ST. LAWRENCE
Action Plan 2011-2026

Overview of the State of the St. Lawrence River 2014

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FOREWORD

For the third time, the Working Group on the State of the St. Lawrence has met the challenge of establishing an overview of the state of the St. Lawrence as part of the Canada–Québec Agreement under the St. Lawrence Plan, also known as the St. Lawrence Action Plan 2011–2026. To accomplish this task, the group used the findings of many scientists from the organizations involved in implementing the State of the St. Lawrence Monitoring Program. This overview cannot claim to take all studies on the state of the St. Lawrence into consideration; rather it provides an account of the findings that are a direct result of the program.

In 2014, the working group adopted a more visual approach for presenting its findings. Symbols now illustrate each indicator and conceptual diagrams provide improved integration of information. In 2014, the river's bill of health presents a fragile balance. Most indicators remain moderate. Following the reintroduction of the Striped Bass, we are seeing significant progress in the natural reproduction, growth, and distribution of this species in the river. Overall, however, the St. Lawrence remains relatively vulnerable. The Beluga Whale and Northern Gannet populations have experienced significant degradation. Several changes have been observed in the ecosystem of the upper estuary, the lower estuary and the Gulf.

We hope that the results of our work will help in making decisions that concern the St. Lawrence. With the knowledge it provides, the Program is one of the basic components of the movement toward an integrated management of the river. The cooperation and commitment of our government partners and non-governmental organizations remain key factors in ensuring the continuity of our work in monitoring the state of the St. Lawrence and in preparing reports on this subject.

We are very pleased to present the 2014 Overview and wish to thank sincerely all the members of our group, as well as those who contributed, in various capacities, to its production.

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INTRODUCTION

The St. Lawrence River originates in the Great Lakes, in the heart of one of the largest industrial centres in North America. It has experienced numerous impacts throughout the 20th century, including alteration of its flow regime, degradation of water quality, riverbank denaturalization and erosion, decline of certain plant and animal communities. Despite the efforts made over the past 30 years to reduce these impacts, this major watercourse remains vulnerable to intensive farming, encroachment on the floodplain, dredging of the shipping channel, and flow regulation. To these stresses can be added new environmental challenges such as climate change, invasive species and emerging toxic substances whose effects are poorly understood. What is the state of the river? To answer this question, a long-term monitoring program on the state of the St. Lawrence was launched in 2003 as part of the Canada–Québec Agreement on the St. Lawrence. Different partners monitor a series of environmental indicators on a regular basis. The area covered extends from the Québec–Ontario border to the Gulf of St. Lawrence. This document follows the first assessment published in 2003, and presents the latest overview of the state of the St. Lawrence, based on the most recent results. The first part of the document describes the program, while the second deals with the state of the St. Lawrence and how it has changed overall, presenting the findings by river sections and from two different angles: the functioning of the ecosystem; and contamination by toxic substances. In the third part, future prospects and the monitoring of this exceptional ecosystem are set forth.

Figure 1. The St. Lawrence Hydrographic System

The St. Lawrence hydrographic system, including the Great Lakes, is one of the largest in the world. Its surface area of 1.6 million km^2 is the third largest in North America, after the Mississippi and Mackenzie rivers. It drains more than 25% of the Earth's freshwater reserves and influences the environmental processes of the North American continent. Over 30 million Americans and 15 million Canadians live in this immense basin. (Source: 2008 Overview)

Background

The State of the St. Lawrence Monitoring Program, established as part of the Canada–Québec Agreement on the St. Lawrence, brings together five government partners—Environment Canada (EC); Québec's ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques (MDDELCC); Québec's ministère des Forêts, de la Faune et des Parcs (MFPP); Fisheries and Oceans Canada (DFO); and Parks Canada—as well as Stratégies Saint-Laurent (SSL), a non-governmental organization working with riverside communities. These partners are pooling their expertise to report regularly on the state of the St. Lawrence and how it is changing. Initial monitoring results for the St. Lawrence were released in February 2003 at the Rendez-vous St. Lawrence event, when an overview of the state of the St. Lawrence was published for the first time. Then an update was made in 2008 on the 20th anniversary of the St. Lawrence Plan. This assessment, focused mainly on water, sediments and biological resources, concluded that the river's bill of health could be described as moderate to good for several indicators, however, the St. Lawrence remains relatively vulnerable. The outlook: though it remains vulnerable, the ecosystem appears to be in better shape than at any other time during the second half of the 20th century. This assessment, focused mainly on water, sediments and biological resources, is encouraging news. However, despite these signs of improvement, the integrity of the ecosystem could be weakened by the cumulative impact of many pressures, including invasion by alien species and the presence of new contaminants.

Community involvement

In addition to lending their expertise and knowledge on the state of the St. Lawrence, non-governmental organizations contribute to the collection of data and the dissemination of information generated by the program. In 2013, six organizations, including five ZIP (*zone d'intervention prioritaire* or priority intervention zone) committees, participated in monitoring the St. Lawrence for invasive plant species. To contribute effectively, the communities receive specific training and scientific and technical support tailored to local situations.

Objectives

The program arose out of the need expressed by numerous stakeholders for information that was as up to date as possible on the overall state of the St. Lawrence. Hence, the primary objective is to provide, on a sound scientific basis, integrated information to support the protection and sustainability of the ecosystem for current and future generations.

First, the data help in assessing the condition of the ecosystem. Second, they guide the decision-making process to ensure the protection of the ecosystem. The challenge consists of integrating the data obtained from the environmental indicators to reach a better understanding of the state of the St. Lawrence and how it is changing. To meet this challenge, we adopted a progressive approach to transform and gradually add to the program in light of the knowledge acquired and the new partnerships formed. The 2014 overview thus adopts a new signature compared with the last two reports, i.e., a more visual and conceptual approach in order to link more easily the various indicators for the St. Lawrence ecosystem.

Frame of reference

The St. Lawrence is a complex ecosystem made up fluvial lakes and fluvial sections, a long estuary and a gulf with marine features. Its physical properties (e.g., current, depth, water masses, salinity, tides) change from upstream to downstream, giving the river a dynamic quality. It shelters a wide variety of freshwater, estuarine and marine habitats, and a rich diversity of flora and fauna. Since the natural physical characteristics of the St. Lawrence have a tremendous influence on biodiversity and habitats, it is important that they be considered in assessing the state of the St. Lawrence, and also that natural impacts be distinguished from those induced by anthropogenic disturbances. In this overview, the indicators are presented by grouping all freshwater activities (fluvial section and estuary), on the one hand, and saltwater activities (lower estuary, upper estuary and Gulf of St. Lawrence), on the other. The complex nature of the river may be approached through a simple frame of reference, comprising five components that form the basis of the ecosystem: water, sediments, biological resources, shorelines and uses. The indicators used in the program fall under one of the above components.

