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REVIEW OF ECOSYSTEM FEATURES, INDICATORS AND SURVEYS FOR ECOLOGICAL MONITORING OF THE BANC-DES-AMÉRICAINS MARINE PROTECTED AREA

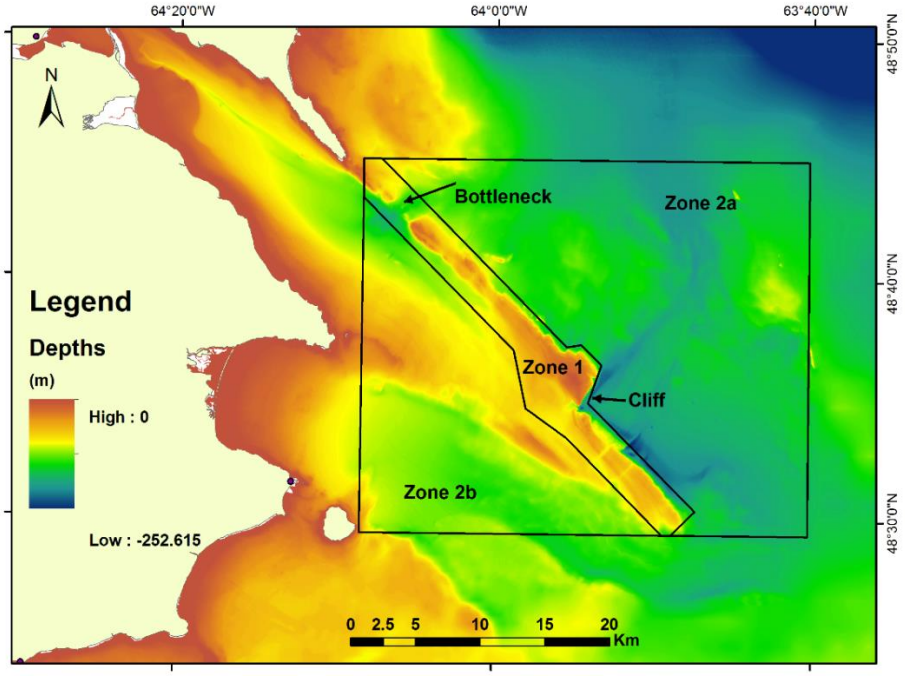

Figure 1. Boundaries of the Banc-des-Américains MPA. Bathymetry data come from a multibeam survey conducted by the Canadian Hydrographic Service.

Context

In order to support the federal government's commitment to establish marine protected areas (MPAs), DFO Science is mandated to implement monitoring plans for MPAs. To develop a monitoring plan, biological and ecological indicators (and related threats), protocols and strategies must be identified to assess the extent to which conservation goals and objectives are being achieved. The monitoring plan is required to 1) feed into the broader MPA monitoring program, which is managed by DFO Oceans; 2) assist managers in developing the MPA management plan; and 3) provide reports to Parliament and Canadians.

In 2011, the American Bank area, located in the Gulf of St. Lawrence off Cap Gaspé, was identified as an Area of Interest, and was designated as an MPA in March 2019 under the Oceans Act. For this MPA, monitoring indicators, protocols and strategies need to be developed by harnessing current knowledge and when possible incorporating existing monitoring programs in the area.

This Science Advisory Report is from the May 22–23, 2018 meeting on the Review of the Indicators and Recommendations of an Ecological Monitoring Plan for the Banc-des-Américains proposed MPA. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- The ecosystem features, anthropogenic pressures, indicators and monitoring tools presented were analyzed in relation to the overarching goal of the Banc-des-Américains MPA and its conservation objectives (CO), to ensure that they provide relevant information for adaptive management of the MPA.
- Two types of indicators for the selected ecosystem features have been identified:
  a) Indirect indicators that allow assessing the state of the MPA ecosystem and interpreting changes in direct indicators, but do not allow possible changes to be directly linked to MPA management measures;
  b) Direct indicators which provide information on the status and trends of communities, habitats and species of interest related to the COs. These indicators can be used to measure the performance of the MPA against the COs as well as the effectiveness of the management measures.
- For CO1 related to benthic habitats, indicators (n=9) were identified to monitor the following ecosystem features: epibenthic and demersal communities, commercial species and substrate characteristics.
- For CO2 related to pelagic habitats (phytoplankton, zooplankton and forage species), all of the proposed indicators (n=8) are indirect ones. Monitoring these indicators is essential in order to describe the environmental conditions influencing the ecosystem and attempt to explain the changes observed in the Banc-des-Américains MPA. According to this logic, indicators (n=3) for monitoring the physicochemical characteristics of the water have also been identified, even though this feature is not directly related to a CO.
- For CO3 related to species at risk, the selected indicators (n=4) allow the monitoring of whale species at risk and the Atlantic wolffish.
- Anthropogenic pressures in the Banc-des-Américains MPA that could affect the achievement of COs have been identified: invasive species, noise and disturbance, collisions and entanglements, commercial fisheries and pollution. Nine indicators have been selected to monitor these pressures, with the exception of pollution, for which baseline knowledge is lacking.
- Endobenthic and suprabenthic communities and capelin have been retained as ecosystem features. However, no monitoring indicators could be selected owing to the significant gaps in baseline knowledge or the lack of current sampling methods for these indicators.
- To facilitate the implementation of an effective monitoring plan, it is recommended to select indicators that are or could be measured by using existing partner or DFO monitoring programs, such as the Atlantic Zone Monitoring Program (AZMP) and multispecies surveys,. Existing surveys have the advantage of covering long time series and may include monitoring conducted within and outside the MPA. However, new surveys will be required to ensure adequate monitoring.
- Research bottom trawl surveys conducted in the Banc-des-Américains MPA provide relevant data for the benthic and demersal indicators.

