



## REVIEW OF THE MANICOUAGAN MARINE PROTECTED AREA (MPA) ECOLOGICAL MONITORING PLAN

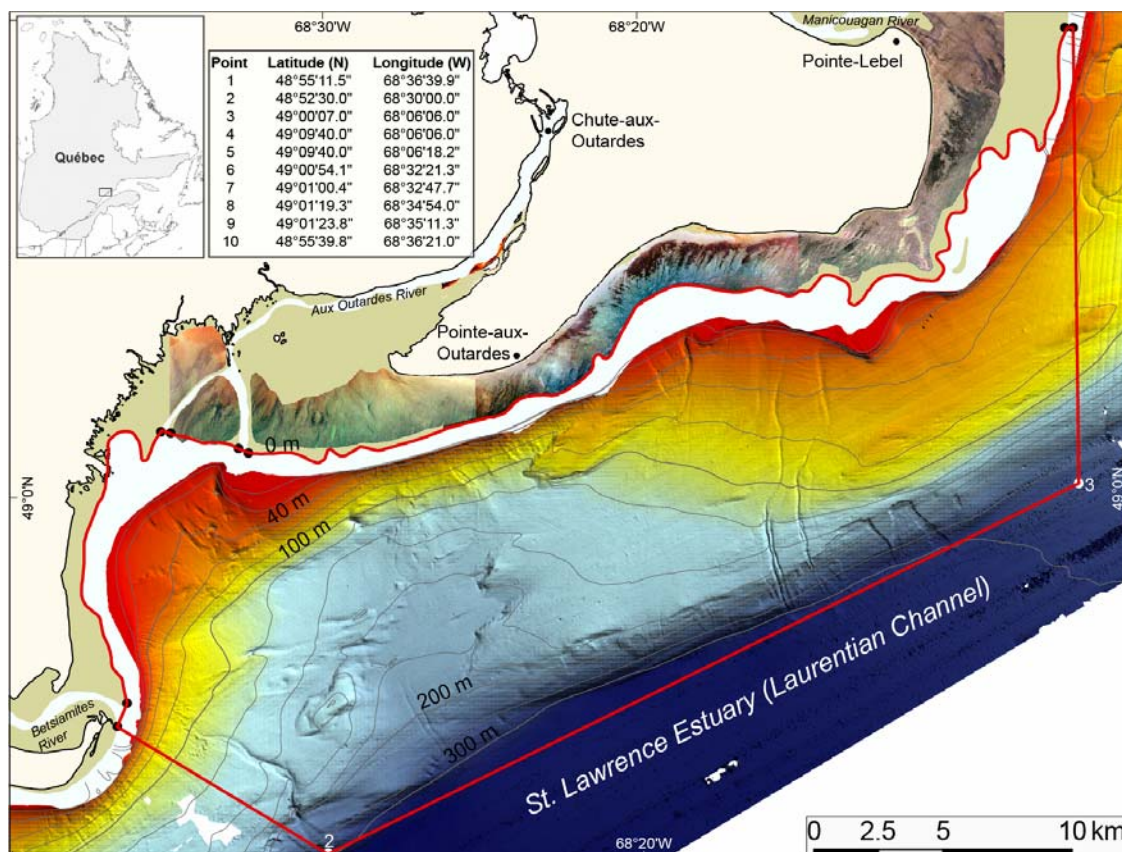


Figure 1. Location and limits (red line) of the future Manicouagan MPA. The sea floor image was produced using data from a multibeam survey conducted by the Canadian Hydrographic Service.

### Context:

Under the Health of the Oceans Initiative (Section 21), DFO Science is responsible for developing indicators, protocols and strategies to monitor each of the conservation objectives associated with established marine protected areas (MPA). Monitoring of biological and ecological indicators (and related threats) may: 1) be integrated to expanded MPA monitoring "plans" or "programs" (being conducted by the DFO Oceans Sector); 2) help monitor the status of populations and habitat, conditions and trends in order to determine whether the MPA can achieve the established conservation objectives; 3) help managers to review MPA management plans in light of conservation objectives; 4) be used to generate reports to Parliament and to Canadians (ultimately, through the management sector). The choice of indicators and protocols for collecting and analyzing data must be scientifically defensible.

In 1998, the Pointe-aux-Outardes Nature Park suggested the Manicouagan Peninsula area as a site of interest in the creation of a possible MPA. We must therefore examine indicators, protocols and strategies for monitoring the MPA in the light of our current knowledge. Research on the benthic communities was conducted from 2006 to 2008. Further research is needed to finalize the development of certain indicators and protocols for other ecosystem components of the MPA.

## SUMMARY

- The objective of the meeting was to review the selected components and the proposed monitoring plan to determine whether the targeted Conservation Objectives in the Manicouagan MPA management plan were met: Target 1 (*Maintain and protect significant habitats and species for the biological diversity and productivity of the MPA*) and Target 4 (*Ensure sustainable exploitation of marine resources*).
- The components of the ecosystem selected in terms of biological diversity and productivity lead to two types of monitoring: 1) monitoring of ecosystem components with which to evaluate the performance of the MPA in meeting the conservation objectives and the effectiveness of the management measures, and 2) monitoring of components for assessing the status of the MPA ecosystem but that potential changes cannot be directly related to its management.
- The biotic components of the ecosystem, which monitoring helps in assessing the performance of the MPA, are those characterized by communities and populations that reside permanently or often frequent the area. A criterion determining the level of residence for each component was applied for their selection. The selected components are: benthic communities (epi-, endo-, supra-benthic), communities of small demersal fishes, harbour seals, and waved whelk.
- The abiotic components of the ecosystem, which monitoring helps in assessing the performance of the MPA, are those that define the habitat of selected biotic components and that help assess the conservation objective aimed at restoring or maintaining the quality of water and sediment. These components are: relief, sediment (composition and quality) and water (quality).
- The components for monitoring the status of the ecosystem have an influence on the MPA ecosystem in terms of biological productivity and diversity, but their spatial distributions extend past the boundaries of the MPA or are located outside of the MPA. This includes species with wide-ranging distributions, oceanographic components (biological, chemical, and physical), as well as salt marshes and eelgrass beds. Monitoring will be important for interpreting the results obtained in the MPA performance assessment.
- A series of indicators was defined to ensure the monitoring of identified biotic and abiotic components. To monitor the majority of the performance indicators, the introduction of a new survey is necessary for monitoring benthic communities, sediment and water quality. This survey will cover 25 stations in 4 ecological zones. Waved whelks will be monitored from research surveys and fisheries data, while community monitoring needs to be developed for harbour seals. Monitoring for ecosystem status indicators are based primarily on existing programs throughout the St. Lawrence.

