indicator relevance and type. Since contaminant monitoring is not part of DFO's mandate, a partnership should be developed with Environment and Climate Change Canada (ECCC) or with the academic community. It would also be worthwhile to conduct monitoring to detect the presence of microplastics in the area.

FEATURES, PRESSURES AND INDICATORS NOT SELECTED

Sand lance

Existing acoustic surveys may not be able to distinguish between sand lance and mackerel and may fail to detect sand lance that have burrowed into the sand. As a result, accurate data on the sand lance are not available. Since the species' presence in the area has yet to be confirmed, it is recommended not to include sand lance in the MPA monitoring.

Total fishery landings (benthic and demersal commercial ssp.)

The abundance or biomass of target species cannot be adequately assessed using this indicator. It is therefore not a good indicator for monitoring commercial species. Note that this indicator has nevertheless been included in the anthropogenic pressures section to provide information on commercial fisheries.

Percent coverage/abundance of dead shell beds

The presence of dead shell beds could indicate massive bivalve mortalities and would therefore provide information on ecosystem health. It should be noted, however, that dead shell beds do not necessarily indicate that mortality occurred at the same location. Sometimes currents carry dead shells to a place where they accumulate. They may also be transported massively seaward during storm surges. This indicator was not selected because monitoring of these deposits would not help to determine their origin or the potential effects of MPA establishment.

Sediment biogeochemistry (deposition rate / organic matter inputs)

The deposition rate and the nature of sediment inputs (marine vs. terrestrial proportion) can be used to assess the strength and nature of pelagic-benthic coupling. Pelagic-benthic coupling is considered "strong" if the quantity of sediment received (deposition rate) and sediment quality (high proportion of fresh organic matter of marine origin) are high. Usually, areas where pelagic-benthic coupling is strong are characterized by high benthic species densities and biomasses (Roy et al. 2014). This indicator has been removed because no information is available on this very complex, potentially difficult-to-monitor and resource-intensive subject. It is recommended, however, that a baseline sediment characterization (e.g. organic matter, isotopes) be carried out with the help of experts and that analyses be conducted to determine whether a signal correlates with the endobenthos.

Abundance of species at risk (whales)

An indicator for monitoring these species has been selected; however, the existing or proposed surveys do not provide accurate information on species abundance.

Number of spills (pollution)

The MPA and the surroundings area is at very little risk from an accidental spill considering the type of vessels that pass through the area and transit frequency. An indicator would therefore not be useful since very little spill-related data would be collected. If an accident occurs, it will be noted in the monitoring report.

Climate change

This component has been removed from the list of anthropogenic pressures and integrated into oceanographic monitoring as part of the O1 indicator. The key parameters—dissolved oxygen, pH and temperature—relate to climate change; the monitoring objective for these parameters needs to be explained clearly.

MONITORING PROTOCOLS AND STRATEGIES

To be able to monitor all these indicators, existing monitoring programs that already collect relevant data in the MPA should be identified. It is recommended first of all that these existing surveys be improved and optimized in order to fill knowledge gaps, and when a new monitoring protocol needs to be developed, it should be linked to broader-scale projects throughout the Gulf to maximize this data collection. The monitoring programs and strategies that could be used for the Banc-des-Américains MPA are based on the best knowledge and technologies available at the time of publication of this research paper (Table 8). This is not an exhaustive list, and depending on how the monitoring plan and technology evolve, other monitoring protocols could be developed and used.

DFO defines protocols as specific methodologies required to monitor indicators (equipment, techniques, quality control, etc.) and strategies as means of implementing monitoring protocols (government agencies, universities, community groups, etc.) (MPO 2013).

Existing monitoring programs

R1 Atlantic Zone Monitoring Program (AZMP)

This program was implemented in 1998 and involves DFO's Gulf, Quebec, Maritimes, and Newfoundland and Labrador Regions. Its purpose is to monitor and predict changes in productivity and in the state of the marine environments by collecting and analyzing the biological, physical and chemical data required to characterize ocean variability and to establish relationships between biotic and abiotic variables. A key component of the program is oceanographic sampling at high-frequency sampling stations as well as along transects and deep channels (Figure 4). High-frequency sampling stations are generally visited every two weeks, depending on weather conditions, while transects and other stations are sampled two to three times a year for large-scale surveys. Regular sampling includes measuring temperature, salinity, fluorescence, oxygen, nitrates, phosphates and silicates and collecting phytoplankton and zooplankton samples at various depths. The monitoring stations in Rimouski and Shediac Valley are part of the AZMP. During this survey, acoustic data are collected continuously to assess krill density, the relative (acoustic) abundance of herring/capelin and the relative (acoustic) abundance of mackerel/sand lance.

No AZMP stations are currently sampled directly in the Banc-des-Américains area. However, the monitoring program can provide large-scale data and extract certain parameters for the area of interest. For MPA monitoring, additional stations visited during major surveys could be added to the program to provide local data.

R2 Real-time Viking buoy network

The real-time buoy network operated by the MLI (DFO) currently consists of six buoys deployed in the Gulf of St. Lawrence that measure a set of optical, oceanographic and meteorological properties, and are equipped with communication systems enabling them to transmit and diffuse data in real time. The information collected is used, among other things, to validate and calibrate satellite imagery that provides large-scale information on surface temperatures and phytoplankton biomass (chlorophyll *a*). The first buoy was installed in 2002 at the Rimouski station. A second buoy was installed in 2004 at the Shediac Valley station in the southern Gulf of St. Lawrence, followed in 2005 by the buoys at the Banc Beaugé, Gaspé Current and Anticosti Gyre monitoring stations. In recent years, most of these buoys have been equipped with a temperature and salinity profiler that takes measurements in the water column under the buoy.

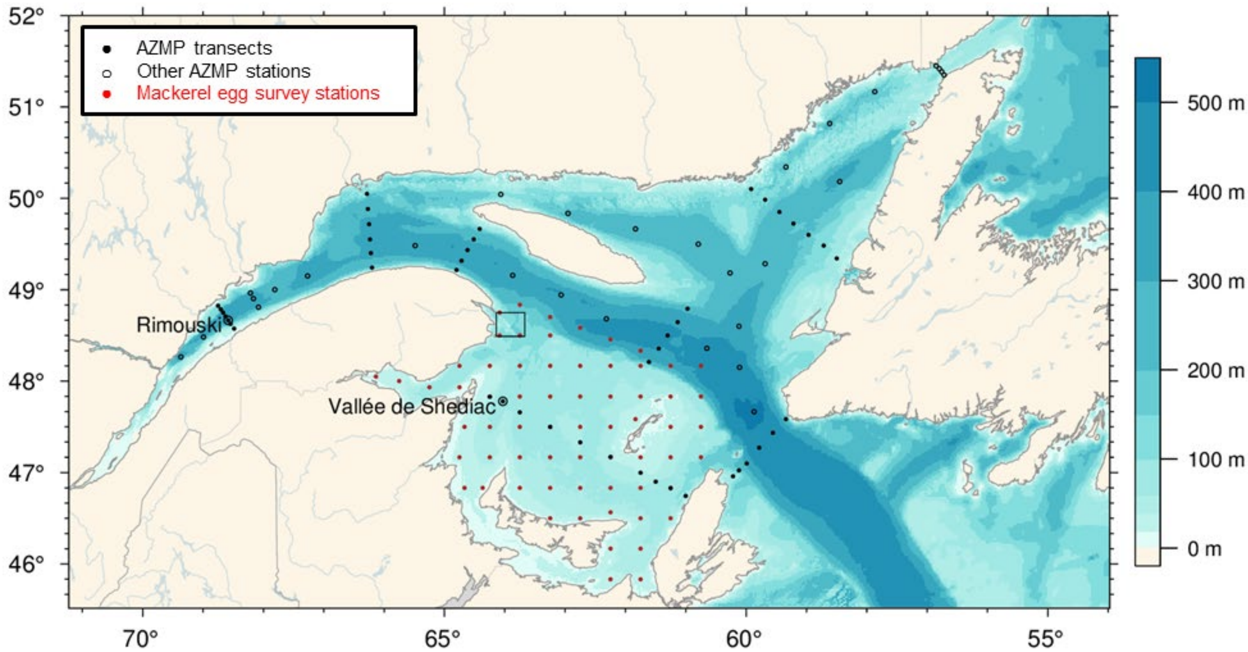

Figure 4. Locations of AZMP and mackerel egg survey stations.