BACKGROUND

The Banc-des-Américains MPA Project

In 2011, the American Bank was identified as an Area of Interest (AOI) for the creation of an 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. This science advisory report has been produced in accordance with the ecological monitoring obligations for the Banc-des-Américains MPA.

Site description

The 1,000-km² Banc-des-Américains MPA is characterized by a 34-km-long underwater rocky ridge (Zone 1 in Figure 1), extending from the Forillon Peninsula to a rocky cliff, and the adjacent plains (Zones 2 in Figure 1) (AECOM Tecsult Inc. 2010; Gauthier *et al.* 2013). The depth of the site ranges from 12 m at the top of the ridge to an average of 90 m on the southwestern plain (Zone 2b), and increases to over 180 m on the northeastern plain (average depth of 140 m; Zone 2a). The substrate types found in the MPA are very diverse, with hard substrates characterizing the ridge and cliff, a variety of soft substrates (very fine to coarse sediments) and large boulders found in some areas of the plains. The physical configuration of this sector contributes to very diverse benthic habitats and influences the movement of water masses, creating unusual hydrodynamic conditions and making this site a unique biological hotspot.

The Banc-des-Américains MPA is under the direct influence of the Gaspé current, which carries nutrient-rich waters and planktonic organisms along the Gaspé coast. In addition, strong hydrodynamic forces have been observed near the cliff which promote vertical mixing of nutrient-rich waters between the cold intermediate layer and the surface. As well, the continuous flow of the Gaspé current, combined with the unusual topography of the bank, favours the temporary accumulation of plankton, including krill, in and around the site. Zooplankton aggregations in the area help to attract marine mammals, including the humpback whale, blue whale, fin whale and the North Atlantic right whale, as well as small pelagic fish such as capelin, herring and mackerel. Data collected in the area suggest that rorquals concentrate near the bottleneck off the eastern tip of Cap-Gaspé (Figure 1).

The epibenthic communities found in the area, which are directly related to the seabed characteristics (substrate type, depth, slope) and current dynamics, are also very rich and diverse. More than 131 taxa have been identified through benthic imaging (Savenkoff *et al.* 2017), with brittle stars being the dominant species in shallower waters (< 100 m). Distinctive assemblages of epibenthic species are found in the different sectors of the MPA (ridge, plains, cliff). On the ridge, for example, very dense colonies of plumose anemones (*Metridium senile*) have been observed in association with bushy hydrozoans, Rhodophyta, sea cucumbers and fish species in the family Cottidae. The cliff, for its part, promotes a vertical zonation of sessile species, including a wide variety of anemones, sponges and starfish. Demersal fish are also present in the American Bank area, such as Atlantic cod (*Gadus morhua*), flatfish (e.g.,

Hippoglossoides platessoides), redfish and Atlantic wolffish (*Anarhichas lupus*). On the plains of the MPA, the seabed consists mainly of fine sediments on which shrimp in the genus *Pandalus* are found. The boulders scattered across the seabed of the northeastern plain are colonized by sponges and anemones.

Conservation objectives

The goal and conservation objectives (COs) of the Banc-des-Américains MPA were developed based on the results of an intersectoral workshop which brought together various DFO experts in 2010 (Gauthier *et al.* 2013). The workshop report was used as a basis for the recommendations related to monitoring set out in this document.

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):

CO1) To conserve and protect benthic (seabed) habitats

CO2) To conserve and protect pelagic (water column) habitats and forage species (prey)

CO3) To promote the recovery of whale and wolffish species at risk

Human activities

Currently, the main human activities carried out in the MPA are commercial ones, such as fishing, shipping and tourist activities focusing on marine mammal observation (Gendreau *et al.* 2018).

Since 1995, the snow crab fishery is the main fishing activity in the Banc-des-Américains MPA, accounting for 94% of all associated fishing income. Atlantic halibut and Greenland halibut are also harvested, though to a lesser extent. Several other species of fish, including Atlantic cod, are fished on a marginal basis. In addition to traps, which are used for snow crab fishing, the bottom longline, gillnet and bottom trawl are used in the MPA, but to a much smaller extent. The impacts of fishing vary with the type of gear used and the type of seabed, and range from mortality (direct or indirect) to alteration of the seabed and effects on the behaviour of species. Also, some types of fishing gear and ghost gear, lost or abandoned at sea, have been associated with marine mammal entanglement in nets or ropes.

Other human activities, such as shipping and tourism, particularly whale-watching at sea, are likely to adversely affect ecological features of the MPA. The main threats related to tourist excursions are disturbances caused by the presence of boats and the noise they generate as well as the risk of collision with marine mammals. Similarly, commercial vessels, including fishing vessels, can impact the environment through noise generation, collision risk, effluent discharges and the introduction of invasive species.

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.

The Banc-des-Américains MPA is divided into two management zones. 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. As a result, some activities may continue to take place in the MPA, such as approved tourism or scientific activities, 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.

ASSESSMENT

Selection of features and indicators

Various criteria were used to assess the indicators for monitoring the Banc-des-Américains MPA, namely their ecological significance, their sensitivity, their measurability and interpretability, their ease of management and, to a lesser extent, their acceptance by researchers and stakeholders, as well as their ability to be understood by the general public (Pomeroy *et al.* 2004). As a rule, it is important to focus on the effectiveness of the indicators, i.e., to select indicators that are inexpensive, sustainable and easy to implement. Instead of developing new protocols, it has been recommended that existing monitoring initiatives be optimized or expanded. In addition, indicator selection should focus on features and parameters that are sensitive enough to show changes.