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## BACKGROUND

### The Manicouagan MPA Project

In 1998, the Pointe-aux-Outardes Nature Park suggested the area of the Manicouagan Peninsula as a site of interest for a possible MPA. This site was brought to attention in order to conserve and protect a very productive marine zone high in biodiversity, but also because of the interest expressed by the local community, thus creating the basis for a common project. A technical committee was established, comprising representatives from the Manicouagan MRC, the Betsiamites band council, the Pointe-aux-Outardes Nature Park and the Department of Fisheries and Oceans. This committee has prepared a preliminary management plan that identifies, among other things, environmental concerns and constraints, conservation objectives of the MPA, and a list of initiatives for managing the area (Technical Committee 2001). The management plan was submitted for public consultation.

### Description of the MPA

The proposed Manicouagan MPA is located on the north shore of the St. Lawrence estuary in Quebec, Canada. It surrounds the Manicouagan Peninsula between the Manicouagan and Betsiamites river estuaries, and extends from the low water mark out to the Laurentian Channel (isobath of 300 m depth), covering 517 km<sup>2</sup> (Figure 1). The bathymetry shows a configuration similar to a mini continental shelf (Figure 1). As with the lower estuary, differences in temperature and salinity results in three types of overlapping water masses in the summer: a surface layer, diluted with fresh water; a cold intermediate layer (CIL); and a deeper layer, warmer and saltier than the CIL. The seabed of the MPA is sedimentary in nature. Sand dominates in shallow waters (5 to 40 m depth), with grain sizes of fine to very fine in the western sector and medium to coarse in the eastern sector. In deeper waters, the sediment gradually becomes finer, with silt found at 120 m depth and downwards to the Laurentian Channel. At greater than 175 m in depth, the water is low in oxygen.

The mixture of freshwater from the three rivers (Betsiamites, Aux Outardes, and Manicouagan) and saltwater from the St. Lawrence estuary creates oceanographic conditions favourable to primary production. Blooms of toxic algae (*Alexandrium tamarense*) are also frequent and intense in the MPA region, although their abundance varies greatly between seasons and between years. High concentration areas are associated with river plumes. The strong presence of *A. tamarense* in the MPA is an important factor for the local ecosystem. Potential effects on other species are even more apparent since the 2008 bloom that caused mortalities in fish, birds, seals and whales over a wide area of the St. Lawrence estuary.

A sampling campaign was conducted from 2006 to 2008 to survey the endobenthos and epibenthos throughout the MPA. Benthic fauna was highly diversified with over 400 taxa identified during the various campaigns. The most significant abundances and biomasses were found in the CIL (at depths of 30 to 100 m) along with the greatest diversity. This zone revealed important numbers and biomass of molluscs and many polychaetes, along with several echinoderm species at the eastern point. Deeper areas had less abundance, biomass and diversity. The underwater bay held mostly polychaetes and crustaceans (northern shrimp *Pandalus borealis* and the amphipod *Neohela monstrosa*). The Laurentian Channel was dominated by sea anemones, sea pens (*Pennatula* spp.), and brittle stars (*Amphiura sundevalli* and *Ophiura sarsii*).

Adjacent to the MPA, several habitats contribute significantly to primary and secondary productivity and to the biodiversity of the MPA. These habitats include the Pointe-aux-Outardes salt marshes, the largest of the North Shore (5 km<sup>2</sup>), and large eelgrass beds covering more than 14 km<sup>2</sup>. The sandy flats also support large beds of softshell clams. With three river estuaries and their concomitant sandbanks, the intertidal zone provides valuable habitat for harbour seals in the St. Lawrence estuary. Five sites for hauling out or calving have been identified at the northern limit or adjacent to the MPA. The Manicouagan MPA also serves as a foraging area for this mammal.

## **Conservation Objectives**

Of the 5 reasons for designating an MPA, that which concerns the Manicouagan MPA is "*the conservation and protection of marine areas, rich in biodiversity and biological productivity.*" Five goals, each supported by more specific related goals, stem from this rationale and are listed in the MPA Management Plan (Technical Committee 2001). Among these goals and objectives, some are more specifically conservation objectives and will be covered by the MPA ecological monitoring plan. These objectives are:

- Maintain and protect significant habitats and species for the biological diversity and productivity of the MPA (Target 1 of the management plan)
  - Restore or maintain the quality, diversity and productivity of the habitats considered significant (Objective 1A)
  - Restore or maintain the quality of water and sediments (Objective 1B)
  - Protect the marine species considered significant (Objective 1C)
- Promote sustainable and respectful use of marine resources and land (Target 4 of the management plan)
  - Ensure sustainable exploitation of marine resources (Objective 4C)

## **Human Activities and Constraints**

The human activities that could impact biological diversity and productivity in the MPA are:

- Hydro-electric projects
- Shoreline development
- Discharge of industrial and domestic wastewater (along the coast and upstream in the St. Lawrence)
- Agriculture, waste disposal sites, and peat bogs (runoff, leaching and drainage)
- Hunting and fishing
- Maritime shipping
- Recreational and tourist activities
- Climate change (warming, acidification)
- Atmospheric fallout

The Manicouagan MPA is not strongly affected by pressure from human activities. The most significant human activity is probably from power generation by hydro-electric projects that began in the 1960s. These projects changed the flow regime of natural freshwater: flow rates now vary much less during the year, with surges (spring flooding) and ebbs (winter minimum flow) no longer as significant. These changes in natural flow lead to hydrodynamic changes near the coast, along with the reduction of nutrient loads and sediment supply from rivers.

However, this situation is not reversible and a certain degree of ecological balance has since taken place. The supply of sediment now originates principally from the erosion of clay cliffs in the sector. Sediment from the shore is carried off to settle on the sea bottom or elsewhere along the coastline. This erosion problem in the Manicouagan Peninsula has led to various shoreline developments that tend to intensify the erosion problem by increasing instead of mitigating the reflection of waves.

The emission of organic and chemical substances occurs through point sources such as sewage outfall, or diffuse sources from non-compliant septic systems, agriculture, waste disposal sites, and clandestine dumps near the coast. Waste discharges from industries (pulp and paper, aluminum smelter) in Baie-Comeau were very significant in the past but are now better controlled. Nevertheless, waste discharges are still occurring, primarily organic substances (fatty acids, oils, mineral grease), but also iron and aluminum. However, it is unclear whether these discharges are toxic and if they are dispersed in the MPA.