In 2017, after new buoys were acquired for the AZMP as part of Science Renewal, a new buoy was deployed on the Magdalen Shallows between Prince Edward Island and the Magdalen Islands (East Southern Gulf), while an old buoy was relocated to the American Bank site. It is recommended that the Viking buoy at the American Bank be maintained. Instruments could be added to the buoy to round out sampling, such as a fluorometer and a dissolved oxygen sensor on the temperature-salinity profiler and a hydrophone.

R3 Monitoring of ice cover

The Canadian Ice Service's mission is to provide the most timely and accurate information about ice (area, thickness and period) and icebergs in Canada’s navigable waters.

Data for the Estuary and Gulf are already collected and processed by the AZMP and therefore could be easily be used for the MPA (Galbraith et al. 2017). By-products specific to this area could be added to the annual report on physical oceanographic conditions, including freeze-up and break-up dates.

R4 Remote sensing of surface temperature

The AZMP annual bulletin on the physical oceanographic conditions in the Gulf includes analyses of historical satellite data from the now-defunct remote sensing laboratory at the MLI (DFO), along with data from the Bedford Institute of Oceanography (DFO). By-products specific to the MPA could be added to the annual report on physical oceanographic conditions.

R5 Thermograph network

DFO's thermograph network (Pettigrew et al. 2016) consists of more than 20 stations with moored instruments that have been used to record water temperature usually at the surface and at the sea bottom every 30 minutes (Figure 5) almost continuously since 1993. Most of the instruments are installed on Coast Guard buoys that are deployed during the ice-free season, but a few stations are present year-round. The stations have a depth ranging from 5 to 450 m.

Data for the Estuary and Gulf are already collected and processed for the AZMP and could therefore easily be made available for the MPA (Galbraith et al. 2017).

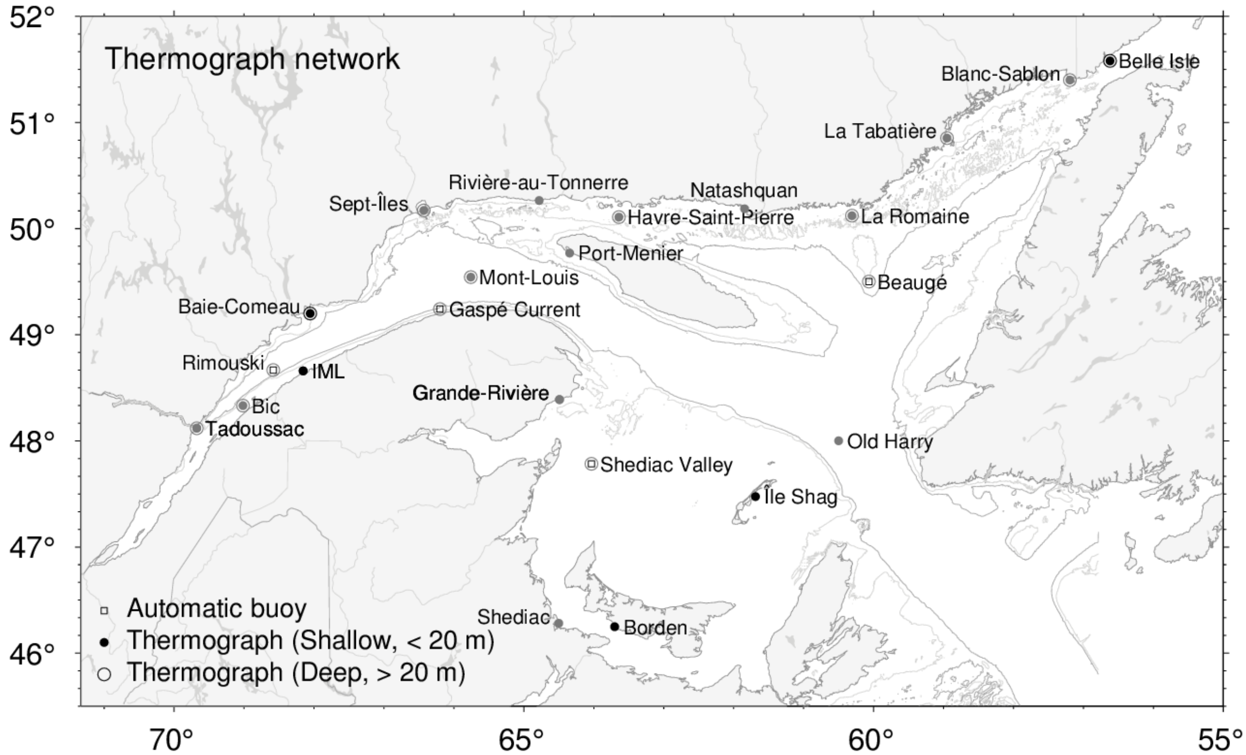

Figure 5. DFO's thermographs network; some stations are located in coastal areas (shallow, < 20 m) and others are in deeper waters (deep, > 20 m).

R6 Monitoring of winter water masses – helicopter mission

Every year since 1996, approximately 60 stations have been visited in March in the Lower Estuary and the Gulf of St. Lawrence using Canadian Coast Guard helicopters. The data collected include temperature, salinity, nutrient salts and plankton (Galbraith 2006).

A sampling station is located in the MPA. These data are also processed and included annually in the AZMP annual bulletin.

R7 Pelagic acoustic survey of the Estuary and northwestern Gulf

DFO's Quebec Region has been conducting an annual acoustic survey since 2009 to estimate the biomass of northern krill and Arctic krill in the Estuary and northwestern Gulf for stock assessments (McQuinn et al. 2015). The survey is carried out in August using systematic transects in predetermined strata (Figure 6). The survey also provides density and distribution data on pelagic fish which could be used to assess the relative (acoustic) abundance of herring/capelin and the relative (acoustic) abundance of mackerel/sand lance.

The MPA is part of a sampled stratum, and every year transects are surveyed which cover the general American Bank area. It would also be useful to consider the data collected in the strata along the Gaspé coast as they encompass the Gaspé Current. The results of this survey could provide data for indicators related to forage species and zooplankton biomass.

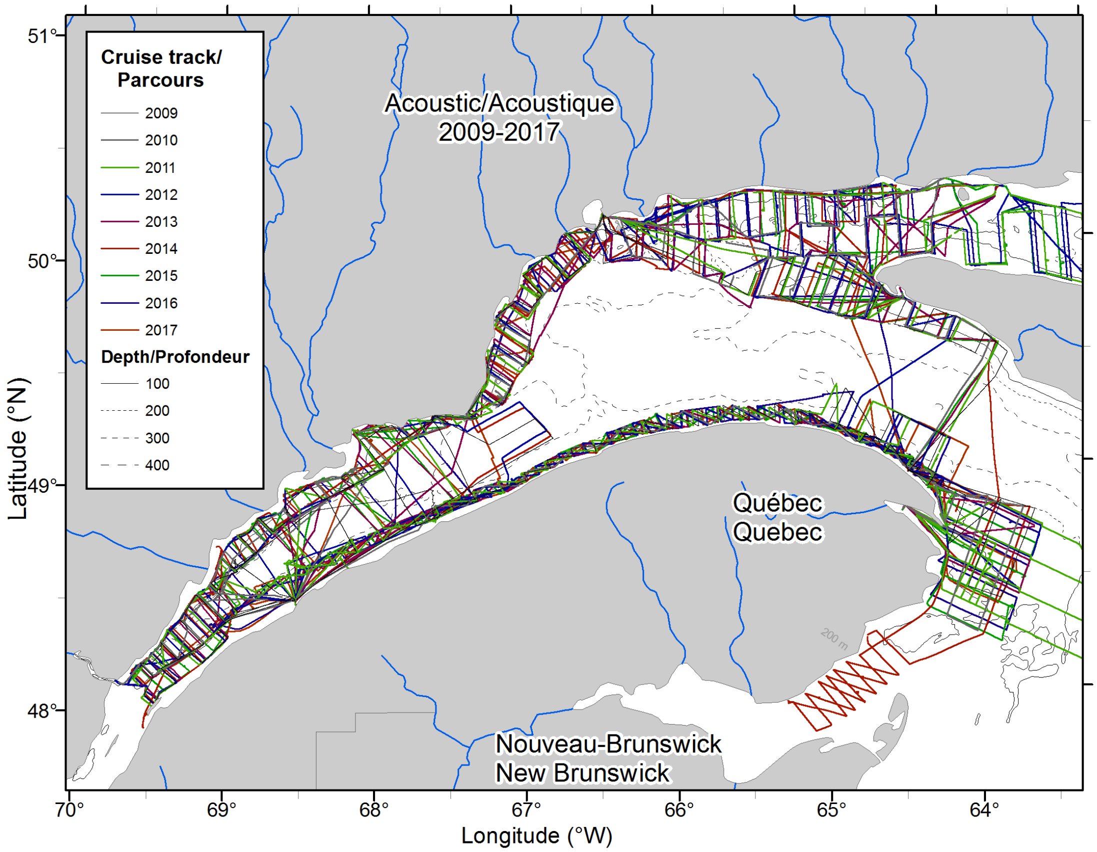

Figure 6. Pelagic acoustic survey of the Estuary and northwestern Gulf, 2009-2017.