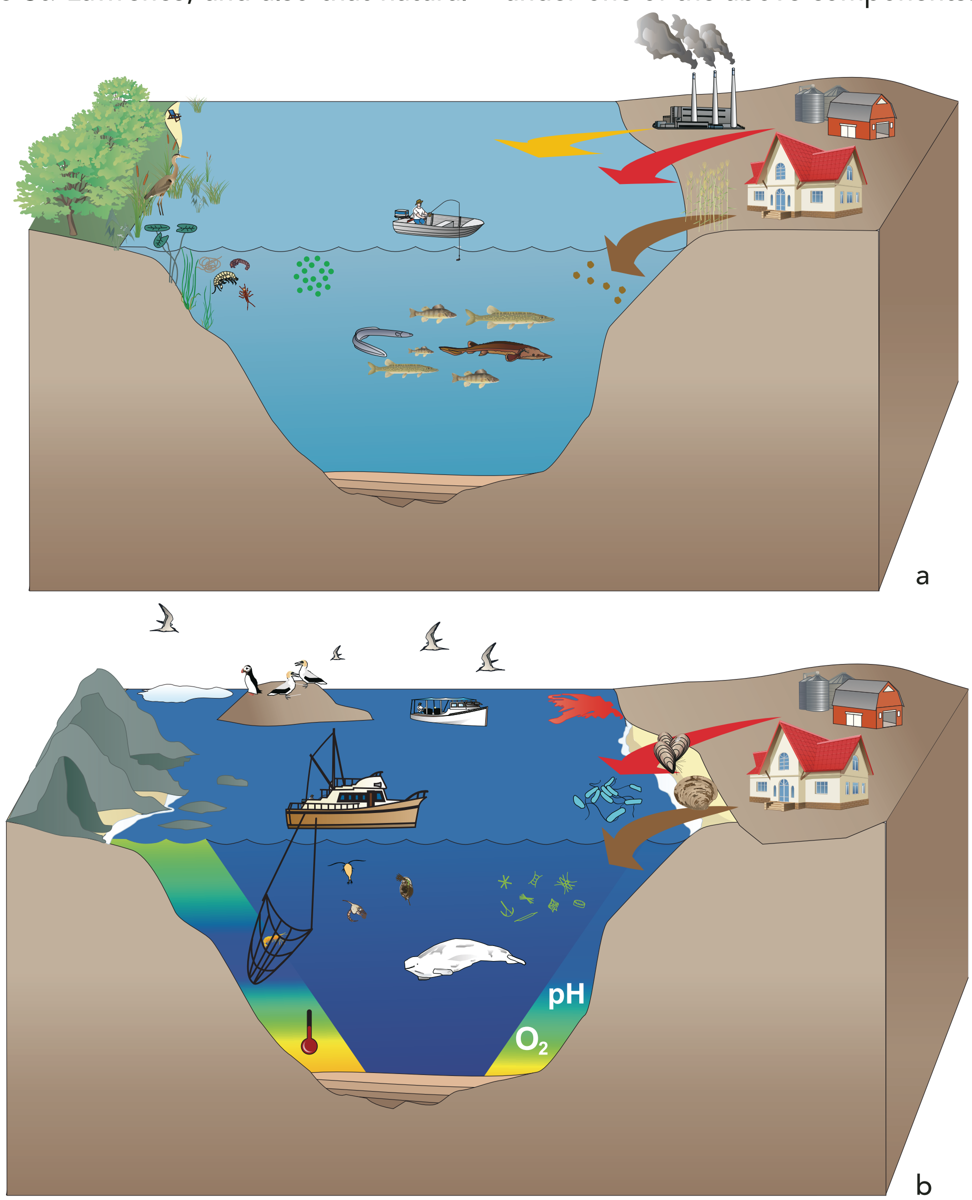


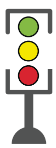
Figure 2. Conceptual diagrams – a) Fluvial St. Lawrence ecosystem; b) Estuary and Gulf of St. Lawrence ecosystem

ENVIRONMENTAL INDICATORS

- **Parameter measured** or **statistic calculated**
- **Key element** of the ecosystem
- **Scope greater** than the actual value of the parameter
- **Effective communication** of the results regarding the **state of the ecosystem** being studied or the **state of a geographic zone**

Three main functions:

- **Scientific**: Assess the state of the environment and, when it is observed periodically, highlight a trend;
- **Policy**: Support decision making;
- **Societal**: Facilitate communication between various stakeholders and foster the appropriate action.

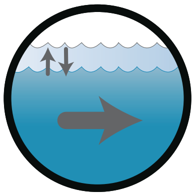
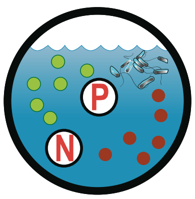
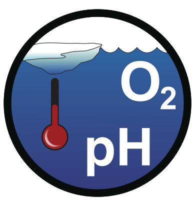
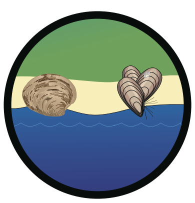
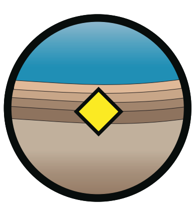


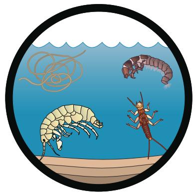
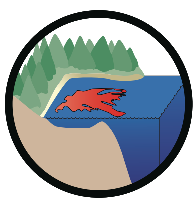
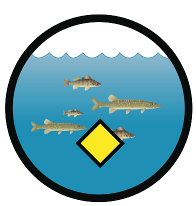
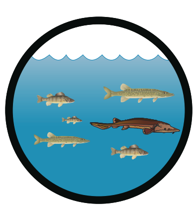
For the purposes of this overview, the colour green generally refers to a good state that is not of concern; the colour yellow refers to a moderate state that is to be monitored; and the colour red refers to a poor state that is of concern.

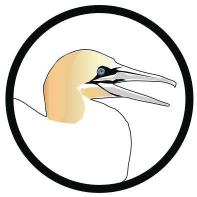
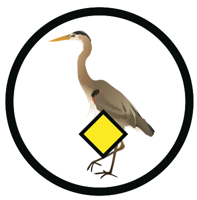
Monitoring activities

The State of the St. Lawrence Monitoring Program is characterized by progressive, continuous improvement. Since the program was launched, the spatial and temporal coverage of existing activities has been improved, new activities and indicators have been added, and new partners have become involved. The environmental variables of the St. Lawrence River were chosen for their representativeness and relevance for assessing the state of the St. Lawrence and for the adequate spatial and temporal coverage they provide (see Table 1).