Fishing intensity is not particularly strong in the MPA. Species caught are snow crab, waved whelk, Greenland halibut, northern shrimp and Stimpson's surfclam. Fishing for shrimp in the MPA has been low since 2002, and no surfclams have been harvested since 2006. Fishing with baited traps (whelk) may increase local productivity by organic enrichment of the environment due to the bait.

The significance of waterfowl and pinniped hunting that occurs within the MPA is relatively low and it is addressed in the current context mainly because of the risk of accidentally injuring or killing harbour seals during the hunt for other seal species.

Maritime activities are relatively high in the area because of the Baie-Comeau port complex. Recreational and tourist use of the area involves kayaking and recreational boating, which is done mainly during the clam harvesting season.

## **MANICOUAGAN MPA MONITORING ASSESSMENT**

### **Selection of Components to be Monitored**

The selected ecosystem components in terms of biodiversity and productivity lead to two types of monitoring: 1) monitoring of ecosystem components with which it will be possible to determine whether conservation objectives have been met and for assessing the performance and effectiveness of the management measures and, 2) monitoring components that provide information on the status of the ecosystem, which will help when interpreting the results obtained from the MPA performance assessment, but that these possible changes cannot be directly related to its management (See Chapter 6 of Mark et al. 2010)

#### **Components for the MPA Performance Assessment**

The biotic components of the ecosystem, which monitoring helps assess MPA performance, are those characterized by the communities and populations that occur there permanently or that often occupy the area. Subject to the MPA conditions, they depend on them for their survival, reproduction and growth. These components will be directly affected by pressure from human activities affecting the MPA. A criterion determining the level of residence for each component of the ecosystem has been applied for their selection (Mark et al. 2010). Essentially, these

components are the benthic communities, the small demersal fishes, and the harbour seals that frequent the MPA to feed or to travel to their haul-out sites, resting areas, and calving sites. Abiotic components that will also help assess MPA performance are those whose quality or composition may be affected by human activities that occur within the MPA. These components are the seabed relief, sediment and water quality. The list of selected components is presented in Table 1.

Table 1. Biotic and abiotic components selected for the Manicouagan MPA monitoring that will help in determining its capacity to meet conservation objectives and the effectiveness of the management measures.

<b>Biotic Components</b>	<b>Targeted Conservation Objectives</b>
<b>Zoobenthos</b>	
Epibenthic communities	1A - Restore or maintain the quality, diversity and productivity of the habitats considered significant
Endobenthic communities	1A - Restore or maintain the quality, diversity and productivity of the habitats considered significant
Suprabenthos	1A - Restore or maintain the quality, diversity and productivity of the habitats considered significant
Waved whelk (population)	4C - Ensure sustainable exploitation of marine resources
<b>Fish</b>	
Small demersals	1A - Restore or maintain the quality, diversity and productivity of the habitats considered significant
<b>Marine mammals</b>	
Harbour seals in the MPA (nearby haul-outs)	1C - Protect the marine species considered significant
<b>Abiotic components:</b>	
<b>Seabed</b>	
Relief (bathymetry)	1A - Restore or maintain the quality, diversity and productivity of the habitats considered significant
Composition of sediment	1A - Restore or maintain the quality, diversity and productivity of the habitats considered significant
Quality of sediment	1B - Restore or maintain the quality of water and sediments
<b>Water</b>	
Quality of water	1B - Restore or maintain the quality of water and sediments

#### Components for Monitoring the Status of the Ecosystem

Other ecosystem components were selected, even if they do not help with the MPA performance assessment, due to the significant information they provide on the status of its ecosystem (Mark et al. 2010). Their temporal or spatial distribution extends well beyond the limits of the MPA, or they are located outside the MPA. In the first case, a change in one of

these components can be related to an event outside the MPA, but this change may have an impact on part of the MPA ecosystem. For example, a decrease in the number of snow crabs in the MPA may be due to over-harvesting outside the MPA, which reduces the overall population. However, because snow crab is a structuring species of the benthic community, a decrease or increase in this species could have an impact on this community. In the second case, a change observed in the MPA may be the result of an altered component located outside the MPA, but that influences the status of its ecosystem. In both cases, monitoring these components is therefore required in order to interpret the results obtained in the MPA performance assessment. While these components may not be directly related to the management and regulation of the MPA, it will be possible to influence the decision makers who have the legislation mandate. Table 2 lists the biotic and abiotic components that sufficiently influence the MPA ecosystem to warrant monitoring. For many of them, monitoring already exists under other programs throughout the St. Lawrence.

Table 2. Biotic and abiotic components for monitoring the status of the Manicouagan MPA ecosystem.

<b>Biotic Components:</b>
<b>Phytoplankton</b>
<i>Alexandrium tamarense</i> and associated community
<b>Zooplankton</b>
Macro- and mesoplankton
<b>Phytobenthos</b>
Eelgrass beds
Salt marshes near the MPA
<b>Zoobenthos</b>
Snow crab
<b>Fish</b>
Pelagic (in particular sand lance and capelin)
Large demersals (in particular Atlantic cod and Greenland halibut)
<b>Marine mammals</b>
Harbour seal (St. Lawrence estuary colony)
Cetaceans
<b>Abiotic components:</b>
<b>Water</b>
Physical and chemical characteristics of the water
Hydrological dynamics
Exogenous contamination (e.g. in the St. Lawrence)
<b>Invasive exotic species</b>

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## **Existing Monitoring**

### **1. Thermograph Network**

The DFO thermograph network is permanent and consists of twenty coastal stations in the estuary and Gulf of St. Lawrence where temperature has been measured almost continuously since 1993. These measures cover depths ranging generally from 1 to 30 m, with some stations reaching 100 m depth. One of these stations is in Baie-Comeau (Figure 2).

### **2. Winter Water Mass Monitoring – helicopter mission**

Each year in March, around 60 stations are visited in the lower estuary (10 stations) and the Gulf of St. Lawrence using Canadian Coast Guard helicopters. This monitoring has existed since 1996. The data collected are temperature, salinity, surface nutrients, and plankton.