R8 Annual herring acoustic survey (sGSL)

DFO's Gulf Region conducts an acoustic survey every year to estimate the biomass of herring in the southern Gulf of St. Lawrence (sGSL) (4T) for the stock assessment. The survey takes place in September and is carried out using systematic transects in predetermined strata (Figure 7). The results of this survey could complement the information collected for the herring indicator and the zooplankton biomass indicator.

R9 Mackerel egg survey

DFO's Quebec Region has been conducting an AZMP survey in the Gulf in June of each year since the 1990s using a fixed grid of stations (Figure 4) to assess mackerel egg density and abundance and therefore mackerel biomass for the stock assessment. Although this assessment covers the Atlantic stock, the southern Gulf is the main spawning area for mackerel.

Four sampling stations are located within the MPA. It would be appropriate to standardize the protocol for quantifying zooplankton at these stations based on the AZMP protocol. It would be interesting to explore the possibility of adding a few stations located within the MPA to get a better picture of the local area.

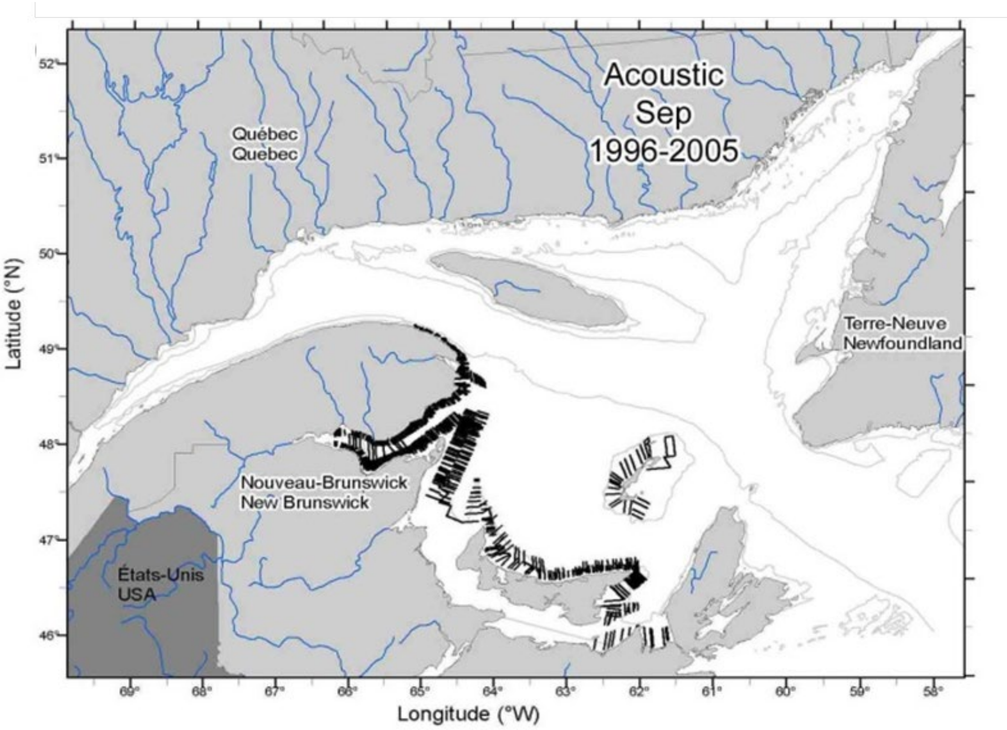

Figure 7. Distribution of transects sampled during sGSL acoustic survey in September, 1996-2005 (McQuinn et al. 2012).

R10 Multispecies bottom trawl survey in the southern Gulf

Every September since 1971, the multispecies bottom trawl survey has been carried out by a research vessel (RV). The survey has random stratified sampling design, with strata defined according to depth and area (see Hurlbut and Clay 1990 for further methodology details), which covers most of the southern Gulf of St. Lawrence (Northwest Atlantic Fisheries Organization [NAFO] Area 4T). Three coastal strata were added to the survey in 1984. Thirty-minute tows are carried out.

Since 1971, data have been collected on fish species, weight and number caught, as well as length frequencies and individual weights. For commercial species, data on the sex and maturity stage are collected, and otoliths are collected for age determination. Since 1980, catches of large crustaceans (crabs, lobster) have also been sorted, weighed and counted, and length frequencies have been recorded since 2000. Since the late 1990s, the other organisms caught have also been sorted by taxonomic group and weighed, which means that the entire contents of the trawl catches have been recorded for nearly 30 years. This survey is also an important source of oceanographic (physical, biological and chemical) data collected at each sampling station, and of acoustic data collected continuously which is used to assess krill density and the relative (acoustic) abundance of pelagic fish.

The RV survey catches over 70 fish species and over 50 invertebrate taxa (Benoît et al. 2009). In addition to providing important baseline data for stock assessments of commercial species, the survey provides important data for several other issues (Benoît et al. 2009), such as the status of species at risk (e.g. MPO 2017b) and changes in the southern Gulf ecosystem (e.g. Benoît and Swain 2008; Swain et al. 2015; Swain and Benoît 2015).

Since the 2000s, one to six stations (three/year, on average) have been sampled in the MPA (Figure 8). It would be useful to keep these survey stations, as they provide a long time series preceding the implementation of management measures and also provide data from outside the MPA (BACI approach). The data can be used for indicators related to demersal fish and also provide information on the benthos, but the level of taxonomic resolution is low. This identification effort will need to be refined, among other things, by standardizing protocols according to those used in the northern Gulf survey and by sharing knowledge and obtaining external support.

R11 Multispecies bottom trawl survey in the northern Gulf

Similar to the southern Gulf bottom trawl survey, a multispecies survey has been conducted in the northern Gulf of St. Lawrence every August since 1990 for the groundfish and shrimp stock assessments, including the taxonomy of all harvested species. Oceanographic data are also collected during this mission.

While this survey does not take any samples in the MPA, the vessel traverses the MPA to reach the Port of Gaspé. It may therefore be possible to visit one or two stations to collect additional oceanographic data according to the AZMP protocol. Acoustic data have also been recorded during this survey since 2005 in order to monitor forage species.