When selecting key species or indicator species, the spatial and temporal scales should be considered in order to maximize an indicator's capacity to detect changes. For example, it may take more time to detect abundance or distribution changes in long-lived and late-maturing species. A given indicator may be less effective at detecting such changes in the short term than in a case where faster growing species are targeted for monitoring purposes. Similarly, for species whose ranges extend beyond the boundaries of an MPA and species that spend little time there, it would be more difficult, if not impossible, to link the effects of the implementation of regulations to their population status. Sessile species, with their small home ranges and poor dispersal capacity (or high degree of residence), are more suitable indicators.

While various protocols can be used in a monitoring plan, the Before-After-Control-Impact (BACI) approach is recommended. This approach involves monitoring sites both within and outside the MPA, and using data collected prior to the implementation of management measures. BACI is the preferred approach because it makes it possible to distinguish between the effects of management measures and natural variability, and thus to ascertain whether changes observed in the MPA are the result of management measures.

To ensure that the MPA meets its conservation objectives, four categories of **ecosystem features** have been selected: 1) physical and chemical oceanography, 2) pelagic ecosystem, 3) benthic and demersal ecosystem, and 4) species at risk. For each feature, indicators have been developed and can be classified in two different types:

1. **Indirect indicators** that assess the state of the ecosystem and the physical and biotic environment, but that do not allow changes to be directly linked to management of the MPA. 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;
2. **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.

In addition, ecosystem features are subject to **anthropogenic pressures,** locally or on a broader scale, that are likely to affect the achievement of COs within the MPA. Indicators related to anthropogenic pressures have therefore also been developed to assess current human activities and their impacts.

As part of this exercise, a list of indicators has been drawn up. The term “indicator” is used in its broad sense, i.e., elements to be measured rather than specific indices or measures. In a later stage, the indices and measures associated with the indicators will need to be refined.

Monitoring Indicators for Ecosystem Features

Physical and Chemical Oceanography Category (O)

Table 1. Ecosystem feature associated with physical and chemical oceanography and indicators selected to monitor the Banc-des-Américains MPA.

Ecosystem Features	Indicators	Type[1]		Status of Monitoring
		D	I	
Physicochemical characteristics of water	O1) T°, salinity, nutrients, dissolved oxygen, pH, turbidity, in the different layers of water (surface, CIL, seabed, etc.)	-	x	Existing* To be developed
	O2) Dynamics of currents and internal waves and tides**	-	x	To be developed
	O3) Ice cover	-	x	Existing

[1] Type of indicator: D = direct, I = indirect.
* One or more monitoring measures exist, but could be enhanced.
** This indicator has raised questions and should be reviewed and clarified by the scientific committee that will be set up.

All of the proposed oceanographic indicators are indirect indicators which are essential for describing the environmental conditions influencing the ecosystem. Indicator O1 is composed of several elements, and the key parameters to be monitored need to be identified. For example, which temperature indices (T°) should be monitored: summer average, spring maximum, near surface layer or seabed, etc. In selecting the parameters to be used, the potential effects of climate change on ecosystem features (dissolved oxygen, pH and temperature) and habitat optimization for key species such as the Atlantic wolffish, among other things, should be considered.

For indicator O2, local dynamics are still poorly understood. Further characterization is required to validate the relevance of this indicator as well as to identify the parameters to be measured and the spatial and temporal scale to be recommended.

Pelagic ecosystem category (P)

Table 2. Ecosystem features associated with pelagic habitats and indicators selected to monitor the Banc-des-Américains MPA.

Ecosystem Features	Indicators	Type[1]		Status of Monitoring
		D	I	
Phytoplankton	P1) Chlorophyll *a* biomass	-	x	Existing*
	P2) Abundance and taxonomy of phytoplankton species	-	x	To be developed
Zooplankton	P3) Total zooplankton biomass	-	x	Existing*
	P4) Abundance of different dominant/key species **	-	x	Existing*
Krill	P5) Biomass of krill	-	x	Existing
Herring	P6) Biomass estimate from the herring stock assessment for 4T (NAFO)	-	x	Existing
Mackerel	P7) Biomass and abundance from the mackerel stock assessment	-	x	Existing
	P8) Abundance of mackerel eggs	-	x	Existing

[1] Type of indicator: D = direct, I = indirect.
* One or more monitoring measures exist, but could be enhanced.
** This indicator raises questions and should be reviewed and clarified by the scientific committee that will be set up.

Here again, all the indicators developed for monitoring the pelagic ecosystem are indirect ones. The pelagic habitat is very dynamic and the features identified are not confined to the boundaries of the Banc-des-Américains MPA. These indicators should be measured at two different spatial scales in order to distinguish between local biomass and biomass located upstream of the MPA since planktonic organisms come mainly from the Estuary, and are transported along the Gaspé coast by the Gaspé current.

The information currently available on forage species comes from the southern Gulf stock assessments (SGSL). Very little data is collected within the boundaries of the MPA. Since the collection of local data is not planned in the short term, these indirect indicators will make it possible to monitor changes in the ecosystem at the scale of the southern Gulf.

For indicator P4, a detailed characterization should be conducted to determine whether there is a link between the different zooplankton species (e.g., *Calanus, Pseudocalanus*, and *Temora*) and their predators in the MPA. If some pelagic species are preferred prey items for key species in the area (e.g., species at risk), the indicator should be retained.

Benthic and demersal (BD) ecosystem category

Table 3. Ecosystem features associated with benthic and demersal habitats and indicators selected to monitor the Banc-des-Américains MPA.