### **3. Remote Sensing of Surface Temperature**

The Remote Sensing Laboratory at the Maurice Lamontagne Institute (DFO) operates two stations for receiving satellite imagery (Mont-Joli and Resolute Bay), allowing it to acquire weather satellite data from the National Oceanic and Atmospheric Administration (NOAA). These data are used to calculate the surface temperature of the sea. These images can help monitor the evolution of various physical phenomena and their relationship to biological processes.

### **4. Remote Sensing of Ocean Colour and Primary Production**

The Bedford Institute of Oceanography (DFO) conducts work aimed at creating a chronological series of images describing the physical and biological conditions of the northwest Atlantic. Images of sea surface temperature and chlorophyll concentrations are produced. The images of primary production are obtained from chlorophyll concentration and temperature data integrated on a bimonthly basis.

### **5. Lower Estuary Zooplankton Biomass Assessment**

Zooplankton samples were collected from a grid of 44 stations in the lower estuary and western Gulf of St. Lawrence, to assess the macrozooplankton biomass once a year. The mesozooplankton is collected and stored but not analyzed. Temperature and salinity data are recorded. This monitoring has existed since 1994. There are two stations in the MPA and two others nearby (Figure 2).

### **6. Rimouski Monitoring Station**

A copepod and phytoplankton monitoring station is located 20 km offshore of the Rimouski marina (48° 40'N, 68° 35'W). Sampling (20-25 times per year) begins in April or early May and ends as late as possible in order to encompass the seasonal cycle of the dominant copepod species in this very dynamic region of the estuary. This monitoring has existed since 1989.

### **7. Atlantic Zone Monitoring Program (AZMP)**

This program was implemented in 1998 and includes the Gulf, Quebec, Maritimes and Newfoundland Regions of DFO. It aims to monitor and predict changes in productivity and status of the marine environment by collecting and analyzing the biological, physical and chemical data required to characterize ocean variability and to establish relationships between biotic and abiotic variables. It uses existing programs and supplements them as needed. A key element of the program is the oceanographic sampling at fixed stations and along transects. Fixed stations are visited approximately every two weeks depending on weather conditions, while transects are sampled 1 to 2 times during the year. Regular sampling includes



measurements of temperature, salinity, fluorescence, oxygen, nitrates, phosphates, and silicates, and the collection of phytoplankton and zooplankton samples. A transect of this program crosses the lower estuary and ends just west of the MPA (Figure 2).

### 8. Toxic Algae Monitoring Program

The Toxic Algae Monitoring Program in the Quebec Region includes the estuary and Gulf of St. Lawrence, with eleven coastal stations that have been sampled weekly from May to October since 1989. The program aims to: 1) identify and track short- and long-term toxic or harmful algae blooms in the estuary and Gulf of St. Lawrence, and 2) determine the factors responsible for their appearance and development. A station is located in Baie-Comeau (Figure 2). When sampling algae, all species from the community are identified. It is recognized that monitoring the composition of this community is an indicator of ecosystem status and long-term changes (climate, eutrophication, acidification).

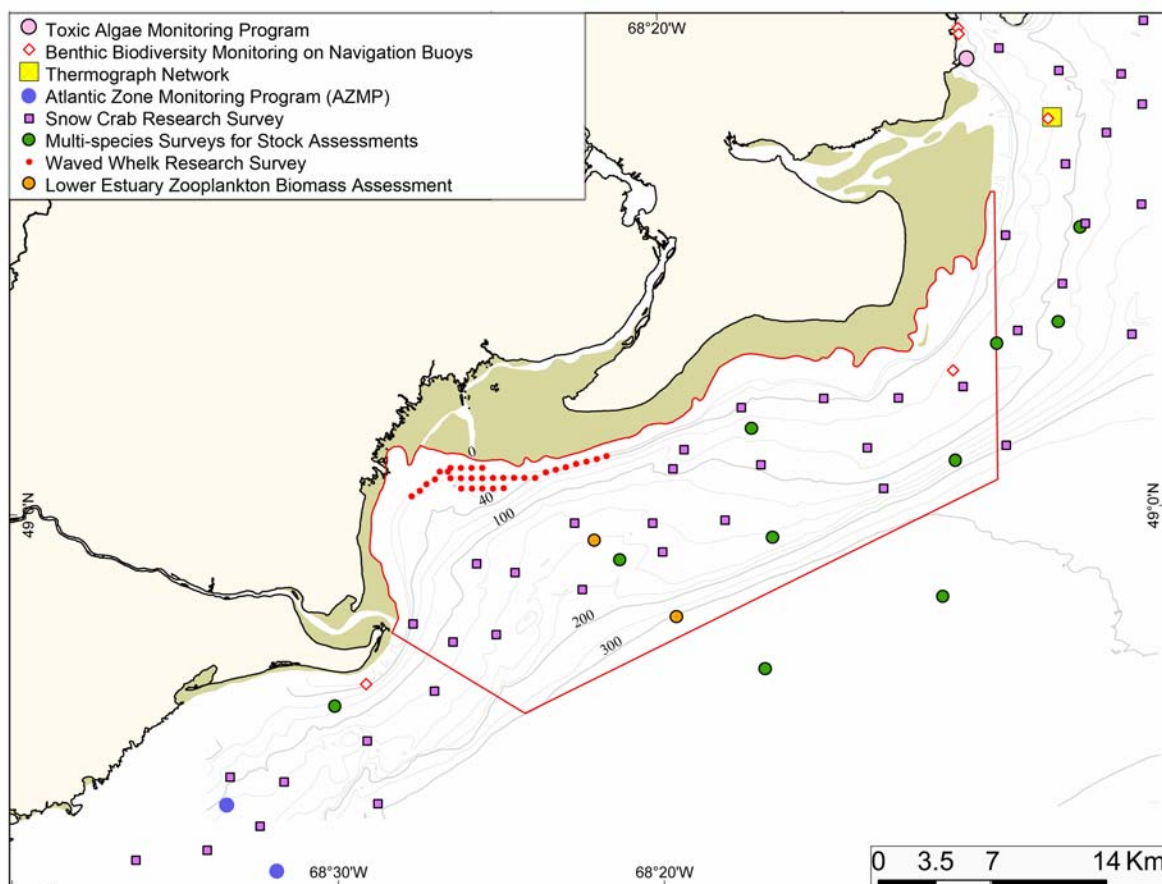


Figure 2. Existing and nearby monitoring activities in the Manicouagan MPA.