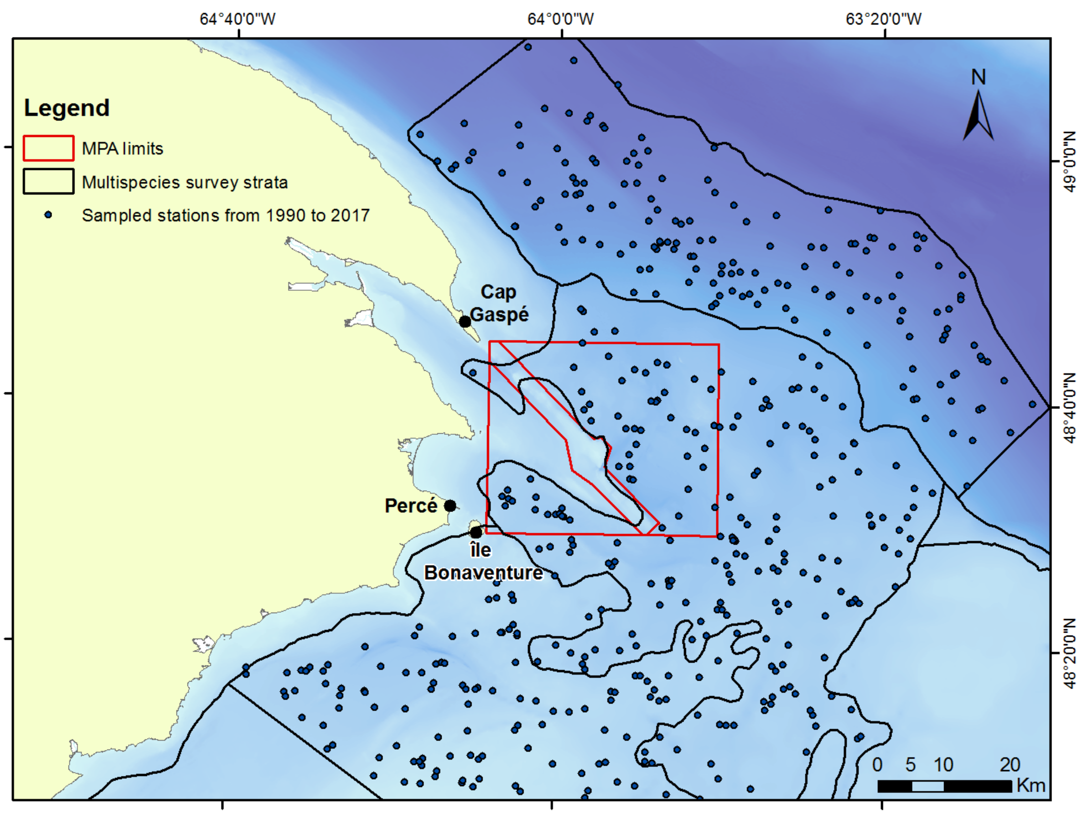

Figure 8. Stations sampled during the multispecies bottom trawl survey in the southern Gulf in strata 415-416-417 around the Banc-des-Américains MPA, 1990-2017.

R12 Multispecies bottom trawl survey conducted by the sentinel fishery

A bottom trawl survey has been carried out by the sentinel fishery in the southern Gulf of St. Lawrence (NAFO Area 4T) every August since 2003 and currently includes 166 stations (Savoie 2016). This survey uses a stratified random sampling design along with a standardized fishing protocol. The strata are the same as in the RV survey, but sampling is done by four commercial vessels that carry out 30-minute tows. Analyses are carried out to standardize the catches of the different vessels in order to maintain homogeneous time series for catch rates. All fish and invertebrate species caught in each tow are sorted, weighed and counted. Length measurements are taken for commercially important species such as cod, American plaice and Atlantic halibut. Biological sampling is performed by two at-sea observers on each vessel, and stations are sampled in the Banc-des-Américains MPA.

The main objectives of this survey are to collect information on the composition and distribution of groundfish stocks and to construct indices that can be used to draw conclusions about fluctuations in groundfish species abundance. The survey is also used to collect information on all demersal fish species caught with trawls. When used in combination with other surveys, this survey can provide new results, including detecting seasonal distribution changes. For example, a recent comparison of the RV and sentinel surveys revealed a concentration of cod in the area around the MPA that is present in August but not in September, thus identifying seasonal movement that would not have been detected by a single survey (Savoie 2016).

An annual longline survey has also been carried out by sentinel fishers since 1995 (Savoie 2014). There are no sampling stations for this survey in the MPA. The nearest ones are farther south, on the Gaspé coast at the mouth of Baie des Chaleurs and on the Miscou Bank.

R13 Snow crab bottom trawl research survey in the southern Gulf

An annual snow crab bottom trawl survey has been conducted in the southern Gulf since 1988; it has sampled 355 stations every year since 2012 (Wade et al. 2018). The area covered has varied over time (Moriyasu et al. 2008); the survey now covers the entire area between 20 to 200 fathoms in the southern Gulf. Despite these changes, the survey has been carried out in the Banc-des-Américains MPA and surrounding area from the outset. The sampling plan includes stations that were initially randomly selected on a regular grid and then subsequently at fixed stations (Figure 9). The survey is conducted after the commercial fishery season ends, typically from July to late September or early October.

A nephrops trawl is towed for 4 to 6 minutes (Wade et al. 2018) and then the biological characteristics (size, sex, stage of development and maturity) of each crab caught are assessed. Other invertebrate species and fish and caught in each tow are sorted by species or taxonomic group (e.g. anemones, brittle stars) and counted. Fish length frequencies have also been recorded at 100 randomly selected stations since 2009.

As with the sentinel survey, comparing the results of this survey with results from another survey may point to conclusions about the ecology of the southern Gulf. This kind of a comparison, for example, revealed that variations in the spatial distribution of the thorny skate, as observed in the RV survey, were actually interannual distribution changes, rather than a variation in seasonal migration dates (Swain and Benoît 2006). These changes include the absence of this species in the MPA for about 15 years (Swain et al. 2015).

Since 2012, 4 to 6 stations (five/year on average) have been sampled in the MPA, including a few stations in Zone 1. This survey provides data from before the MPA was established as well as from outside its boundaries (BACI approach). More precise identification of benthic invertebrate taxa should be encouraged.

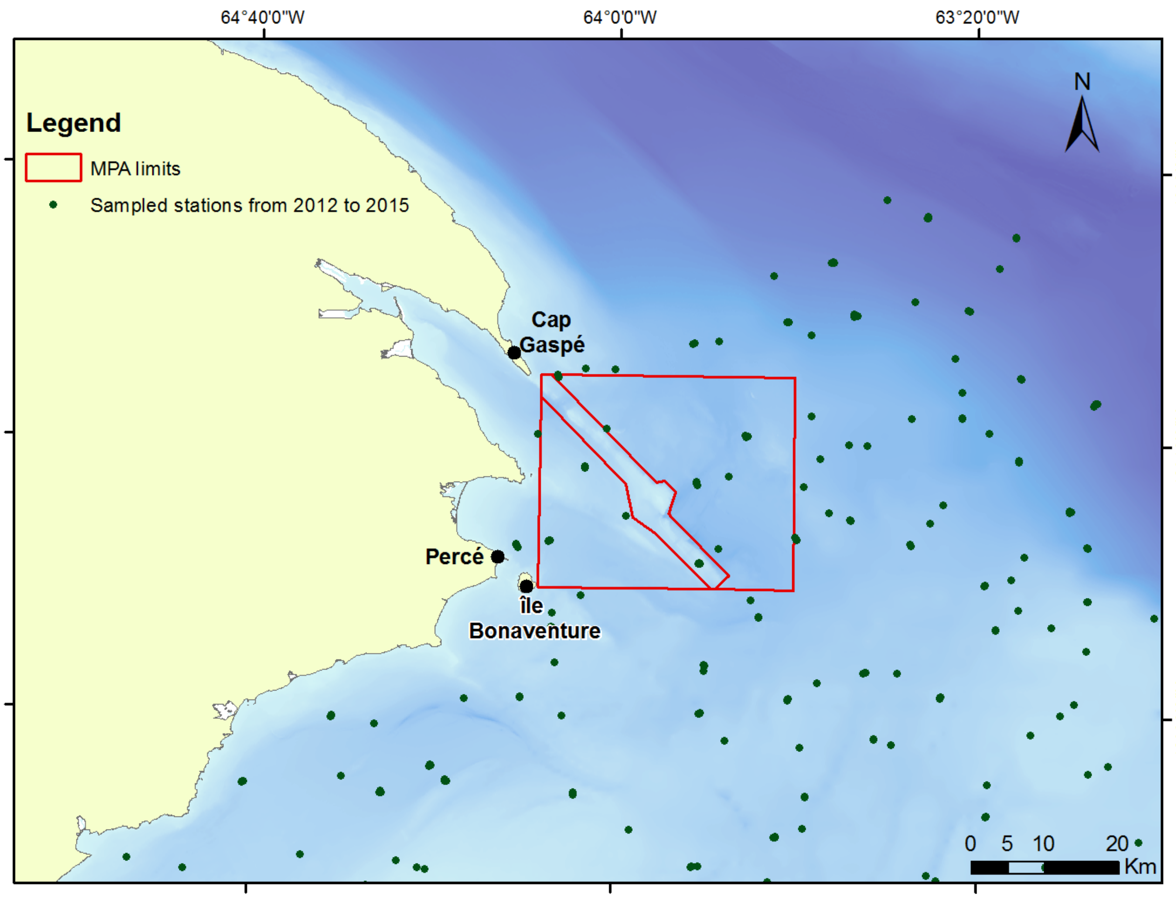

Figure 9. Stations sampled during the snow crab bottom trawl research survey in the southern Gulf, 2012-2016. Boundary of the Banc-des-Américains management areas in red.