Ecosystem Features	Indicators	Type[1]		Status of Monitoring
		D	I	
Epibenthic communities	BD1) Presence, abundance and size of fixed, erect organisms	x	-	To be developed
	BD2) Composition of epibenthic communities: species richness, diversity, abundance, density and biomass of species or taxa	x	-	Existing*
	BD3) Biomass, abundance and size of indicator/dominant species **	x	-	Existing*
Demersal communities	BD4) Composition of demersal communities: specific richness, diversity, abundance, density, biomass of species or taxa	x	x	Existing
	BD5) Presence, size classes and abundance classes of indicator species on the ridge	x	-	To be developed
Benthic and demersal commercial species	BD6) Biomass and abundance of commercial species	x	x	Existing
	BD7) Size structure, sex and maturity of commercial species	x	x	Existing
	BD8) Abundance of lobsters on the ridge	x	-	To be developed
Substrate characteristics	BD9) Sediment type and grain size	x	-	To be developed

[1] Type of indicator: D = direct, I = indirect.
* One or more monitoring measures exist, but could be enhanced.
** This indicator has raised questions and should be reviewed and clarified by the scientific committee that will be set up.

All the indicators developed to monitor the benthic and demersal ecosystem are direct ones; some have an indirect component. For indicators BD2 and BD4 relating to community composition, the parameters to be measured (diversity, abundance, richness, etc.) can be assessed for all species; they can also be calculated for functional groups of species present in the habitats concerned. The preferred approach would be to define functional groups on the basis of existing surveys.

Data from existing surveys should also be used to draw up a list of indicator epibenthic species. The indicator species that are selected should be easily identifiable, fairly abundant and sensitive to the management measures put in place, such as reduced fishing on the adjacent plains.

Species at risk (SAR) category

Table 4. Ecosystem features associated with species at risk and indicators selected to monitor the Banc-des-Américains MPA.

Ecosystem Features	Indicators	Type[1]		Status of Monitoring
		D	I	
Atlantic Wolffish	EP1) Presence/absence of Atlantic wolffish on the ridge	x	-	To be developed
	EP2) Occupancy and availability of potential habitats (number of burrows)	x	-	To be developed
	EP3) Atlantic Wolffish bycatch (commercial fisheries/scientific surveys)	x	-	Existing
Whales	EP4) Presence of fin whales, blue whales, humpback whales and right whales	-	x	Existing and to be developed

[1] Type of indicator: D = direct, I = indirect.

Only the Atlantic wolffish (*Anarhichas lupus*) will be monitored since the other wolffish species, northern wolffish (*Anarhichas denticulatus*) and spotted wolffish (*Anarhichas minor*), are fairly rare in the southern Gulf.

With regard to whales targeted by CO3 (blue whale [*Balaenoptera musculus*], North Atlantic right whale [*Eubalaena glacialis*], fin whale [*Balaenoptera physalus*) and humpback whale [*Megaptera novaeangliae*]), although the data sources are incomplete and acquiring more precise data would be a complex undertaking, indicator EP4 has been selected since these species are protected under the *Species at Risk Act*.

Additional ecosystem features to be considered

Further to the review of ecosystem features and proposed indicators, three ecosystem features have been retained even though no monitoring indicators have been identified for them. These features are essential for establishing a comprehensive monitoring plan that meets all COs. As soon as sufficient information becomes available, indicators for monitoring these features should be identified.

Table 5. Ecosystem features to be retained despite the absence of associated indicators.

Features to be considered	Rationale
Capelin	A quantitative indicator should be used, but biomass is not measured at present in the stock assessment for this species and multispecies surveys do not adequately sample pelagic fish. A new monitoring program under development at the Maurice Lamontagne Institute (MLI) should provide an indicator that can be used in the future.
Endobenthic communities	No inventory of these communities is available. A baseline characterization of the environment needs to be carried out before monitoring indicators (e.g., indicator species) can be identified.
Suprabenthic communities	

Monitoring indicators for anthropogenic pressures (PA)

Table 6. Anthropogenic pressures and indicators selected to monitor the Banc-des-Américains MPA.

Anthropogenic Pressures	Indicators	Status of Monitoring
Aquatic invasive species (AIS)	PA1) Presence/absence of AIS	Existing*
Noise	PA2) Measurement of anthropogenic noise	To be developed
	PA3) Commercial traffic intensity	Existing
Disturbance	PA4) Intensity of whale-watching activities at sea and recreational activities	To be developed
Collisions	PA5) Commercial vessel speed	Existing
	PA6) Number of incidents	Existing
Entanglement	PA7) Number of incidents	Existing
Commercial fisheries	PA8) Landings and commercial fishing effort for all fish and invertebrates	Existing
	PA9) Distribution of fishing effort determined from Vessel Monitoring System (VMS) data or logbooks	Existing

* One or more monitoring measures exist, but could be enhanced.

Indicator PA4 includes the monitoring of disturbance caused by recreational boating and whale-watching activities at sea. The intensity of recreational boating traffic can be assessed based on the number of marinas in the area, the number of marina members, the expected number of visitors and the number of overnight stays in the area. This type of data was collected in 2012 by the DFO Aquatic Invasive Species (AIS) team. For companies involved in whale-watching activities, the annual number of trips could be used.

Pollution has been identified as a pressure that should be monitored in the Banc-des-Américains MPA, but no indicators have been identified since no data are available. It is necessary to have baseline sediment quality data (presence and concentrations of contaminants) before a decision can be made on the relevance of and the type of indicator to be monitored. Since contaminant monitoring does not fall within 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

In addition to the 33 indicators detailed above, a number of ecosystem features, pressures and indicators were covered during the peer review but were not selected, for various reasons.