Table 1. State of the St. Lawrence monitoring indicators

Element	Symbol	Indicators	Partners	Sections monitored
Water		Flow and water level	Several partners*	Fluvial section
		Contamination of water by toxic substances	EC	Fluvial section and estuary
		Physical, chemical and bacteriological parameters	MDDELCC	Fluvial section and estuary
		Oceanographic processes	DFO	Lower estuary and Gulf of St. Lawrence
		Shellfish water quality**	EC	Upper estuary, lower estuary and Gulf of St. Lawrence
Sediments		Toxic contamination of sediments	EC	Fluvial section and estuary

Element	Symbol	Indicators	Partners	Sections monitored
Biological resources		Benthic communities	EC	Fluvial section
		Phytoplankton communities	DFO	Lower estuary and Gulf of St. Lawrence
		Zooplankton communities	DFO	Lower estuary and Gulf of St. Lawrence
		Toxic algae**	DFO	Lower estuary and Gulf of St. Lawrence
		Striped Bass	MFFP	Fluvial estuary, upper estuary, lower estuary and Gulf of St. Lawrence
		Contamination of fish by toxic substances**	MDDELCC	Fluvial section
		Fish communities	MFFP	Fluvial section

Element	Symbol	Indicators	Partners	Sections monitored
Biological resources		Beluga Whale	DFO	Upper estuary and lower estuary
		Northern Gannet	EC	Lower estuary and Gulf of St. Lawrence
		Contamination of the Great Blue Heron by toxic substances	EC	Fluvial section, upper estuary, lower estuary and Gulf of St. Lawrence
		Seabird populations	EC	Lower estuary and Gulf of St. Lawrence
		Wetlands	EC	Fluvial section
		Invasive species	MDDELCC, MFFP and DFO	Fluvial section and estuary

EC: Environment Canada, **MDDELCC:** ministère du Développement durable, de l'Environnment et de la Lutte contre les changements climatiques (Québec); **MFFP:** ministère des Forêts, de la Faune et des Parcs; **DFO:** Fisheries and Oceans Canada

* **MDDELCC,** Hydro-Québec, DFO, EC, U.S. Geological Survey, New York Power Authority/Ontario Power, St. Lawrence Seaway

** Related to usage criteria.

◇ Contamination by toxic substances.

Improvements to the program since 2008

- Addition of river water-quality monitoring stations at Lavaltrie and Bécancour, and at the mouth of the Richelieu, Yamaska, Saint-François, Nicolet and Saint-Maurice rivers.
- Extension of sediment characterization work to the fluvial section from Montréal to Sorel and in the Québec City region.
- Addition of the monitoring of invasive animal species in freshwater and saltwater (see boxes below).
- Monitoring of benthic communities extended from Lake Saint-François to Lake Saint-Pierre.
- Creation of symbols to identify each indicator, standardization in the dissemination of information, and visualization of results in the form of conceptual diagrams.

A monitoring program for invasive aquatic species was implemented by Fisheries and Oceans Canada to give an overview of the situation on the Magdalen Islands, the Gaspé Peninsula and the North Shore. Since 2003, various invasive aquatic species have been detected and their progression is being monitored.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Codium Algae


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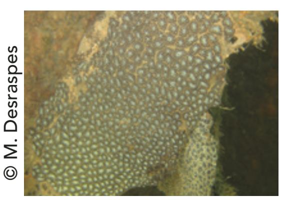
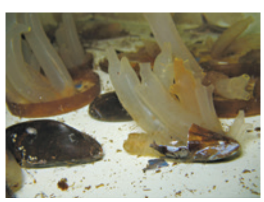
Green Crab


© MPO T. Gosselin
Japanese Skeleton Shrimp


© M. Desraspes
Golden Star Tunicate


© MPO I. Bérubé
Membranipora Bryozoan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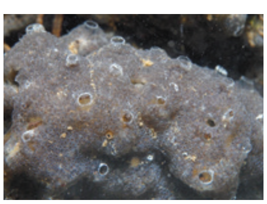
Sea Squirt


© R. Groeneveld
Diplosoma Tunicate

An early detection network for invasive alien aquatic species in the St. Lawrence was implemented in 2007 by the Direction régionale du Bas-Saint-Laurent (MFFP). The network, made up of commercial fishers, provides a current vision of aquatic species present in the river and monitors their trends from Montréal to Rimouski.


© MFFP
Chinese Mitten Crab


© UQTR, Andrea Bertolo
Round Goby


© MFFP
Blueback Herring


© MFFP, Yves Paradis
Tench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Butterfish

1. STATE OF THE ST. LAWRENCE AND HOW IT IS CHANGING

1.1 Overall finding on the state of the St. Lawrence: A fragile balance

The overview is now in its third edition. The distribution of all indicators, based on their current state, is presented in Figure 3. The upper portion presents saltwater indicators (downstream from Québec City) and the lower portion presents freshwater indicators (from Cornwall to Québec City). Note that the monitoring of the contamination of the Great Blue Heron population is included in both freshwater and saltwater. Overall, most indicators remain moderate. Based on their respective indicators, the upper estuary, the lower estuary and the Gulf of St. Lawrence sections seem to show signs of greater degradation than the fluvial section and fluvial estuary. However, the scale of observation of the indicators is very important and the findings can differ from one sector of the St. Lawrence to another. This explains why a number of indicators show a moderate state. Some sectors monitored show a good state and others a poor state, which gives an overall moderate state.