R14 Fishing data from *zonal interchange file format (ZIFF) files*

ZIFF files integrate information from logbooks completed by commercial fishers (fishing locations and catches) with landing data for different species from the Dockside Monitoring Program (DMP).

In the MPA, several fishing activities are permitted in Zone 2. Fisheries data are therefore valuable for assessing the biomass removed from the MPA along with bycatches, as well as for assessing the abundance of target species outside the area (spillover).

R15 At-Sea Observer Program

The At-Sea Observer Program is another source of data on catches of benthic and demersal species; it is aimed at ensuring the effective management and control of fisheries. This program involves placing certified private sector observers on board fishing vessels to collect scientific data and monitor industry compliance with fisheries regulations and licence conditions. At-sea observers provide information on all catches (fish and invertebrates) made by a given vessel.

In the MPA, the snow crab fishery is the main commercial fishery covered by this program. In 2018, at-sea observers were required to be present for 20% of fishing trips.

R16 Marine Mammal Observation Network (MMON)

MMON is a not-for-profit organization dedicated to the protection and conservation of cetaceans and pinnipeds and their habitats. The cornerstone of the organization is a well-established network of observer members, including boat tour operators (who cover different areas), conservation parks and ocean carriers. MMON-trained observers also participate in marine mammal observation cruises and apply a standardized observation protocol. Since 1998, these observers have been collecting data on whales and seals observed throughout their operating season as part of a broad environmental observation project seeking to better define the distribution of these animals in the St. Lawrence.

Observers collect a lot of data in and around the MPA, given that many marine mammal watching tours take place in the area. However, these observations are concentrated in the western portion of the Banc-des-Américains MPA, which is closer to the coasts and ports. Boat operators do not have time to travel farther offshore during boat tours. It would be interesting to consider possibilities for optimizing this survey.

R17 Annual monitoring of whales at the Mingan Islands Research Station

Since 1979, the Mingan Island Cetacean Study (MICS) has been conducting annual monitoring using photo-identification of blue whales, humpback whales, fin whales and minke whales present in the Gulf of St. Lawrence (Comptois et al. 2010). One of the areas used includes the MPA. Thus, a lot of data is collected in this sector. Data are collected in this area during the blue whale's peak use period, from late June to early July. However, due to the logistics involved, the MICS does not visit the sector every year.

R18 Quebec Marine Mammal Emergency Response Network (QMMERN)

The Groupe de recherche et d'éducation sur les mammifères marins (GREMM) has been in charge of monitoring beached marine mammals since 2003 and, in 2004, it created the Quebec emergency network (QMMERN) for marine mammals in distress, in collaboration with 13 partners including DFO and Parks Canada. One of the network's mandates is to promote the acquisition of knowledge about marine mammal carcasses and live animals that are stranded or drifting in the waters of the St. Lawrence in Quebec. If the carcasses of these animals are in good condition, the cause of death can be determined either on site, if the cause is obvious (e.g. a bullet hole), or though a necropsy.

QMMERN data could be used for indicators related to anthropogenic pressures, such as the number of collisions and entanglements. This existing monitoring activity was assessed as fairly reliable (incomplete and non-specific data) during the review of indicators for the Estuary MPA project (Provencher et al. 2012).

R19 Monitoring of marine traffic using navigation information system

The international Automatic Identification System (AIS) identifies and tracks commercial vessels operating in the Estuary and Gulf of St. Lawrence. These data can be used to assess traffic intensity in the MPA and the related spatial and temporal variations. With this tool, it is possible to know the speed of ship and traffic density. The main commercial traffic in this sector transits to the Port of Gaspé. The traffic data derived from the AIS can also be used as an approximation of noise and collision risks.

R20 Monitoring of northern gannets

Northern gannets feed on capelin and mackerel, two species targeted by MPA monitoring measures. Monitoring of gannets is carried out by Île-Bonaventure-et-du-Rocher-Percé National Park and the Université du Québec à Rimouski (UQAR) and includes assessment of stomach contents (availability of capelin and mackerel prey), condition, reproductive success and nesting success. While it has been suggested that this survey could provide information on the availability of some forage species, the quantitative data collected and the area covered should be examined in greater detail.

R21 Annual summer monitoring of aquatic invasive species (AIS)

In 2006, DFO implemented an AIS monitoring program on the Atlantic coast. This program covers three sectors in Quebec: the Magdalen Islands, the Gaspé, and, since 2009, the North Shore. The aim of this program is to detect new AIS and minimize the risk of introduction and spread. Monitoring is carried out in coastal environments (marina, port, etc.) using collectors (PVC, 10 x 10 cm) designed to capture sessile species that can attach themselves to them. Analysis of the species that colonize collectors allows early detection of new AIS, and also provides information on native species. PVC collectors could be deployed on the ridge of the MPA to collect samples.

R22 Vessel Monitoring System (VMS)

DFO's VMS is a near real-time satellite vessel tracking system used to monitor vessel locations and movements. The VMS provides the latitude, longitude, date and time of a ship's movements. In some cases, the VMS also provides vessel speed and direction data. Licence conditions for some fisheries require that license holders have a VMS unit on board their fishing vessel. Fishing effort can be determined with the data from this monitoring system.

Monitoring activities to be developed

Surveys should be added so that all indicators can be monitored. The proposals generated by the internal workshops in February 2018 are briefly outlined in this section, but should be evaluated based on how feasible it is to implement and maintain them over time as well as based on the information they provide.

RD1 Benthic imagery survey and RD2 Benthic grab sampling survey

Although the COs target the benthic communities directly, none of the surveys conducted at present provide comprehensive coverage of this ecosystem component, especially on the ridge. It is therefore recommended, in line with the suggestion made by Provencher and Nozères (2011), that distinct species assemblages be identified and then monitored to ensure adequate monitoring of the epibenthic and endobenthic communities. Using data already collected by benthic imagery (Figure 10) (Savenkoff et al. 2017), average-linkage hierarchical cluster analysis was conducted to try to identify large species assemblages. It should be noted that there are gaps in the data on the endobenthos. To improve current knowledge of endobenthic communities in the MPA, a few stations were surveyed using a grab sampler in the summer of 2018. To fill these gaps, data on depths and substrate types, which are well defined in Savenkoff et al. (2015), will be used to help identify distinct zones in terms of species assemblages.

A protocol could be developed using fixed stations with random replicates in each of these distinct zones. For epibenthos monitoring, a benthic imagery survey could be developed using equipment available at the MLI (drop camera and benthic sled), which could be used to inventory both the plains and the ridge. A complementary survey using a grab sampler should be used to monitor the endobenthos on the plains since the ridge is predominantly rocky. Measures of species abundance and biomass at each station will be used to monitor benthic assemblages in the MPA. Abiotic variables will also be monitored so that the environment of these communities can be assessed and indicators can be better interpreted. The required frequency of these surveys should be specified; however, they cannot be conducted every year given the costs and effort involved.

Benthic surveys could also be used to monitor substrates. For soft substrates, sediment samples could be collected at the same stations as for the endobenthos with a view to performing grain size analyses. For hard substrates, benthic imagery could be used to describe cobble and rock cover and size.