Table 7. Ecosystem features, pressures and indicators considered but not selected.

Features, pressures or indicators not selected	Rationale
Sand lance	This feature was not selected because the species' presence and significance in the area have yet to be confirmed. Accurate data on the sand lance are not available at present. Sand lance may be confused with mackerel in existing acoustic surveys, which are unable to detect sand lance buried in the sand.
Climate Change	This pressure has been removed and integrated into oceanographic monitoring as part of indicator O1. The key parameters—dissolved oxygen, pH and temperature—are related to climate change and specific monitoring measures need to be identified.
Total fishery landings (commercial benthic and demersal spp.)	This indicator is not suitable for monitoring the ecosystem feature related to benthic and demersal communities because it does not adequately assess the target species' abundance or biomass. However, this indicator was selected for monitoring anthropogenic pressures related to commercial fisheries.
Percent cover/abundance of dead shell banks	This indicator has been removed as dead shells can be transported massively seaward during storm surges. Monitoring of these banks would not help identify their origin and consequently would not be useful for assessing the potential effects of the implementation of the MPA.
Sediment biogeochemistry (deposition rate/organic matter contribution)	This indicator has been eliminated because no information is available on this very complex, potentially difficult-to-track and resource-intensive subject. However, it has been suggested that a baseline characterization of sediments be carried out in collaboration with experts and that it include determining whether a sedimentary feature is correlated with the structure of the endobenthic communities. If a relationship exists, the possibility of using this indicator as a proxy for direct monitoring of the endobenthos (cost-effectiveness comparison of the two indicators) should be evaluated.
Number of spills (pollution)	The area is at very little risk from an accidental spill. Retaining a monitoring indicator for which almost no data will be collected is therefore not justified. If an incident occurs, it will be noted in the monitoring report.
Abundance of species at risk (whales)	An indicator for monitoring these species has been retained; however, the existing or proposed surveys do not provide accurate information on species abundance.

Surveys and monitoring protocols

Existing surveys covering the MPA or the broader Gulf of St. Lawrence region were evaluated to determine their suitability as a source of data for the various monitoring indicators considered. The surveys selected and their associated indicators are presented in Table 8.

Table 8. Surveys selected to monitor indicators.

#	Surveys/Monitoring Protocols	Status	Related Indicators
R1	Atlantic Zone Monitoring Program (AZMP)	Existing, to be optimized	O1-P1-P2-P3-P4
R2	Viking buoy network	Existing, to be optimized	O1-O2-P1-P2
R3	Monitoring of ice cover	Existing	O3
R4	Remote sensing of surface temperature	Existing	O1
R5	Thermograph network	Existing	O1
R6	Monitoring of winter water masses–helicopter mission	Existing	O1
R7	Pelagic acoustic survey of the Estuary and northwestern Gulf	Existing	P5
R8	Annual herring acoustic survey (SGSL)	Existing	P6
R9	Mackerel egg survey	Existing, to be optimized	P3-P4-P7-P8
R10	Multispecies bottom trawl survey in the southern Gulf of St. Lawrence	Existing, to be optimized	O1*-BD2-BD3-BD4-BD6-BD7-EP3
R11	Multispecies bottom trawl survey in the northern Gulf of St. Lawrence	Existing, to be optimized	O1*-EP4*
R12	Multispecies bottom trawl survey by the sentinel fishery	Existing, to be optimized	O1*-BD2-BD3-BD4-BD6-BD7-EP3-EP4*
R13	Snow crab bottom trawl research survey in the southern Gulf of St. Lawrence	Existing, to be optimized	BD2-BD3-BD4-BD6-BD7-EP3
R14	Zonal Interchange File Format (ZIFF) fishing data	Existing	EP3-PA8-PA9
R15	At-sea observer program	Existing	EP3-PA8-PA9
R16	Réseau d'observation des mammifères marins (ROMM)	Existing	EP4-PA4
R17	Annual monitoring of whales at the Mingan Island Cetacean Study (MICS)	Existing	EP4
R18	Quebec Marine Mammals Emergency Response Network (RQUMM)	Existing	PA3-PA5-PA6-PA7
R19	Monitoring of marine traffic using a navigation information system (AIS)	Existing	PA3
R20	Monitoring of northern gannets	Existing	P6*-P7*
R21	Aquatic invasive species (AIS) survey	Existing, to be optimized	PA1
R22	Fishing vessel VMS data	Existing	PA9
RD1	Benthic imaging survey	To be developed	BD1-BD2-BD3-BD5-BD9-EP2-PA1
RD2	Endobenthos survey	To be developed	Endoben. comm. - BD9
RD3	Moorings for physicochemical data collection	To be developed	O1-P1-P2-P3
RD4	Scuba diving	To be developed	BD5-BD8-EP1-EP2-PA1
RD5	Environmental DNA (eDNA)	To be developed	BD1-BD8*-EP1-PA1
RD6	Passive acoustics–hydrophone	To be developed	EP4-PA2

Existing surveys are identified by "R," and surveys to be developed, by "RD."
* Complementary data collected by the survey which could be used as supplementary information for this indicator.

R1 Atlantic Zone Monitoring Program (AZMP)

This DFO program has been collecting biological, physical and chemical data for the entire Estuary and Gulf of St. Lawrence since 1998; however, indices could be extracted in a more precise manner for the area around the MPA. Sampling includes measurements of temperature, salinity, fluorescence, oxygen, nitrate, phosphate and silicates, phytoplankton and zooplankton samples, as well as acoustic measurements to assess krill density, among other things. Currently, no AZMP stations are sampled directly in the MPA. However, stations could be added to the program of major annual surveys in order to obtain data directly from the MPA. The Shediac Valley fixed monitoring station is located not far from the sector and is sampled once or twice a month.