### 9. Canadian Shellfish Sanitation Program (CSSP)

Environment Canada is responsible for assessing water quality and for classifying shellfish growing areas. It regularly monitors the bacteriological quality of shellfish waters, which is determined by the presence of fecal coliforms in water samples taken from the site. The results are used to classify the areas and recommend their opening or closure, with DFO being responsible for making the final decision. Each sector contains several stations for collecting water samples. The Canadian Food Inspection Agency (CFIA) in turn controls the quality of shellfish during handling, processing and marketing, whether for export or import. It also

monitors marine biotoxins in shellfish flesh to ensure an acceptable level. The CFIA also makes recommendations to DFO on the opening and closing of shellfish areas based on the level of toxicity in shellfish. The DFO ensures their implementation. Shellfish beds in the MPA have been monitored by this program since 1948.

#### 10. Multi-species Surveys for Stock Assessments

Since 1990, every August in the estuary and northern Gulf of St. Lawrence, a multi-species survey is conducted for groundfish and shrimp stock assessments. The goal is to monitor trends in abundance and biomass indices for the different species in order to recommend appropriate exploitation levels and total allowable catch (TAC). In 2008, coverage of Division 4T was increased in the upstream part of the estuary by adding four strata to sample the depths between 20 and 100 fathoms (37 to 183 m) (Figure 2). In each stratum, stations were chosen at random and vary from year to year. The main objectives of the survey since 2008 have been: 1) to obtain abundance and biomass estimates for about ten demersal species, indicate their spatial distribution and determine their biological characteristics; 2) collect data on other species as part of the ecosystem approach; 3) obtain, in parallel, a portrait of environmental conditions in the estuary and northern Gulf; 4) inventory and assess zooplankton abundance. An analysis of presence/absence of pelagic species caught when lifting the trawl is also conducted. With the addition of new strata, four trawl tows in 2008 and 2009 were sampled in the MPA (Figure 2).

#### 11. Benthic Biodiversity Monitoring on Navigation Buoys

More than 1,200 buoys (about 600 in freshwater and 600 in saltwater) are used for navigation in the St. Lawrence. Of these buoys, approximately 150 are removed and cleaned by the Coast Guard to collect benthic organisms. This procedure is carried out annually in the various sectors of the St. Lawrence. Unlike planktonic organisms, benthic organisms are integrators of environmental changes occurring in an area. They are recognized by many as ideal organisms for environmental monitoring. This monitoring was conducted by Laval University between 1975 and 1985, and was resumed by ISMER in 2004. Five buoys targeted for monitoring are anchored nearby or in the MPA (Figure 2).

#### 12. Fishery Data and Waved Whelk Research Survey

Waved whelk (*Buccinum undatum*) stock assessments are made from various data sources such as logbooks filled out by commercial fishermen, purchase receipts provided by processing plants, size structures of individuals landed provided by the DFO commercial sampling program, and a research survey. The logbooks provide fishing positions and the effort deployed for each hauled trap (number of traps used, soak time and date hauled). Landings are calculated primarily from purchase receipts.

Since 2005, a research survey has been conducted every two years in the Forestville, Pointe-aux-Outardes and Baie-Comeau areas on the Upper North Shore (fishing areas 1 and 2). Among the stations sampled, about thirty are located within the MPA. Surveys are conducted using a Digby-type scallop dredge and baskets lined with 19 mm mesh. Various parameters are measured such as abundance, biomass and size of whelks and their eggs. Other caught species are also counted.

#### 13. Fishery Data and Snow Crab Research Survey

Snow crab stock assessments are made using commercial fishery data from fishing logbooks, purchase receipts from processing plants, summaries of dockside weighing, as well as the sampling of the fishery conducted by the DFO observers and samplers program.

Independent data from the commercial fishery are collected at the end of the fishing season: 1) a trap survey is conducted annually by the industry in all areas, to determine the mean NUE (number per unit effort) per area of commercial size crab and the NUE of adolescent crabs over 78 mm carapace width (pre-recruits); 2) a beam trawl survey has been conducted by the DFO every two years in the estuary since 1992 and annually in the western part of Area 16 since 1989, providing abundance index (density) and size structures for juvenile and adult crabs. The trawl's capacity to capture even very small crabs can predict recruitment trends up to 8 years in advance. Spider crabs (*Hyas* spp.) and northern stone crab (*Lithodes maja*) are counted and measured, and since 2009 sea urchins and sea cucumbers are also collected and measured. About twenty stations within the MPA and several others nearby are sampled (Figure 2).

#### 14. Capelin Observer Network (CON)

In 2002, the Oceans Management Division, DFO Quebec Region, in collaboration with the maritime sector and local partners, established the Capelin Observer Network. This network involves the general public in identifying the sites and dates of spawning capelin in order to document and better protect these habitats and their productivity.

#### 15. Marine Mammal Observation Network 'Réseau d'observation de mammifères marins'

The *Réseau d'observation de mammifères marins* (ROMM) is a non-profit organization dedicated to the protection and conservation of cetaceans and pinnipeds and their habitats. It was originally created by the *Corporation PARC Bas-Saint-Laurent* in 1998 and officially incorporated in March 2004. Its primary area of activity covers the estuary and Gulf of St. Lawrence. Its mission includes the planning, organization, management and monitoring of projects to acquire knowledge, conservation, education and awareness throughout the covered area. The organization is based on a well-established network of member observers from different sectors, including excursionists, conservation parks and maritime carriers. They collect data on whales and seals observed throughout their active season as part of an extensive environmental monitoring project aimed at better understanding the distribution of these mammals in the St. Lawrence.

## **Choice of Indicators**

### Performance Indicators

#### *For monitoring biotic components*

The performance indicators associated with the selected biotic components are those that will help monitor benthic communities and small demersal fishes, as well as the whelk population and harbour seals that occur in the MPA (Tables 1 and 3). The indicators for monitoring communities will have to provide an assessment of the composition, species diversity and the productivity of communities, along with their changes over time. The indicators for monitoring biological communities are described and explained in Mark et al. (2003). The number of species, number of individuals, diversity indices (specific richness, Shannon-Wiener index, and Warwick taxonomic index), and the cumulative dominance curve K (abundance/biomass) are the most often used indicators. These indicators require taxonomic identification of all species present in a sample. However, if financial resources do not allow for this difficult and expensive procedure, the use of key species may be an acceptable compromise. A key species may be the most abundant one or that is representative of the entire community. In the latter case, the ecological relationships between the species from different communities will have to be better understood before identifying key species. Productivity is more difficult to measure but can be estimated by tracking over time total biomass or biomass by major taxonomic groups. Assessing mollusc growth by examining shell growth rings (e.g. *Mesodesma arctatum*.) also

provides an indication of productivity of the community to which it belongs. The ecological size spectrum applied to communities helps monitor their productivity and identify exogenous disturbances of species assemblages. However, the use of this index applied to benthic communities will have to be validated.