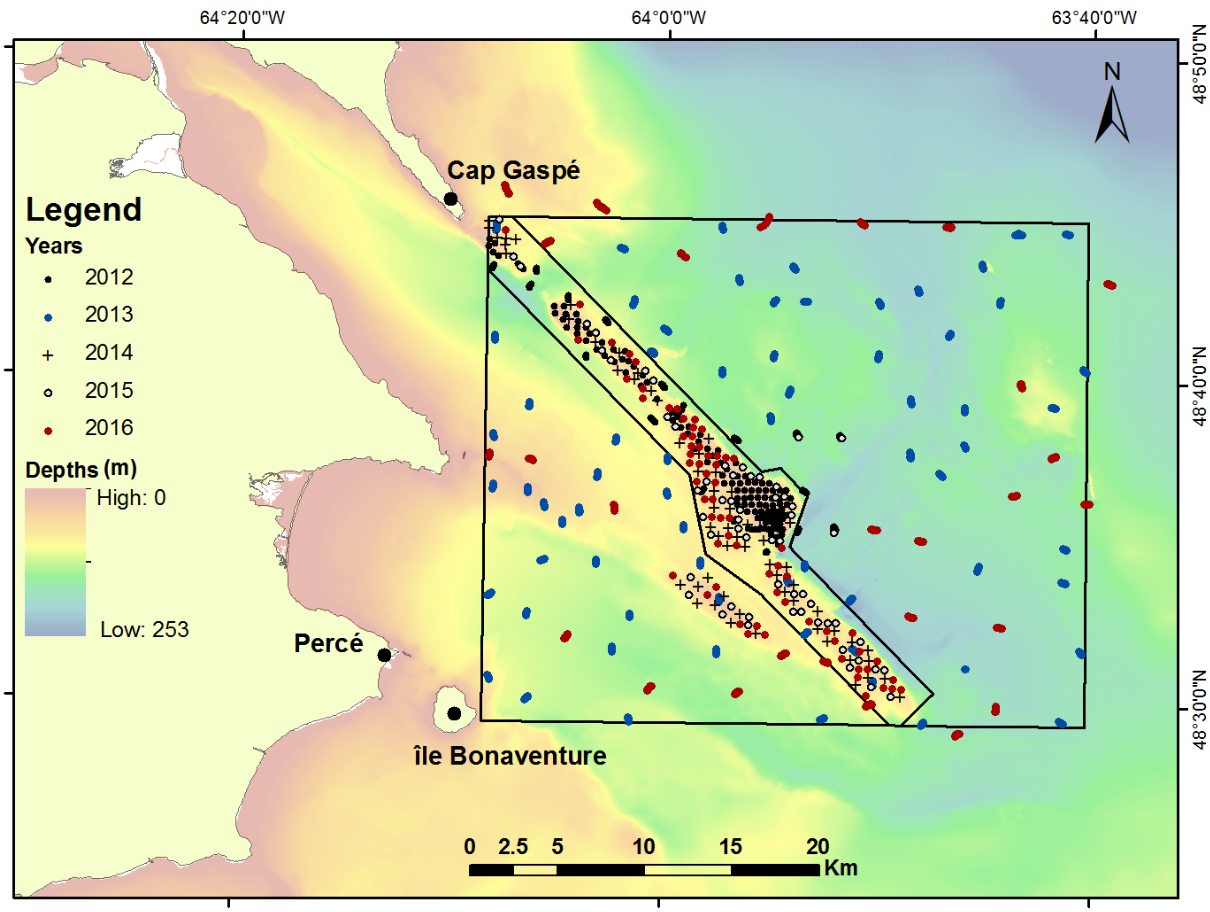

Figure 10. Stations sampled during benthic imagery surveys from 2012 to 2016 using a high-resolution bathymetric grid of the Banc-des-Américains MPA.

RD3 Moorings for physicochemical data collection

As a complement to data collection by the Viking buoy in the MPA, it has been suggested that additional moorings be deployed in the area, for example one on either side of the ridge. These moorings would enhance continuous measurement of physicochemical parameters and characterization of phytoplankton elsewhere (not only in front of the cliff) and thus better understand the dynamics of this sector. An acoustic Doppler current profiler (ADCP) could be added to the moorings to monitor currents and zooplankton.

A multifrequency acoustic zooplankton fish profiler (AZFP) system, which monitors both zooplankton and fish in a more efficient way than an ADCP, could be considered, but this approach would be more expensive.

RD4 Scuba diving

Monitoring could be carried out on the ridge by scuba divers to detect the presence of Atlantic wolffish, validate the potential habitats already identified by benthic imagery and identify other potential habitats.

The scuba diving method could also be used to collect data on the presence and abundance of lobsters and other demersal species on the ridge. The frequency of this survey needs to be determined, but given the high cost involved, it could not be carried out on an annual basis.

RD5 Environmental DNA (eDNA)

A survey to collect eDNA samples has been proposed as a first step in monitoring the Atlantic wolffish. eDNA can be used to monitor a target species in a non-invasive way and at a lower cost (Ulibiri et al. 2017) by identifying the species from DNA fragments present in seawater (Thomsen et al. 2012; Turner et al. 2015). The analysis technique has yet to be developed. It will be necessary to develop a precise protocol and identify genetic markers specific to wolffish. Monitoring would be conducted as an exploratory survey over the next few years; it could be combined with scuba diving in an effort to refine the technique. In the future, eDNA could also be used to monitor other target species (e.g., lobster and cod) on the ridge or AIS.

RD6 Passive acoustics – Hydrophone

Measuring underwater noise can provide information on natural sounds produced by organisms, among others, as well as on anthropogenic sound. Acoustic monitoring can be used to identify species and provide information on how cetaceans use the MPA and the surrounding area. Measuring noise would also provide information on anthropogenic pressures related to navigation activities and the associated indicator.

Vocalizations specific to blue whales were detected between 2010 and 2015 using passive acoustic monitoring (PAM) at several recording stations, including one at Cap-d'Espoir near the MPA (Simard et al. 2016). It would be interesting to establish links with acoustic monitoring projects in this sector and to consider whether it would be worthwhile to install a PAM station directly in the MPA. The station would ideally be located near the bottleneck on the northwest side of the site.

CONCLUSION AND RECOMMENDATIONS

The selection of indicators for ecological monitoring of the Banc-des-Américains MPA is a key step toward adaptive management. The ecosystem features and indicators selected were analyzed in relation to the overall goal of the MPA and its COs to ensure that they provide relevant information for its management. Since the MPA environment is not under much pressure at this time, the site will be monitored primarily to determine whether its current state is being maintained over time. Some improvements may be observed over the long term. There are no recovery objectives for the MPA, only conservation objectives.

As a first step, based on the existing information, a total of 33 indicators have been developed to help managers ensure that appropriate ecological monitoring is conducted in the MPA. These indicators may change and be enhanced as additional knowledge of the environment is acquired. Whereas indirect indicators (n=11) were selected to cover physical and chemical oceanography and the pelagic ecosystem, most of the indicators (n=9) selected for the benthic and demersal ecosystem are direct indicators. In addition, four indicators were selected to monitor whales at risk and the Atlantic wolffish, and nine indicators were selected to monitor the identified pressures. Because of knowledge gaps, however, no indicator was identified for capelin and the endobenthic and suprabenthic communities, even though these ecosystem features should be monitored. Data therefore need to be collected to fill these gaps before indicators can be specified for these features.

An opportunistic strategy for ensuring the sustainability of monitoring at a lower cost must be put forward. A review of the existing surveys and the data they collect made it possible to identify a number of programs that can be used to support monitoring efforts. Some of these surveys could be improved to enhance spatial coverage, among other things, in or near the MPA, without requiring a significant investment of time and money. New surveys need to be developed for some indicators, however; six new surveys have been proposed, some are already in the planning states or undergoing testing, including the imagery survey, the endobenthos survey, eDNA survey and scuba diving. These surveys should be implemented in the coming years. Other surveys, such as additional moorings and passive acoustics would require a much greater investment and are therefore not being considered in the short term.

At present, there is insufficient information to propose a comprehensive monitoring plan. Sampling protocols need to be described in greater detail and the parameters that will be used to measure indicators need to be precisely defined. It is therefore recommended that a scientific committee be established to review and validate certain features and indicators, to describe all the necessary protocols in more detail and thus propose a comprehensive monitoring plan, and lastly to work on implementing this plan. The BACI approach should be used, where possible, to assess existing surveys and develop monitoring protocols, since it makes it possible to ascertain whether changes observed in the MPA are the result of management measures. The committee should include MPA managers and representatives responsible for the various activities undertaken to monitor aspects covered by the conservation objectives.