The AZMP annual report includes data from several other surveys, such as **R3: ice cover monitoring** (area, thickness and period), **R4: remote sensing of surface temperature**, **R5: thermograph network** (water temperature) and **R6: winter water mass monitoring–helicopter mission** (temperature, salinity, nutrient salts, plankton). Data from these surveys for the Estuary and Gulf are already captured and processed by the AZMP and are readily accessible. By-products specific to the MPA could be extracted.

R2 Viking buoy network

The network of real-time buoys operated by the Maurice Lamontagne Institute (MLI) currently consists of six buoys deployed in the Estuary and Gulf of St. Lawrence. Each buoy measures a set of optical, oceanographic and meteorological properties. In recent years, most of these buoys have been equipped with a temperature and salinity profiler that takes measurements in the water column beneath the buoy. In 2017, a Viking buoy was deployed in the Banc-des-Américains MPA. It is recommended that the buoy be kept on site for future years. A fluorometer and a dissolved oxygen probe could be added to this buoy to enhance sampling.

R7 Pelagic acoustic survey of the Estuary and northwestern Gulf

DFO Quebec Region conducts an acoustic survey every year to estimate the biomass of northern and Arctic krill in the Estuary and northwestern Gulf of St. Lawrence for stock assessment purposes. The survey is carried out in August using random transects in predetermined strata. The MPA is part of a sampled stratum. The data collected in the strata including the Gaspé current along the Gaspé coast are also important. The acoustic signal of this survey also makes it possible to derive relative abundance data for pelagic fish, particularly herring, which could provide qualitative information.

R8 Annual herring acoustic survey (SGSL)

DFO Gulf Region conducts an acoustic survey every year to estimate the herring biomass in the southern Gulf of St. Lawrence (4T) for the stock assessment. The survey is carried out in September using transects in predetermined strata. No transects are present in the MPA, but the data could be used for a general characterization of the region.

R9 Mackerel egg survey

In June, DFO conducts a zooplankton net survey using a grid of fixed stations in the SGSL to assess mackerel egg density and abundance in order to estimate mackerel biomass for the stock assessment. Four sampling stations are located in the MPA.

R10 Multispecies bottom trawl survey in the southern Gulf

DFO has conducted this multispecies survey in the southern Gulf of St. Lawrence in September of every year since 1971. Data on fish are collected: species identification, weight of catch and of individual fish, abundance and length frequencies. For commercial species, sex and maturity stage are also determined. Since the late 1990s, the other organisms caught have been sorted by major taxonomic group and weighed. This survey is also a source of continuously collected oceanographic (physical, biological and chemical) and acoustic data (krill density and relative abundance of pelagic fish). As a complement, on-board observers collect data on seabirds and marine mammals. Since the 2000s, one to six stations (on average three per year) located in the MPA have been sampled. The taxonomic level of benthic species identifications should be refined in the future and standardized with the R11, R12 and R13 surveys.

R11 Multispecies bottom trawl survey in the northern Gulf

Since 1990, DFO has conducted a multispecies bottom trawl survey in the northern Gulf of St. Lawrence in August of every year. The species caught during this survey are counted, weighed and identified to the lowest taxonomic level. Oceanographic and acoustic data, as well as observations on mammals and seabirds, are also collected. This survey does not take any samples in the MPA, but the vessel crosses the MPA to reach the Port of Gaspé. It may therefore be possible to survey one or two stations according to the AZMP protocol.

R12 Multispecies bottom trawl survey conducted by the sentinel fishery

A bottom trawl survey has been conducted by the sentinel fishery every year in August, since 2003, in the southern Gulf of St. Lawrence. Although the main objective of this survey is to collect information on the composition and distribution of groundfish stocks, information is recorded on all demersal species caught. All species of fish and invertebrates caught in each trawl tow are sorted, weighed and counted. Length measurements are taken for commercially important species such as Atlantic cod, American plaice and Atlantic halibut.

R13 Snow crab bottom trawl research survey in the southern Gulf

A snow crab bottom trawl survey has been conducted annually since 1988 in the southern Gulf, usually between July and late September. This survey is currently being conducted at fixed stations, some of which are located in the MPA and nearby (on average five per year). Sampling includes identifying the biological characteristics (size, sex, maturity stage) of the crab caught. Other invertebrate species and fish are sorted by species or taxonomic group and counted. More accurate taxonomic identification of the benthic invertebrates collected in this survey should be encouraged.

R14 Zonal Interchange File Format (ZIFF) fishing data

ZIFF files incorporate information from logbooks completed by commercial fishermen. These files provide fishing position, catches and landings data for the various species covered by the Dockside Monitoring Program (DMP). Several fishing activities are permitted in Zone 2 of the MPA. These fishing data will be valuable for assessing biomass removal from the MPA and by-catches, as well as the spillover of species targeted by the management measures.

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 in Area 12.

R16 Réseau d'observation des mammifères marins (ROMM)

ROMM is a not-for-profit organization dedicated to the protection and conservation of cetaceans and pinnipeds as well as their habitats. Since 1998, observers have been gathering data on the sightings of whales and seals made during the tourist season. Specialized observers apply a standardized observation protocol during marine mammal watching cruises. Several whale-watching excursions take place in the MPA and represent a source of data. However, these observations are concentrated in the western part of the Banc-des-Américains MPA, which is closer to the coast and ports.