Indicators for monitoring whelk are those already used for assessing the MPA population using with fishery and research survey statistics (Table 4). Those for monitoring the abundance and distribution of harbour seals focus on individuals that use the MPA for hauling out, resting and foraging (Table 4).

Table 3. Performance indicators for biological communities in the Manicouagan MPA.

	Conservation Objectives*	Indicators								
		Community composition and structure	Diversity S-W	Taxonomic index (Warwick)	Dominance-K (abundance-biomass)	Key species (abundance-biomass)	Biomass by major taxonomic groups	Width of shell growth rings	Community size spectrum	Recruitment
<b>Endobenthos</b>	1A	x	x	x	x	x	x	x	x	
<b>Epibenthos</b>	1A	x	x	x	x	x	x		x	x
<b>Suprabenthos</b>	1A	x	x		x	x	x		x	
<b>Small demersals fishes</b>	1A	x	x		x	x	x		x	

\* See section at top of document: Conservation Objectives

Table 4. Performance indicators for whelk and harbour seals.

	Conservation Objectives*	Indicators
<b>Harbour seal</b>	1C	- Abundance at haul-out sites - Distribution of seals - Abundance of pups
<b>Whelk</b>	4B	- Size distribution - Size at maturity - Recruitment (egg masses) - Number of traps and NUE

\* See section at top of document: Conservation Objectives

*For monitoring abiotic components*

The indicators associated with the selected abiotic components are those that will help monitor seafloor relief, sediment structure and quality, along with water quality (Tables 1 and 5). The compounds to be monitored are the persistent organic pollutants (e.g., PCB, BPDE, PAH) and heavy metals. For some compounds, threshold values were established (see "Canadian Sediment Quality Guidelines", <http://cegg-rcqe.ccme.ca/?lang=en>).

Contaminants are also measured in the organisms. This method allows screening at lower concentrations than direct measurements. It focuses on the biologically-active portion of a pollutant that is integrated over time, which reflects the periodic peak concentrations of contaminants that might otherwise be difficult to monitor. For sediment, a polychaete is a reliable indicator, while filter feeders will be a good indicator for water. The nearshore polychaete *Praxillella praetermissa* and the bivalve *Mesodesma arctatum* are abundant in the MPA, which makes them good candidates.

A sediment core collected at a location conducive to sedimentation will help observe the historic evolution of the contaminants by 1) determining the granulometry and percentage of water, 2) the reliability (in terms of sedimentation rate) of the core examined using a deposition tracer (lead-210 or cesium-137), and by 3) determining the concentrations of heavy metals and persistent compounds of anthropogenic origin.

Table 5. Performance indicators for abiotic components in the Manicouagan MPA.

Indicators							
	Conservation objectives *	Granulometry, % of water,	Persistent organic pollutants ** and heavy metals***	Persistent organic components** and heavy metals*** ( <i>Praxillella praetermissa</i> )	Persistent organic components** and heavy metals*** ( <i>Mesodesma arctatum</i> )	Sediment core (historical)	Bathymetry
<b>Water</b>	1A, 1B		x		x		
<b>Sediment</b>	1A, 1B	x	x	x		x	
<b>Relief</b>	1A						x

\* See section at top of document: Conservation Objectives

\*\* Persistent organic pollutants: PCB, BPDE, PAH

\*\*\* Heavy metals: Hg, Cd

### Indicators of Ecosystem Status

Most indicators for monitoring ecosystem status are those used in surveys conducted within the framework of various programs (See Section: Existing monitoring); such as phytoplankton (Monitoring no. 7 and 8), zooplankton (Monitoring no. 5 and 6), snow crab (Monitoring no. 13), demersal and pelagic fish (Monitoring no. 10 and 14), cetaceans (Monitoring no. 15), invasive

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species (Monitoring no. 11), physical and chemical characteristics of water (Monitoring no. 1, 2, 3, 4, 5, 6, 7, 8 and 10). To a certain extent, these will also be used to monitor the hydrological regime, along with additional indicators that will need to be defined. A model for understanding the hydrodynamics characterizing the MPA ecosystem should be developed in order to select the appropriate indicators. Indicators for exogenous contamination were the same as those used for performance indicators for water and sediment quality (Table 5).

## **Monitoring Protocols**

Various surveys have been identified and developed for monitoring the performance of the MPA ecosystem status. Table 8 at the end of this section lists the effective surveys for monitoring each component.

### **Monitoring Performance Components**

The components for assessing MPA performance have not yet been part of any monitoring, except for waved whelk research surveys, which have been conducted since 2005. Therefore, a new annual survey was developed to monitor most of the performance indicators. This survey targets benthic communities, small demersal fishes, sediment and water. The protocol for the *Survey of benthic communities and their habitats* is described later in this section.

For monitoring harbour seals occurring in the MPA, an observation protocol will have to be developed to monitor seal abundance and occurrence at the haul-out and pupping sites. This monitoring could be managed by the Pointe-aux-Outardes community. Some residents, whose homes face haul-out and calving sites, have shown an interest. The staff at the Pointe-aux-Outardes Nature Park could also be involved in this monitoring.

Whelk has been monitored using fishery statistics, and DFO research surveys since 2005. This monitoring is conducted every 2 years and the last was held in 2009. The MPA, which straddles whelk fishing areas 1 and 2 is well covered by this monitoring (Figure 2). Also, the survey of benthic communities and their habitats will provide additional information on whelk, completing the DFO research survey.

Reference sites for comparing MPA components with similar components outside the MPA have not been located in the current exercise. Nevertheless, this comparison is important for assessing MPA performance. For example, if the whelk population in the MPA is in good condition compared to surrounding populations, it could be assumed that MPA management is appropriate and beneficial for whelk. The location of these sites can be determined at a later time.

### **Monitoring Ecosystem Status Components**

Most of the components for assessing ecosystem status are monitored through various existing surveys throughout the St. Lawrence estuary. These surveys are identified for each component in Table 8 and are described in the section “Existing Monitoring”. These monitoring programs are adequate as currently conducted, except for monitoring toxic algae and it is recommended that a station be added in the MPA. The abundance of *Alexandrium tamarense* in the MPA is a significant factor for the local ecosystem. This station will have to be sampled weekly during the bloom period to document the various events during the season. The contribution of the community could be useful for collecting samples. The Pointe-à-Michel area would be a good

place for sampling. This monitoring program is currently pending. We wish to emphasize that this is an important element for monitoring the Manicouagan MPA.