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APPENDIX 1- ACRONYMS

ADCP	Acoustic Doppler Current Profiler
eDNA	environmental DNA
AIS	Automatic Identification System
AIS	Aquatic invasive species
AOI	Area of interest
AZMP	Atlantic Zone Monitoring Program
BACI	Before after controls impact analyses
BdA	Banc-des-Américains
CIF	Cold intermediate layer
CO	Conservation objective
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPUE	Catch per unit of effort
DFO	Fisheries and Oceans Canada
EBSA	Ecologically and Biologically Significant Area
ECCC	Environment and Climage Change Canada
GREMM	Group for Research and Education on Marine Mammals
MICS	Mingan Island Cetacean Study
MLI	Maurice Lamontagne Istitute
MMON	Marine Mammal Observation Network
MPA	Marine protected area
NAFO	Northwest Atlantic Fisheries Organization
nGSL	Northern Gulf of St. Lawrence
PAM	Passive acoustic monitoring
QMMERN	Quebec Marine Mammal Emergency Response Network
ROPOS	Remotely Operated Platform for Ocean Sciences
RV	Research vessel
SARA	*Species at Risk Act*
sGSL	Southern Gulf of St. Lawrence
SLAP	St. Lawrence Action Plan
VMS	Vessel monitoring system
ZIFF	Zonal interchange file format

APPENDIX 2- TABLE

Table 1. Species at risk present or potentially present in the Banc-des-Américains Marine Protected Area

Species	Status of COSEWIC[1] (date of appointment)	Status of SARA[2] (date of appointment)
Atlantic wolffish	Special concern (2012)	Special concern (2003)
Spotted wolffish	Treathened (2012)	Treathened (2003)
Northern wolffish[3]	Treathened (2012)	Treathened (2003)
American plaice - Maritime population	Treathened (2009)	No status
Thorny skate	Special concern (2012)	No status
Atlantic cod - Laurentian South population	Endangered (2010)	No status
Atlantic bluefin tuna	Endangered (2011)	No status
Leatherback sea turtle - Atlantic population	Endangered (2012)	Endangered (2013)
White shark - Atlantic population[4]	Endangered (2006)	Endangered (2011)
Porbeagle shark	Treathened (2006)	No status
Spiny dogfish - Atlantic population	Special concern (2010)	No status
Basking shark - Atlantic population[4]	Special concern (2009)	No status
Deepwater redfish - Gulf of St. Lawrence and Laurentian Channel population	Endangered (2012)	No status
Acadian redfish - Atlantic population	Treathened (2010)	No status
Blue whale - Atlantic population	Endangered (2012)	Endangered (2005)
Humpback whale - Western North Atlantic population	Not at risk (2003)	Special concern (2003)
Fin whale – Atlantic population	Special concern (2005)	Special concern (2006)
North Atlantic right whale[4]	Endangered (2013)	Endangered (2005)
Beluga whale - St. Lawrence Estuary population[4]	Endangered (2014)	Endangered (2016)
Harbour porpoise Northwest Atlantic population	Special concern (2006)	Treathened
Killer whale - Northwest Atlantic / Eastern Arctic population[4]	Special concern (2008)	No status

[1] COSEWIC: Committee on the Status of Endangered Wildlife in Canada, [2] SARA: *Species at Risk Act*, [3] Uncertain presence, [4] Occasional: Species that are observed from time to time (not every year)

Table 2. List of human activities that may cause pressure on the ecosystem features of the Banc-des-Américains Marine Protected Area and their current status (presence/absence).

Activities	**presence (✓) absence (-)**
Fishing	
Bottom trawl	✓
Gillnet	✓
Scallop dredge	-
Dragnet	-
Traps	✓
Longline	✓
Ghost fishing gear	✓
Fish farming	-
Maritimes transport	✓
Recreotourism	
Marine mammals observation	✓
Diving	potentially ✓
Industrials	
Oil activities	-
Seismic activities	-
Dredging	-
Underwater cables	-
Marine industrial releases	-
Scientifics	✓
Municipal, industrial and agricultural discharges of land-based wastewater	potentially ✓
Native activities	-

Table 3. List of human activities and pressures associated with the Banc-des-Américains marine protected area (adapted from Gendreau et al. 2018).

Human activities / pressures	Climate changes (Temperature/acidity)	Invasive species	Wastewater discharges	Physical disturbance of the substrate	Turbidity	Oil spill	Biomass sampling	Entanglement	Collisions	Noise and disturbance
Human activities causing climage change	X	X	-	-	-	-	-	-	-	-
Terrestrial anthropogenic activities (releases)	-	-	X	-	-	-	-	-	-	-
Fishing	-	-	X	X	X	-	X	X	X	X
Maritime transport	-	X	X	-	-	X	-	-	X	X
Scientific activities	-	-	X	X	X	-	X	-	X	X
Recreotourism	-	-	X	-	-	-	-	-	X	X

Table 4. Management measures: list of exceptions to the "general prohibition" that prohibits any activity that disrupts, damages, destroys or removes from the Marine Protected Area any living marine organism or any part of its habitat, or that is likely to do so.

What	Precisions	Where
Social and ritual food **fisheries**	authorized by the *Aboriginal Communal Fishing Licenses Regulations*	the whole MPA
Commercial **fishing**	using traps, longline, line, hand line and species other than capelin, herring, mackerel, sandeel, krill and copepods	area 2
Recreational **fishing**	at the line or at the hand line,	area 2
Navigation – marine marchande	Allowed, but - no anchorage allowed in the **area 1** - no sewage or gray water may be discharged by vessels of 400 tons gross tonnage or more, or allowed to carry 15 or more persons, **throughout the MPA**	the whole MPA
Security or emergency	any activity to ensure public safety, national defense, national security or law enforcement, or to respond to an emergency will be permitted at any time in the MPA	the whole MPA
Scientific research and monitoring, habitat restoration, commercial maritime tourism	any activity forming part of an activity plan approved by the Minister may be done in the MPA	the whole MPA

Table 5. Proposed monitoring indicators for the Banc-des-Americains MPA. The indicators are direct (D) or indirect (I).

Ecosystem features	Indicators	Type D	Type I	Suggested monitoring methods
Physical and chemical oceanography (O)				
Physico-chemical properties of the water	*In the MPA and an expanded sector:*			
	O1) Temperature, salinity, nutrients, dissolved oxygen, pH, turbidity in different water layers (surface, (CIF), bottom, etc.)	-	x	R1-R2-R4-R5-R6-R10-R11-R12- RD3
	O2) Internal current, wave and tidal dynamics	-	x	R2- RD3
	O3) Ice cover	-	x	R3
Pelagic (P)				
Phytoplankton	*In the MPA and an expanded sector:*			
	P1) Chlorophyll a biomass	-	x	
	P2) Abundance and taxonomy of species	-	x	R1-R2- RD3
Zooplankton	*In the MPA and an expanded sector:*			
	P3) Total zooplankton biomass	-	-	R1-R9- RD3
	P4) Abundance of different dominant / key species	-	x	
Krill	*In the Gaspé current and east of Gaspé including the BdA*			
	P5) Krill biomass	-	x	R1- R7-R10-R11
Herring	*In the 4T OPANO area:*			R7-R8
	P6) Biomass from herring stock assessment	-	x	Potential: R20
Mackerel	P7) Biomass and abundance from the mackerel stock assessment	-	x	R7-R9
	P8) Mackerel egg abundance	-	x	Potential: R20

Ecosystem features	Indicators	Type		Suggested monitoring methods
		D	I	
Benthic and demersal (BD)				
Epibenthic communities	*In fixed monitoring sites in the MPA and in controls sites outside, as well as in the surrounding survey strata:*			
	BD1) Presence, relative abundance and size of fixed erected organisms (sponges and other species)	x	-	
	BD2) Composition of epibenthic communities: richness, diversity, abundance, density, biomass of species or taxa	x	-	R10-R12-R13-RD1
	BD3) Biomass, abundance, size structure of indicator/dominant species	x	-	
Demersal communities	*In the MPA and in the surrounding survey strata:*			
	BD4) Composition of demersal communities : richness, diversity, abundance, density, biomass of species or taxa	x	x	R10-R12-R13
	On the ridge:			
	BD5) Presence, size and abundance classes of indicator species	x	-	RD1-RD4 Potential : RD5
Commercial benthic and demersal species	*In the MPA and in the surrounding survey strata:*			
	BD6) Biomass and abundance of commercial species	x	x	R10-R12-R13
	BD7) Size structure, sex and maturity of commercial species	x	x	
	BD8) Lobster abundance on the ridge	x	-	RD4 Potential : RD5
Substrates characteristics	*In monitoring sites in the MPA:*		-	
	BD9) Type of sediment and granulometry	x	-	RD1-RD2