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. One of the areas used by the blue whale includes the MPA. 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.

A18 Quebec Marine Mammals Emergency Response Network (RQUMM):

The RQUMM, created in 2004, has a mandate to promote the acquisition of knowledge on dead, stranded or drifting marine mammals in the St. Lawrence River in Quebec and to determine the causes of mortality. Data from the RQUMM could be used to quantify anthropogenic pressures such as the number of collisions and entanglements in the area. This monitoring effort was assessed as being of intermediate reliability during the review of indicators for the Estuary MPA project.

R19 Monitoring of marine traffic using a 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. 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, the frequency of monitoring 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, monitor their dispersal 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.

RD1 Imaging survey and RD2 Endobenthos survey

Two new surveys were selected for monitoring of the MPA: a benthic imaging survey and an endobenthos survey. These surveys could be implemented to monitor the epibenthic and endobenthic communities. They would also provide information on substrate types and the presence of Atlantic wolffish or potential habitat for this species. It is suggested that these surveys be conducted at representative fixed sites selected according to species assemblages, substrate types and depth. The imaging survey would be carried out using equipment available at the MLI (drop camera and benthic sled) to collect photo and video images that can be used to identify, count and even measure the species present. No baseline information is available on the endobenthos. To begin with, an exploratory survey using a grab sampler or a box corer would be conducted to collect organisms, which would be identified and counted, as well as samples of sediment for grain size analyses. Complementary data on abiotic parameters such as temperature and dissolved oxygen could also be collected. The frequency of these surveys should be specified; however, they cannot be conducted every year given the costs and effort involved.

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. 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 imaging and identify other potential habitats. This survey method could also be used to collect data on the presence and abundance of lobsters and other benthic and demersal species. 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 by identifying the species from DNA fragments present in seawater. The analysis technique has yet to be developed. There is a need to gain a better understanding of local current dynamics and to further document the life span of Atlantic wolffish DNA in the environment. 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) or AIS on the ridge.

RD6 Passive acoustics–hydrophone

Passive acoustic monitoring using a hydrophone is a potential option for monitoring whales and anthropogenic underwater noise. Acoustic monitoring can identify species and provide information on the use of the MPA and the surrounding area by cetaceans. Noise measurement would also provide information on anthropogenic pressure associated with navigation activities. No systematic noise surveys are carried out in the sector at present; however, between 2010 and 2015, blue whale sounds were detected at a station off Cap-d'Espoir near the MPA. It would be interesting to link up with acoustic monitoring projects carried out in this sector and to assess the usefulness of installing a listening station directly in the MPA.

Monitoring strategies

For physical and chemical oceanography and the pelagic ecosystem

Existing surveys (AZMP [R1-R3-R4-R5-R6], buoy [R2], acoustic [R7-R8] and mackerel eggs R9]) already make it possible to monitor most of the indicators related to physical and chemical oceanography and the pelagic ecosystem. However, some of these surveys could be optimized to collect local data. For forage species, information from stock assessments is the best source of data currently available. It has been suggested that the information that could be obtained from the northern gannet survey (R20) and the bird inventories conducted during multispecies surveys should be assessed as a potential complement.

For the benthic and demersal ecosystem

Two types of complementary surveys were identified as essential for monitoring the benthic and demersal ecosystem: imaging (RD1) and endobenthos (RD2) surveys, which need to be developed, and the existing trawl surveys (R10-R11-R12-R13). Imaging is essential for clearly visualizing assemblages of epibenthic species, sediment types and the heterogeneity of the environment. In addition, imaging can be carried out on both the ridge and the adjacent plains and it has a minimal impact on existing organisms. However, a new survey is required in order to adequately cover the endobenthos and soft substrates. The surveys will focus mainly on megafauna for epibenthos (> 2 cm) and macrofauna for endobenthos (> 1 mm).

A trawl survey can cover a larger seabed area, increase the chances of collecting less common organisms with a heterogeneous distribution in the environment and capture demersal species. However, trawl use will be limited to the plains adjacent to the American Bank. Trawl survey data are important in a monitoring context because they provide a long time series prior to the implementation of management measures and information gathered outside the boundaries of the MPA (BACI approach). However, trawling has a much greater impact on the seabed and on benthic and demersal ecosystems than imaging. The feasibility of continuing trawl surveys in the MPA with a focus on protection of benthic habitat should be independently assessed in accordance with the 2012 framework document on the use of bottom-contact scientific gear in protected areas.

For species at risk

The ROMM (R16) and MICS (R17) surveys have been selected as an initial approach for monitoring whale species at risk, but they could be optimized. Although incomplete, the data obtained are the only available recurrent data available at present. In addition, opportunistic DFO data from occasional aerial surveys in the Gaspé sector could be used. DFO monitoring of the North Atlantic right whale has been stepped up recently, but these additional surveys may

not be sustainable. The development of a new monitoring approach using passive acoustics (RD6) could provide more accurate and systematic data for the sector; however, a lot of resources would be required and therefore is not the preferred approach in the short term.

No survey currently exists to monitor Atlantic wolffish. As a first step and a complementary source of data, a scuba diving survey (RD4) and an imaging survey (RD1) could be used to collect the necessary monitoring data. In parallel, the development of a survey based on eDNA sampling (RD5) has been proposed and, once the technique has been developed, this approach could replace the use of divers.

For anthropogenic pressures

Certain types of pressures can be monitored through existing survey methods such as fisheries (R14-R15), commercial vessel traffic monitoring (R19) and RQUMM (R18). Some surveys could also be optimized, such as the AIS survey (R21), for which a station could be added to the MPA. A noise survey (RD6) could also be developed to directly monitor pressure related to commercial traffic. With respect to disturbance caused by recreational activities, monitoring could be done by collecting information on the number of marinas in the area, the number of marina members and expected visitors, and the number of trips made by whale watching tour companies.