The assessment of snow crab stocks obtained from commercial fishery data and two annual research surveys, one conducted by industry and the other by the DFO, provides effective monitoring of the snow crab population in the estuary. Several sampling stations are located in the MPA to which provide an assessment of crab abundance in the MPA (Figure 2). The survey of benthic communities and their habitats will also provide additional data on snow crab in the MPA, completing the DFO research survey.

The hydrological regime in the MPA should be better studied and understood before adequate monitoring can be developed. However, several existing surveys currently provide data that will be relevant for this monitoring. The monitoring of exogenous contamination can be added to the monitoring of benthic communities and their habitats. However, a station will have to be added, located outside the MPA. This site will serve as a reference point to compare the internal and external contamination values and in some cases, to explain the source of contaminants.

Optical images from various Earth observation satellites (ASTER, LANDSAT, IKONOS, SPOT) can be used to perform the mapping of salt marshes and eelgrass beds. These satellite images, collected year after year, will help monitor the spatial and temporal evolution of the size and range of grass beds and marshes. However, protocols for analyzing these images must be developed.

#### Survey Protocol for Benthic Communities and their Habitats

The new proposed survey for monitoring benthic communities and their habitats covers four ecological zones that were defined in terms of benthic communities sampled from 2006 to 2008 in the MPA (Figure 3). The results of these studies, which helped distinguish and define these areas, are presented in Provencher and Nozères (in prep.). From the shore to offshore, these four zones are defined as follows:

1. Wedgeclam (*Mesodesma arctatum*) and sand dollar (*Echinarachnius parma*) zone. These species are significant in terms of biomass and abundance and can generally be found at depths of 0-20 m.
2. Mollusc zone (primarily chalky macoma *Macoma calcarea* and the cockles *Serripes groenlandicus* and *Clinocardium ciliatum*), polychaetes (primarily *Goniada maculata*, *Praxillella gracilis*, *Maldane sarsi*, *Melinna cristata*, *Axiiothella catenata*), striped shrimp (*Pandalus montagui*) and, at the eastern point of the MPA, echinoderms (spiny brittle star and green sea urchin). The area is rich in diversity, and high in biomass. The area is located primarily between 15-80 m, encompassing the cold intermediate layer (CIL) that occurs at depths of around 30+ m.
3. Polychaete and crustacean zone (snow crab, northern shrimp, and the amphipod *Neohela monstrosa*) in the underwater bay west of the MPA, between 80-200 m. Most of the polychaetes found in Zone 2 occur here as well, but not the molluscs and echinoderms. This zone diminishes in terms of biomass, abundance and diversity as depth increases.
4. Echinoderm and cnidarian zone (sea anemones and sea pens) on the slope or at the bottom of the Laurentian Channel, between 200-320 m. Some species occur more on

the slope while others such as the sea anemones (*Cerianthus borealis*, *Actinauge* sp., *Edwardsia sipunculoides*), sea pens (*Pennatula* spp.), and brittle stars (*Amphiura sundevalli*, *Ophiura sarsii*) occupy the bottom of the channel.

The limits between these areas are approximate because the transition between the groups of species characterizing them is progressive. The rough boundaries of these areas have helped position the sampling stations within the main species assemblages. The stations were selected from those sampled in studies on benthic communities in the MPA from 2006 to 2008. This sampling serves as the baseline for monitoring. Twenty-five stations were selected, including 21 covering Zones 1 and 2, which were high in diversity and productivity (Figure 3). Moreover, these two areas are more likely to be affected by human coastal activities. Three stations are in Zone 3 and one in Zone 4 (Figure 3). These two areas are more homogeneous and low in diversity and productivity, which is the reason for the poorer coverage.

Table 7 summarizes the sampling protocol at these stations. The location and number of stations required for sampling the suprabenthos and small demersal fishes have not yet been determined; knowledge of the composition and distribution of these communities is currently insufficient. A characterization study of the suprabenthic community is recommended. The results from a study conducted in July and October 2004 on demersals fishes in the Manicouagan MPA will provide knowledge on the composition and distribution of this community and will be a first step towards developing a sampling protocol for small demersal fishes.

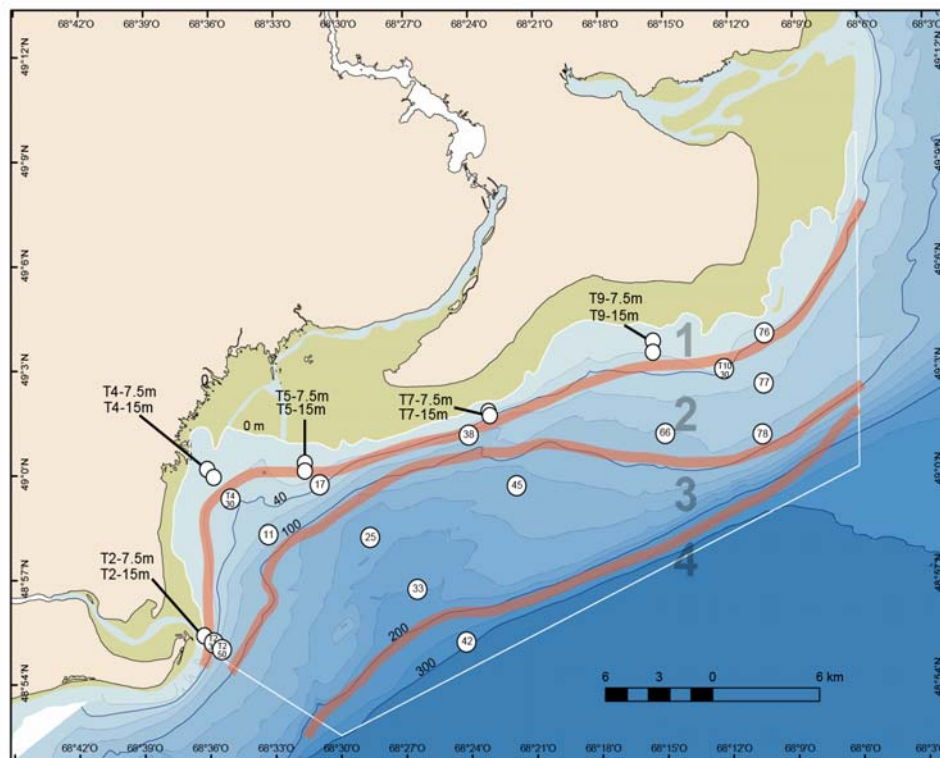


Figure 3. Sampling stations for the survey of benthic communities and their habitats. The stations labelled represent those sampled between 2006-2008. The pink lines roughly delineate Ecological Zones 1 to 4.