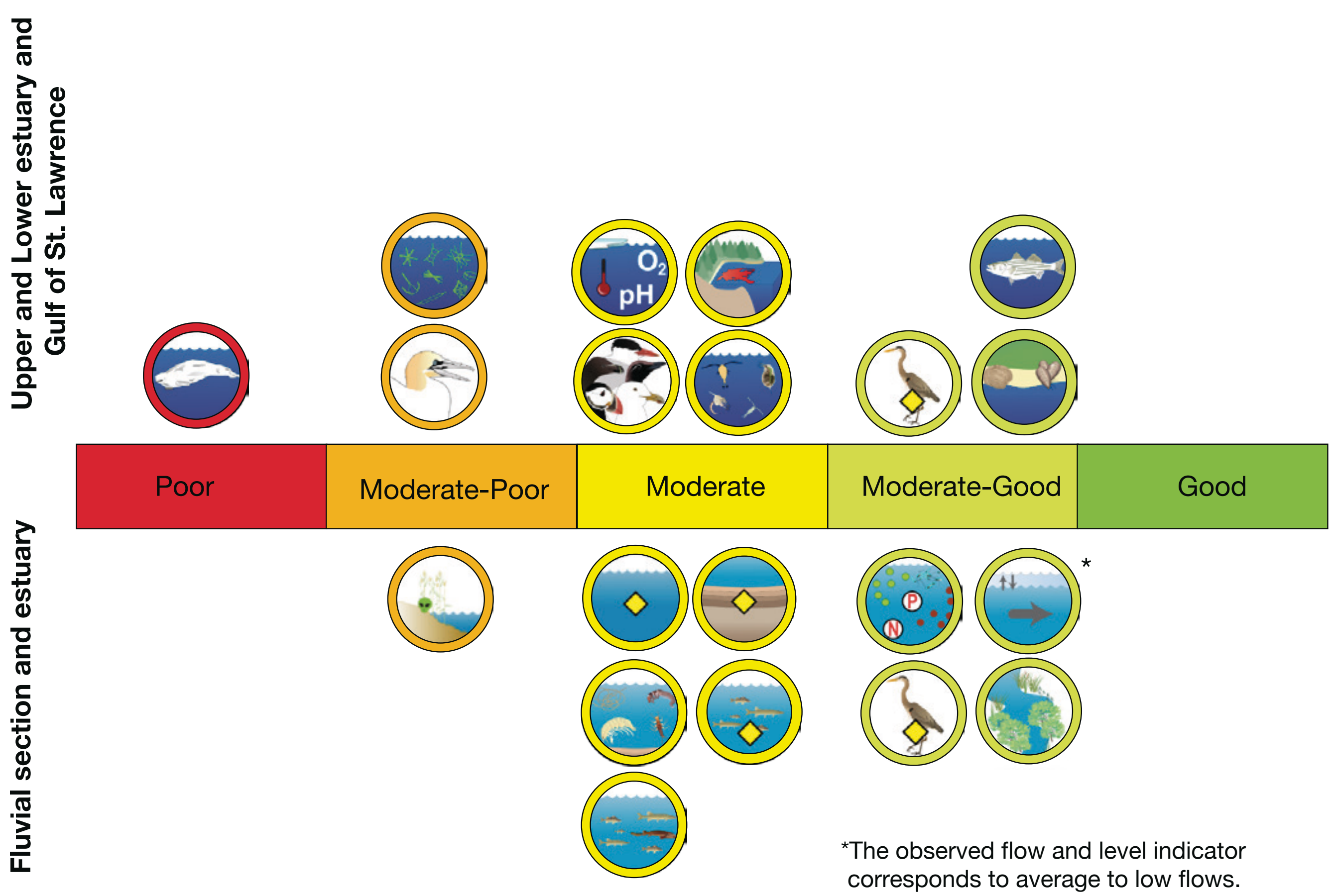


Figure 3. Distribution of indicators assessed in 2014 based on the findings of their current state

Throughout the St. Lawrence, certain indicators seem to actually be more sensitive to change than others. The reintroduction of the Striped Bass saw remarkable progress, from a poor state in 2003 to a moderate-good state in 2014. However, several indicators have worsened recently, primarily in the upper estuary, the lower estuary and the Gulf of St. Lawrence. The Beluga Whale population declined dangerously from a moderate state in 2008 to a poor state in 2014, and the Northern Gannet population also declined to a worrisome degree from a good state in 2003 and 2008 to a moderate-poor state in 2014.

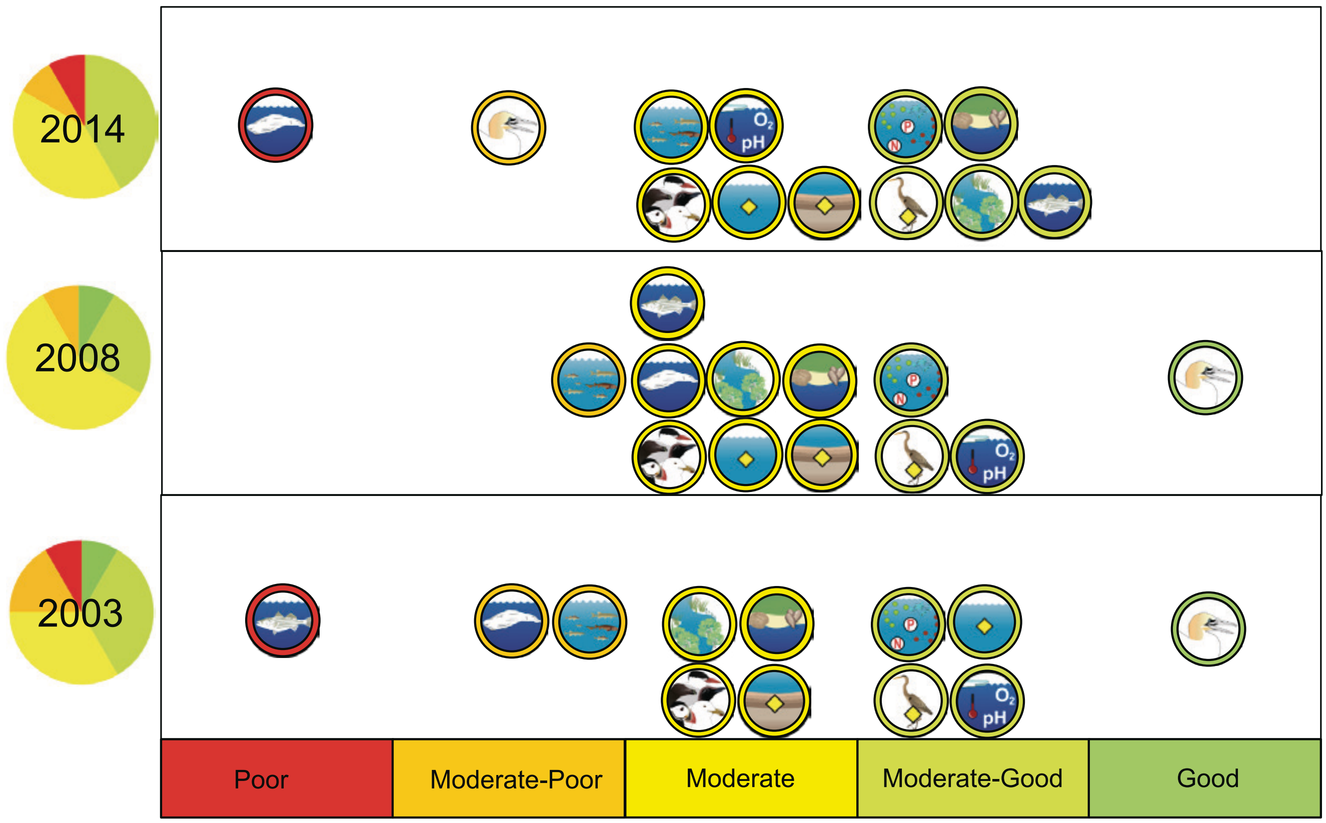


Figure 4. State of indicators common to the three overviews and pie charts showing their distribution

1.2 The fluvial corridor

The fluvial corridor extends from Cornwall to Québec City and is made up of various fluvial lakes, namely Lake Saint François, Lake Saint Louis and Lake Saint Pierre, and fluvial portions such as the section between Montréal and Sorel that includes numerous islands. Figure 5 presents, on a smaller scale, the findings observed in the various sections of the fluvial portion of the St. Lawrence. The pie charts represent, for each indicator, the proportion of sites at which the state was assessed as good, moderate or poor (green, yellow or red) or in five classes, with the addition of the moderate-poor category in orange, and moderate-good in light green. Each indicator is described in greater detail in the following pages. In the upper left corner, there is usually a symbol that illustrates the indicator. The coloured ring around the symbol indicates the finding of the overall state of that indicator, based on the five classes presented above (red = poor; orange = moderate-poor; yellow = moderate; light green = moderate good; dark green = good). The background on the map is a satellite image, on which the sampled sites are indicated. Several indicators present various levels of information, a finding for the sampled site, a finding for the section of the river, which corresponds to a sectoral finding, and the overall finding for the indicator for all sampled sites.