Sources of uncertainty

The main source of uncertainty is the lack of baseline knowledge about certain ecosystem features identified as essential for assessing the achievement of conservation objectives. For the suprabenthic and endobenthic communities as well as pelagic fish such as capelin, there is a lack of accurate information to support indicator development. It is crucial to acquire new data to fill these knowledge gaps and it will take a long time to identify indicators for these features.

Some indicators are designed to monitor functional groups, key species or indicator species but could not be identified due to a lack of information. A rigorous literature review and database analysis should be carried out in order to clarify these elements.

CONCLUSIONS AND ADVICE

Since the Banc-des-Américains MPA is not under much pressure, monitoring of the site will be used primarily to assess whether the current status is maintained over time. Some improvements may be observed, but this is likely to be over the long term.

In the light of existing information, a series of indicators has been selected to carry out monitoring of the MPA. However, some gaps in knowledge of this sector have made it impossible to identify monitoring indicators for capelin and the endobenthic and suprabenthic communities and pollution.

To ensure adequate monitoring of the MPA, indirect indicators (n=11) have been identified for monitoring physical and chemical oceanography and the pelagic ecosystem. For the benthic and demersal ecosystem, most of the indicators selected are direct ones (n=9). Four indicators have been selected for monitoring whale species at risk and the Atlantic wolffish, and nine indicators for monitoring anthropogenic pressures.

The review of existing surveys and associated data collection has identified several programs that can be used to monitor the selected indicators. Some of these surveys could be enhanced to increase their spatial coverage in or around the MPA. However, additional surveys will be required for some indicators. Six new surveys have been recommended. Some surveys are

already planned or currently being evaluated, including imaging surveys, endobenthos sampling, eDNA sampling and scuba diving. These surveys should be put in place over the coming years. Other surveys, such as additional moorings and passive acoustic monitoring, would require a much greater investment and are not expected to be implemented in the short term.

At present there is insufficient information to propose a comprehensive monitoring plan for the Banc-des-Américains MPA. Sampling protocols need to be precisely described and the parameters that will be used to measure the indicators need to be defined along with the method for assessing the status and trends of these indicators.

It is recommended that a scientific committee be established to review and validate certain features and indicators, as well as to further develop all the protocols required for monitoring. This would enable the scientific committee to propose a comprehensive monitoring plan and work toward its implementation. The committee should include MPA managers and representatives responsible for the various monitoring approaches related to the aspects covered by the conservation objectives.

During the evaluation of existing surveys and the development of monitoring protocols, the BACI approach should be used, where possible, as it makes it possible to ascertain whether the changes observed in the MPA are the result of the management measures. If the BACI approach cannot be used, the monitoring protocols should be carried out within and outside the MPA for comparison purposes.

LIST OF MEETING PARTICIPANTS

Name	Affiliation
Albert, Elaine	DFO, Oceans Management, Quebec Region
Arsenault, Lisa	MMAFMA
Beauchamp, Jacinthe	DFO, Oceans Management, Quebec Region
Ben Mustapha, Selima	DFO Science, Quebec Region
Benoit, Hughes	DFO Science, Quebec Region
Bourdages, Hugo	DFO Science, Quebec Region
Cantin, Guy	DFO Science, Quebec Region
Christopherson, Virginie	DFO Science, Quebec Region
Clermont, Yves	DFO Science, Quebec Region
Côté, Stéphanie	DFO Science, Quebec Region
Côté, Geneviève	DFO Science, Quebec Region
Cyr, Charley	DFO Science, Quebec Region
Desjardins, Christine	DFO Science, Quebec Region
Dionne, Suzan	Parks Canada
Faille, Geneviève	DFO Science, Quebec Region
Galbraith, Peter	DFO Science, Quebec Region
Gendreau, Yanick	DFO Science, Quebec Region
Labbé-Giguère, Stéphanie	DFO, Oceans Management, Quebec Region
Mark, Susanne	DFO, Oceans Management, Quebec Region
McQuinn, Ian	DFO Science, Quebec Region
Méthé, Denise (tel.)	DFO Science, Gulf Region

Name	Affiliation
Mosnier, Arnaud	DFO Science, Quebec Region,
Nozères, Claude	DFO Science, Quebec Region
Plourde, Stéphane	DFO Science, Quebec Region
Poirier, Mélanie	DFO Science, Quebec Region
Pomerleau, Corinne	DFO Science, Quebec Region
Renard, Sébastien	SSLMP
Ricard, Daniel (Tel.)	DFO Science, Gulf Region
Roy, Virginie	DFO Science, Quebec Region
Sainte-Marie, Bernard	DFO Science, Quebec Region
Savenkoff, Claude	DFO Science, Quebec Region
Simard, Nathalie	DFO Science, Quebec Region
Thorne, Marilyn	DFO Science, Quebec Region
Tremblay, Claude	DFO Science, Quebec Region
Velasquez, Sandra	DFO Science, Quebec Region

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This Science Advisory Report is from the May 22–23, 2018 regional peer review meeting on the Review of the indicators and recommendations of an Ecological Monitoring Plan for the Banc-des-Américains proposed MPA. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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Centre for Scientific Advice (CSA)
Quebec Region
Fisheries and Oceans Canada
Maurice Lamontagne Institute
850 Route de la Mer, P.O. Box 1000
Mont-Joli, Quebec G5H 3Z4

Telephone: 418-775-0825
Email: bras@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

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