Table 7. Sampling protocol for the survey of benthic communities and their habitats.

Components	Stations	Sampling tools	n*	Frequency
Epibenthos	All	Photo, video	3	Annual
Endobenthos	All	Grab sampler (0.5 m <sup>3</sup> ) at stations > 15 m deep. Photos at all stations**	3	Annual
Suprabenthos	To be determined	To be developed (baited cage or suprabenthic sled)	3	Annual
Small demersal fishes	To be determined	Video and/or beam trawl	3	Annual
Sediment (granulometry)	All	Grab sampler (0.5 m <sup>3</sup> )	1	Annual
Sediment (contamination) - in <i>P. praeterrissa</i> - in surface sediment	T2-30m, T4-30m, 33, 38, 42, 66, 78	Grab sampler (0.5 m <sup>3</sup> )	3	Annual
Historical sediment	33	Box corer	1	Every five years
Water (contamination) - in <i>M. arctatum</i> - in the water	T2-7.5m, T4-7.5m, T5-7.5m, T7-7.5m, T9-7.5m	Shippek grab sampler Niskin bottle	3	Annual
Water (temperature, salinity, oxygen)	All	Niskin bottle, CTD	1	Annual
Invasive exotic species	All	Monitoring	3	Annual

\*n = number of replicates

\*\* For the endobenthos, the stations at depth ≤ 15 m, dominated by the mollusc *Mesodesma arctatum*, are to be sampled using underwater photos, covering this species which is readily-visible at the surface of the sediment.

## **Sources of Uncertainty**

The main source of uncertainty is the lack of knowledge regarding certain selected components for assessing how the conservation objectives have been met. In particular, the communities for suprabenthos and small demersal fishes will have to be characterized and located for monitoring.

The toxic algae monitoring program, which is currently suspended, leaves an important component of the MPA unmonitored. However, the sum of the stations of the monitoring program will nevertheless be sampled through collaboration with the commercial fishery samplers. While taxonomic analysis will not be conducted, the samples will be available if monitoring is resumed.

Table 8. Sampling surveys for each selected component for monitoring the Manicouagan MPA.

<b>Components for monitoring MPA performance</b>	
<i>Zoobenthos</i>	
Epibenthic communities	Survey of benthic communities and their habitats
Endobenthic communities	Survey of benthic communities and their habitats
Resident Suprabenthos	Survey of benthic communities and their habitats
Waved whelk	DFO research survey (12)* Fishery data
<i>Fish</i>	
Small demersals	To be developed
<i>Marine mammals</i>	
Harbour seal	Community survey
<i>Sea floor</i>	
Relief (bathymetry)	Multibeam survey CHS (DFO) (unscheduled)
Sediment composition	Survey of benthic communities and their habitats
Sediment quality (contamination)	Survey of benthic communities and their habitats
<i>Water</i>	
Water quality (contamination)	Survey of benthic communities and their habitats
<b>Components for monitoring the status of the MPA ecosystem</b>	
<i>Phytoplankton</i>	
<i>Alexandrium tamarens</i>	Toxic algae monitoring (DFO) (8)
Community associated with <i>Alexandrium tamarens</i>	Toxic algae monitoring (DFO) (8) AZMP (DFO) (7) Rimouski monitoring station (DFO) (6)
<i>Zooplankton</i>	
Meso and macrozooplankton	Rimouski monitoring station (DFO) (6) Macrozooplankton biomass monitoring (DFO) (5)
<i>Phytobenthos</i>	
Salt marshes and eelgrass beds	Monitoring satellite imagery (distribution and area)
<i>Zoobenthos</i>	
Snow crab	Research survey (DFO) (13) Fishery data Survey of benthic communities and their habitats
Invasive species	Survey of benthic communities and their habitats Navigation buoys (ISMER) (11)
<i>Fish</i>	
Demersal (such as cod and turbot)	Multispecies survey (DFO) (10) Fishery data
Pelagic (such as sand lance and capelin)	Multispecies survey (DFO) (by-catches) (10) Capelin observer network (14)
<i>Marine mammals</i>	
Cetaceans	Marine mammal observer network (15)
<i>Water</i>	
Physical and chemical characteristics of the water	Survey of benthic communities and their habitats Existing surveys (1 to 8 and 10)
Water regime	To be developed
Exogenous contamination	Site near the MPA to be added to the new survey

\* Numbers in parentheses represent the survey numbers described in the section: Existing monitoring.

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## CONCLUSION

The review found that the biotic and abiotic components currently selected for monitoring the Manicouagan MPA are adequate. Monitoring these components, using the proposed indicators, will help determine whether the conservation objectives have been met. The introduction of a new survey of benthic communities and their habitats is the body of the monitoring plan. However, further studies are needed to refine the proposed protocols and to develop new ones for some of the components for which knowledge is limited. Considerable effort has been made for studying the benthic communities, but other important functions or components of the ecosystem still need to be examined. For example:

- The ecological and trophic roles of species that make up the benthic communities should be better understood in order to determine the monitoring of certain key species;
- Suprabenthic assemblages of crustaceans and small demersal fishes should be characterized and located;
- The effect of hydroelectric dams on the various biotic and abiotic components of the MPA should be defined;
- The estuarine transition zone of rivers, in terms of biological retention, is an important area to be studied;
- A model for understanding the hydrodynamics that characterize the MPA ecosystem should be developed.

It is therefore recommended to develop a research program to deal with these weaknesses and improve the proposed monitoring plan. In addition, monitoring in the MPA will be a progressive process and its implementation will lead to improvements and new proposals. Finally, this monitoring plan should be reassessed on a five-year basis.

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ISSN 1919-5109 (Print)

ISSN 1919-5117 (Online)

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*La version française est disponible à l'adresse ci-dessus.*



## CORRECT CITATION FOR THIS PUBLICATION:

DFO. 2011. Review of the Manicouagan Marine Protected Area (MPA) Ecological Monitoring Plan.  
DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/075.