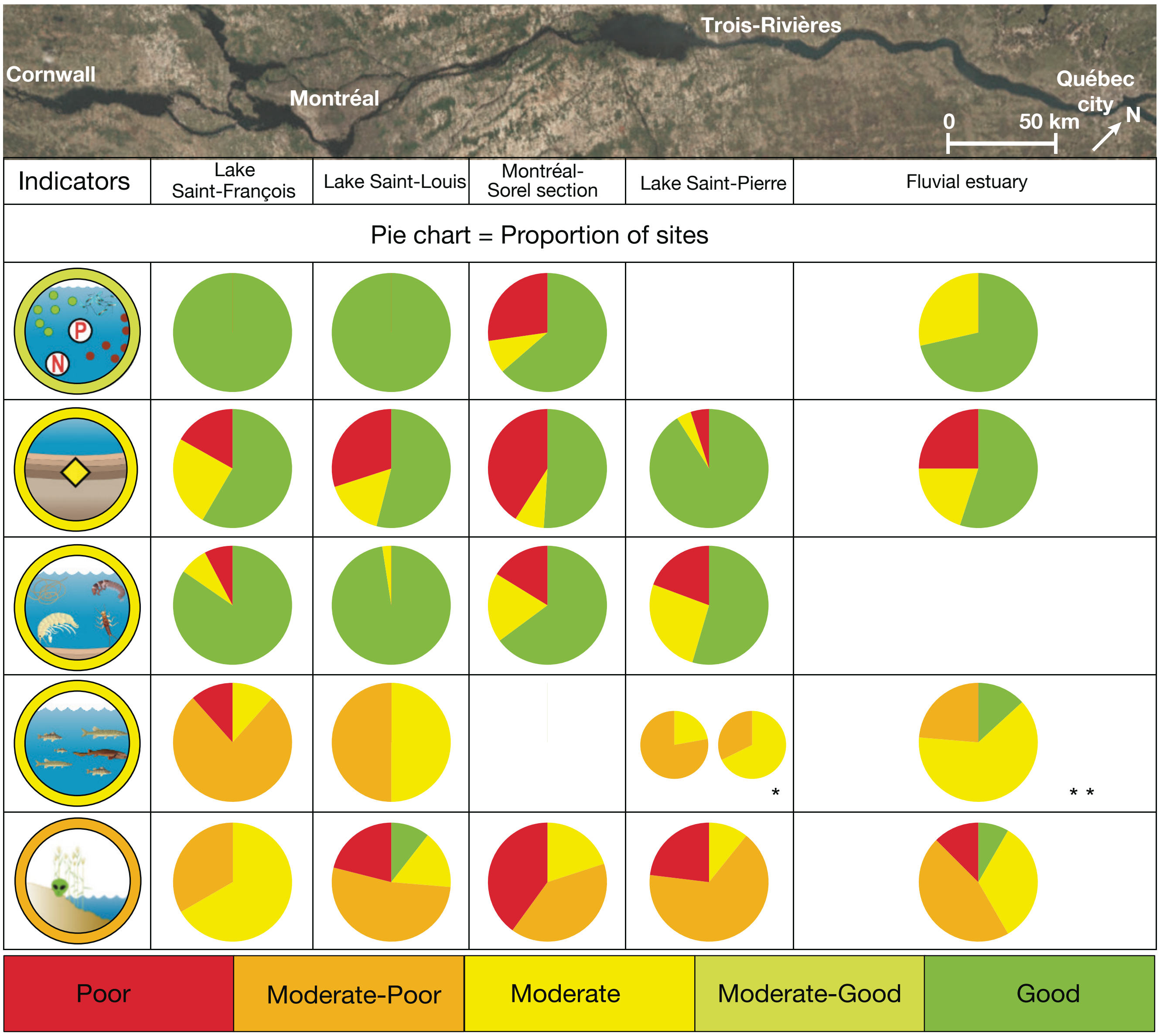


Figure 5. Sectoral findings for each indicator, presented as a proportion of sites for the fluvial corridor from Cornwall to Québec City

* The finding on the left corresponds to the Lake Saint-Pierre archipelago, and the one on the right to the north and south shores of Lake Saint Pierre.