Ecosystem features	Indicators	Type D	Type I	Suggested monitoring methods
Species at risk (EP)				
Atlantic wolffish	*On the ridge:*			
	EP1) Presence/absence	x	-	RD4-RD5
	EP2) Occupancy and potential habitat availability (number of burrows)	x	-	RD4
	In the MPA and in the surrounding survey strata:	-	-	
	EP3) Bycatch (commercial fishing / scientific surveys)	x	-	R10-R12-R13-R15
Whales	*In the MPA and surrounding:* EP4) Presence of species at risk : fin whale, blue whale, humpback whale and right whale	-	x	R16-R17-RD6 Potential: R11-R12

Table 6. Proposed monitoring indicators for the Banc-des-Américains MPA (anthropogenic pressures).

Anthropogenic pressures (AP)	Indicators	Suggested monitoring methods
Aquatic invasive species (AIS)	AP1) Presence/absence of AIS in the MPA	R21- RD1-RD4-RD5
Noise	*In the MPA and surrounding:* AP2) Measurement of anthropogenic noise AP3) Intensity of commercial traffic	 RD6 R19
Disturbance	AP4) Intensity of observation and recreational activities in and around the MPA	Potential: R16
Collision	*In the MPA and surrounding:* AP5) Speed of commercial vessels AP6) Number of reported accidents (collisions)	 R19 R18
Entanglement	AP7) Number of accidents (entanglement) reported in and around the MPA	R18
Commercial fisheries	*In the MPA and surrounding:* AP8) Landing and commercial fishing effort for all fish and invertebrates (total landings) AP9) Distribution of fishing effort from vessel monitoring system (VMS data) and logbooks	R14-R15

Table 7. Fixed erected taxa observed during benthic imagery missions in the marine protected area.

Phylum	Scientific name	Common name	Size
Rhodophyta	*Rhodophyta*	Red algae	Up to 5 cm
Porifera	*Porifera*	Sponge	0 to 10+ cm
Cnidaria	*Hydrozoa*	Hydrozoan	Up to 20 cm
Cnidaria	*Tubulariidae*	Hydroid	10 to 30 cm
Cnidaria	*Urticina felina*	Dahlia anemone	12 to 13.5 cm
Cnidaria	*Stomphia coccinea*	Swimming anemone	12.5 cm
Cnidaria	*Metridium senile*	Clonal plumose anemone	46 cm
Cnidaria	*Nephtheidae*	Soft coral (sea strawberry)	7.5 up to 30 cm
Bryozoa	*Alcyonidium*	Marine bryozoan Alcionidium	10-20 cm and more
Chordata	*Boltenia ovifera*	Sea potato	30 cm +
Chordata	*Halocynthia pyriformis*	Sea peach	12-13 cm

Table 8. List of existing surveys and surveys to be developed.

#	Surveys / monitoring protocols	Sampled parameters	Sampling within the boundaries of the BdA	Frequency/ Date	Financial and Human Resources
Existing retained					
R1	Atlantic Zone Monitoring Program (AZMP)	CTD / rosette: T °, salinity, nutrients, dissolved oxygen, pH, turbidity, depth, current, phytoplankton, zooplankton	no	Bi-Annual may and october	Partially supported, data analysis
R2	Oceanographic Buoy network (Viking)	CTD: T°, O_2, pH, salinity, depth	buoy for 1 year in the BdA	Estival continuousl y	Partially supported, data analysis
R3	Ice cover monitoring	Extent, thickness, period	no	In winter continuousl y	Already supported
R4	Remote sensing of water surface temperature	Sea surface temperature	no	Continuousl y	Already supported
R5	Thermograph Network	Sea water temperature	no	Estival continuousl y	Already supported
R6	Monitoring winter water masses – helicoptered mission	Temperature, salinity, surface nutrients and plankton	yes	Winter	Already supported
R7	Pelagic acoustic survey of the estuary and northwestern Gulf	Krill Biomass, herring / capelin abundance (acoustic), mackerel / sandeel abundance (acoustic)	yes	Annual June	Already supported
R8	Annual acoustic survey of herring (SGSL)	Estimated herring biomass	yes	Annul September	Already supported
R9	Mackerel eggs survey	Biomass of mackerel eggs Bongo trait (0-50m): Estimated zooplankton	yes	Annual June	Partially supported

#	Surveys / monitoring protocols	Sampled parameters	Sampling within the boundaries of the BdA	Frequency/ Date	Financial and Human Resources
R10	Multispecies southern Gulf of St. Lawrence bottom trawl survey	Abundance, biomass, size, sex, stage of maturity of fish (mostly demersal), benthic invertebrates Oceanographic data and zooplankton (partial or complete PMZA protocol) Presence / Abundance mammals and seabirds	1-6 stations (average 3/year)	Annual September	Already supported
R11	Multispecies in the estuary and northern Gulf of St. Lawrence bottom trawl survey	Abundance, biomass, size, sex, stage of maturity of fish (mostly demersal), benthic invertebrates Oceanographic data and zooplankton (partial or complete PMZA protocol) Presence / Abundance mammals and seabirds	none, but transit of the vessel (port of Gaspé)	Annual August	Already supported
R12	Multispecies survey sentinel bottom trawl survey	Abundance, biomass, fish size and invertebrate identification	yes	Annual	Already supported
R13	Southern Gulf of St. Lawrence snow crab bottom trawl survey	Biological characteristics of crabs (size, sex, stage of development and maturity) Abundance and biomass of fish and benthic invertebrates	yes	Annual	Already supported
R14	Fishing data from ZIFF statistics	Position, catch weight, CPUE	yes	Estival continuousl y	Partially supported, data analysis
R15	At-sea observer program	Position, catch weight, CPUE	yes	Estival continuousl y	Partially supported, data analysis
R16	Marine mammal observation network (MMON)	Presence and abundance	yes	Estival continuousl y	Partially supported, data analysis
R17	Annual monitoring of whales at Mingan Island cetacean study (MICS)	Presence and abundance	yes	annuel ou bisannuel	Partially supported, data analysis

#	Surveys / monitoring protocols	Sampled parameters	Sampling within the boundaries of the BdA	Frequency/ Date	Financial and Human Resources
R18	Quebec Marine Mammal Emergency Response Network (QMMERN)	Number of accidents	variable	Estival continuously	Already supported
R19	Monitoring of maritime traffic via a navigation information system (AIS)	Traffic intensity	yes	Continuously	Partially supported, data analysis
R20	Monitoring of northern gannets	Stomach contents (prey availability, capelin, mackerel), condition diet, breeding success, nesting success	variable	Estival	Partially supported, data analysis
R21	Annual monitoring of aquatic invasive species (AIS)	AIS and other sessile species attached to collectors)	no	Estival	Partially supported, data analysis
R22	Vessel Monitoring System (VMS)	VMS data of fishing boats and estimated fishing effort	yes	Continuously	Partially supported, data analysis
Potential, to be developed					
RD1	Benthic community survey by image	Epibenthos, substrates, dead shell beds, potential habitat of the Atlantic wolffish			$$
RD2	Benthic community survey with grab	Endobenthos, substrates			$$
RD3	Moorings (physico-chemical data)	T °, salinity, nutrients, dissolved oxygen, pH, turbidity, depth, current, zooplankton			$$$
RD4	Scuba diving	Presence of Atlantic wolffish, potential habitat of the Atlantic wolffish, presence of lobster on the ridge			$$
RD5	Environmental DNA	Presence of Atlantic wolffish and other species			$$
RD6	Passive acoustics - Hydrophone	Anthropic noise (disturbance), whales, noise benthic organisms (invertebrates, Atlantic wolffish)			$$$