** This finding concerns only the section located between the cities of Bécancour and Batiscan.

1.2.1 The physical, chemical and bacteriological parameters of the water and their effects on the ecosystem

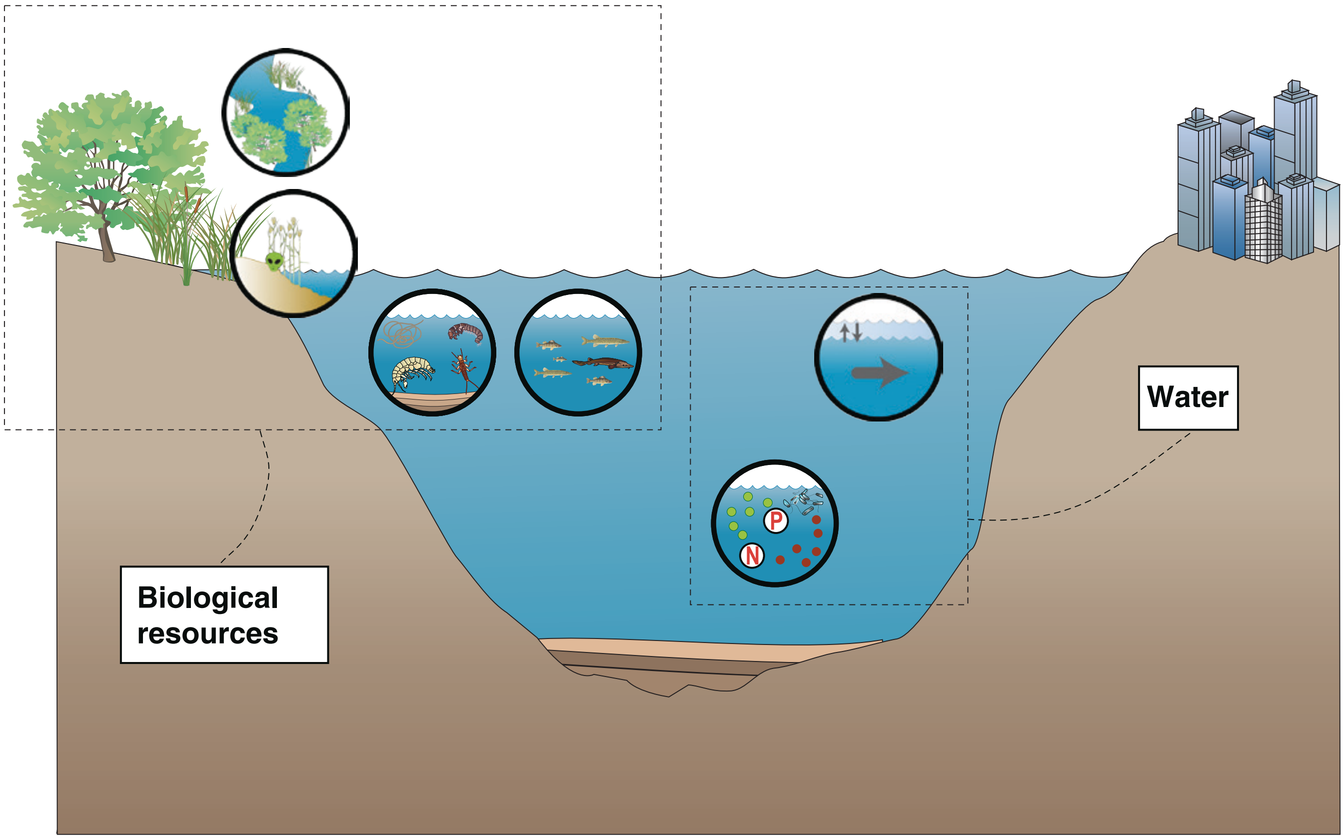


Figure 6. Conceptual diagram representing the freshwater environmental indicators related to the ecosystem function

A healthy aquatic ecosystem includes a quantity and quality of water that provides a space for biological communities to live, feed and reproduce, allowing for the creation of a biological diversity of species in benthic and fish communities and among wetland plants. A healthy aquatic ecosystem maintains its structure, processes and ecological functions and allows for resilience to change while conserving a natural variability. Within an aquatic ecosystem, there are numerous complex links within the food webs, with the various elements acting on each other. It is therefore difficult, in a monitoring study, to identify the causes of the changes observed in the ecosystem. In this regard, research work can provide more explanatory elements regarding cause and effect.

Flows And Water Levels

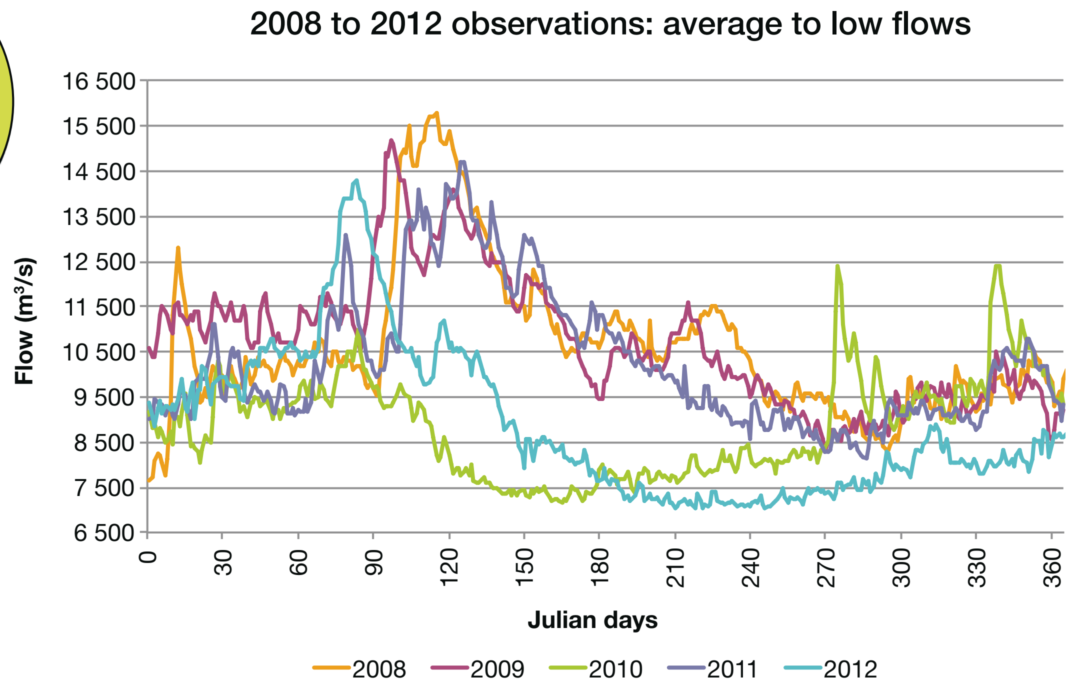


Figure 7. Annual flow pattern of the St. Lawrence River calculated at Sorel from 2008 to 2012

The St. Lawrence River is fed by two main controlled watersheds: the Great Lakes and the Ottawa River. The flow at the outlet of Lake Ontario near Cornwall generally varies between 6,000 and 9,000 m3/s over the course of a year (average annual flow: 7,060 m^3/s), whereas the outflow of the Ottawa River at Carillon varies between 1,000 and 8,000 m3/s (average annual flow: 1,910 m3/s). Several tributaries also contribute to the flow of the river on its way to the estuary, the largest being the Richelieu and Saint-Maurice rivers.

The flow of the St. Lawrence varies a lot from year to year and is dependent on the inter-annual variations in water inflows to Lake Ontario, which are themselves dependent on climate conditions. Over the last few decades, the St. Lawrence water flow pattern has been modified through several human interventions, the consequences of which, whether local or extended, have had a direct impact on water levels. Therefore, using the level as an indicator of water quantity in the St. Lawrence remains useful, but is limited in scope. The river's flow is therefore a better indicator of the state of its hydrology.

For the 2008-2012 period, the inter-annual and seasonal variation has been significant (figure 7). The years 2008, 2009 and 2011 resemble one another with annual average flows that are near the historical average, whereas the flows observed in 2010 and 2012 are lower. Among other things, the freshet observed in 2010 was very low, with a flood peak that was nearly non-existent and subsequent flows that were very low until mid-summer. In 2012, the high water came early and the flows dropped quickly afterward resulting in values that were below the bar of 7,500 m^3/s for an extended period starting in mid-summer.

Water Quality

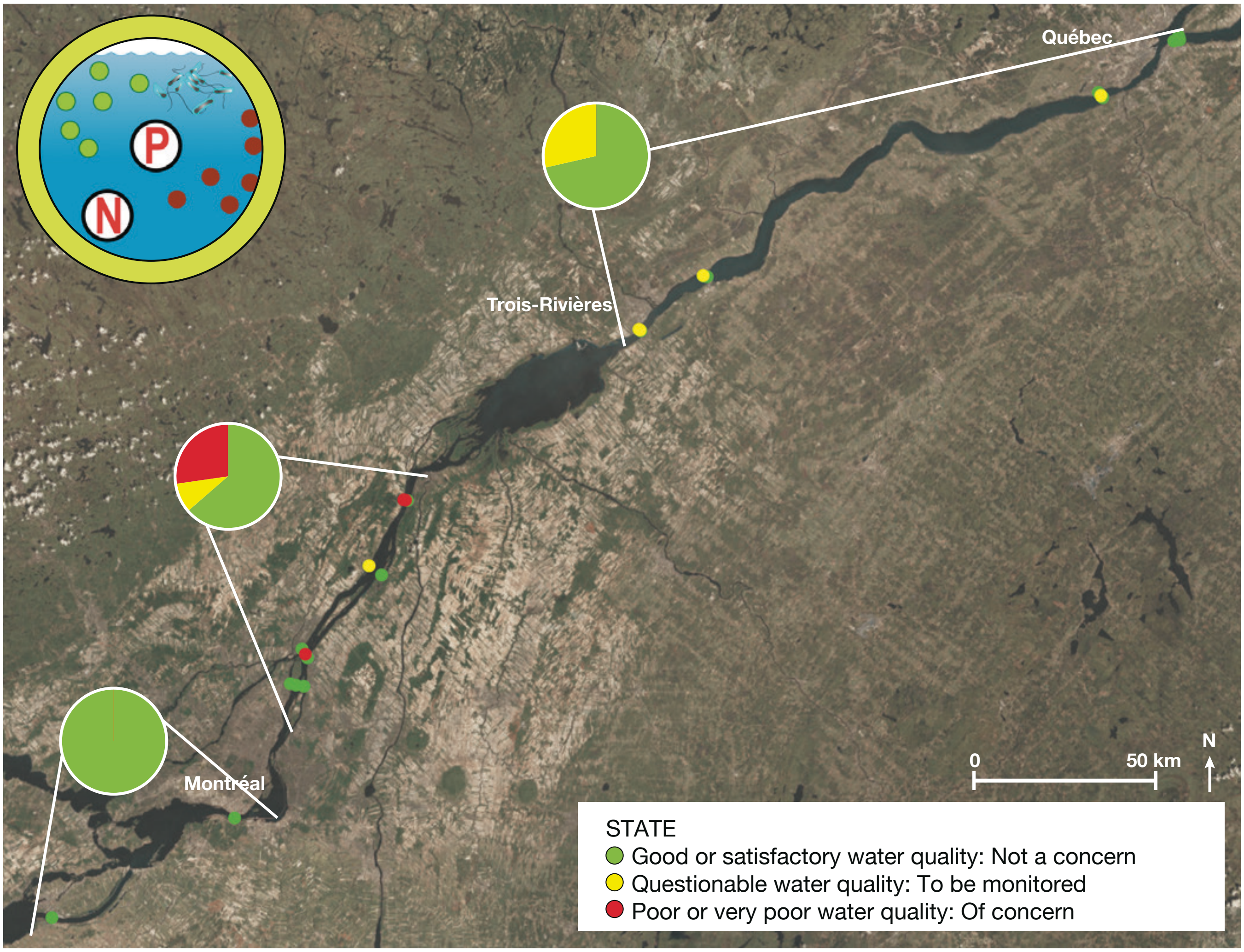


Figure 8. State of the bacteriological and physical and chemical water quality (IQBP) indicator from 2008 to 2010

The finding regarding water quality in terms of physical, chemical and bacteriological parameters is moderate-good, a slight decrease since the last report. We see a decrease in bacteriological quality, the result of an increase in flow and untreated wastewater overflows following more significant precipitation over the last few years. In effect, average annual precipitation recorded from May to October in southern Québec increased from 2000 to 2010. The annual percentage for stations at good or satisfactory remained above 59% from 1995 to 2010, but rose to 75% between 2003 and 2005 and 67% from 2008 to 2010.

Water quality at Québec City depends on pollution sources located upstream, but is also influenced by precipitation and flow. This station makes it possible to briefly summarize what is happening in the fluvial St. Lawrence. From 1995 to 2010, we do not see any significant trends in findings regarding concentrations of suspended solids and phosphorous. However, we do see a slight rise in concentrations of fecal coliforms, with the estimated values rising from 107 UFC/100 mL at the start of the period to 171 UFC/100mL at the end of 2010.

Macroinvertebrate Community

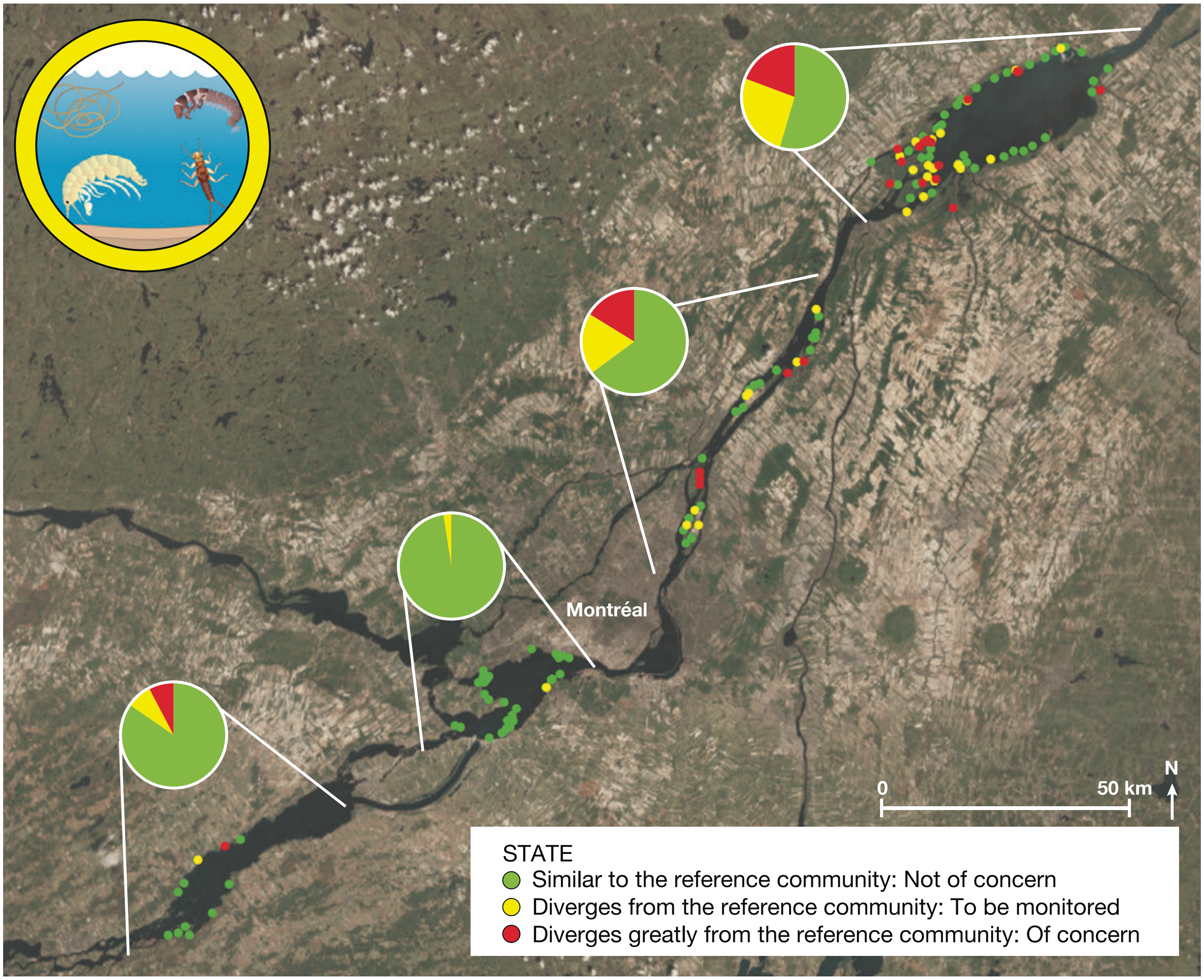


Figure 9: State of the benthic macroinvertebrates indicator

The general finding for the benthic macroinvertebrate communities indicator in the fluvial section is moderate, the same finding as for data from Lake Saint-Pierre in 2004. Three parameters are considered for findings for this community: the number of taxa, the percentage of mayflies, stone-flies and caddisflies (groups of insects sensitive to pollution), and the percentage of oligochaetes (group of worms tolerant to pollution). To determine the state of a site, the criteria were established based on data from reference sites considered to be less disturbed sites. The colour green thus corresponds to a state similar to or of better quality than the reference sites; the colour yellow corresponds to a state that diverges slightly from the reference (between 25th and 10th percentile or between 75th and 90th percentile); and the colour red represents the most disturbed sites, which diverge the most from the reference (< 10th percentile or > 90th percentile). Although the parameters retained assess different properties of the benthic communities, they react in a similar manner. Once combined, we see that the most degraded benthic communities are in the fluvial section, in the Berthier-Sorel archipelago and, to a lesser degree, on the north shore of Lake Saint-François.

Fish Communities

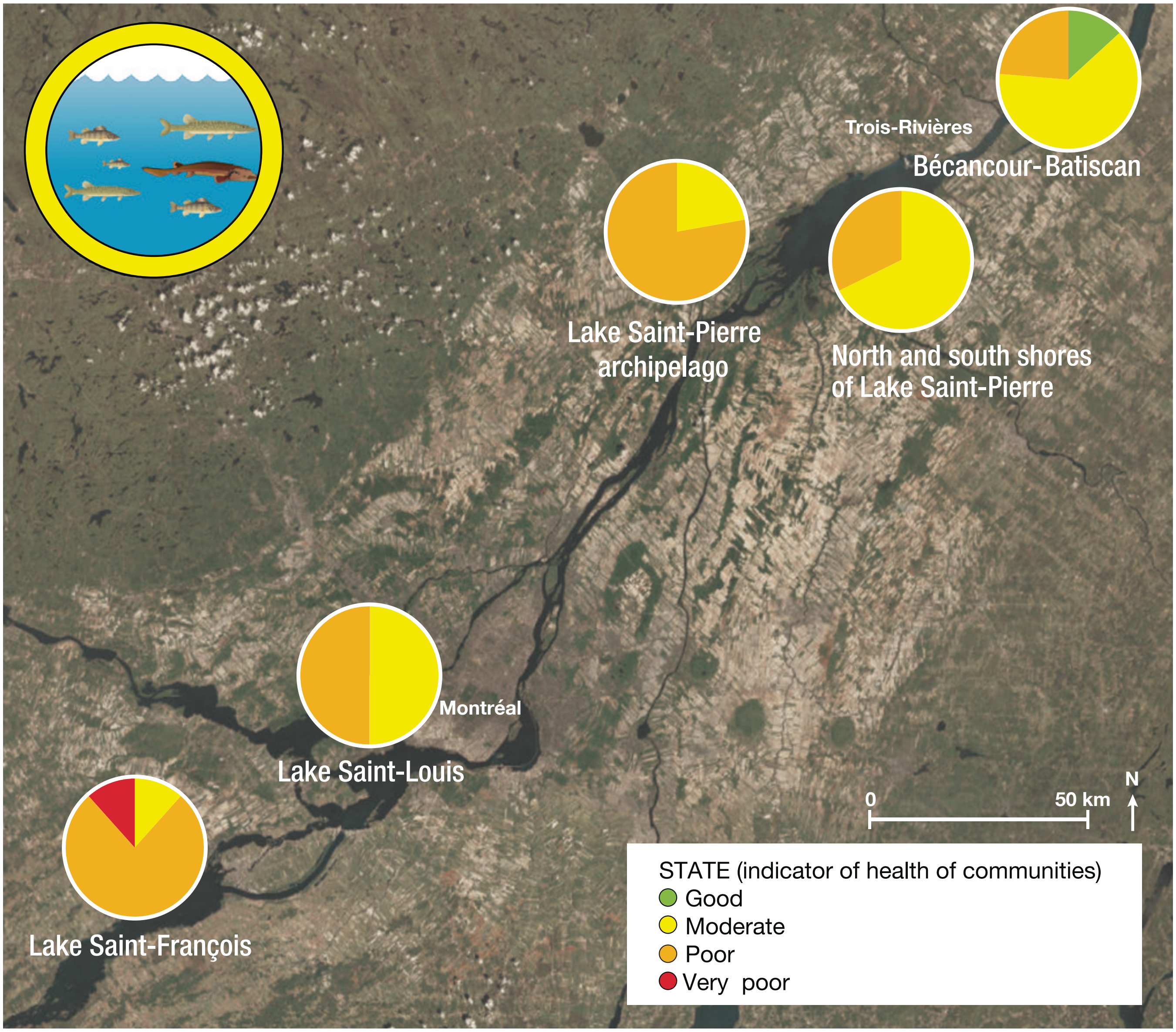


Figure 10. State of health of the fish communities indicator based on the index of biotic integrity (IBI)

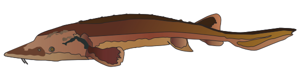
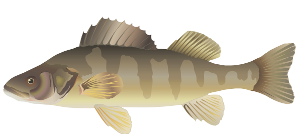
The fluvial St. Lawrence ecosystem, which is unique in North America, gradually turns into an estuary and then an inland sea before flowing into the Atlantic. The 118 species of freshwater fish found there reflect its diversity and full complexity. Of these species, about 15 migratory species use saltwater and freshwater habitats alternatively to complete their life cycles. More than half of these species are in a vulnerable situation due to the anthropogenic problems that they encounter in freshwater.

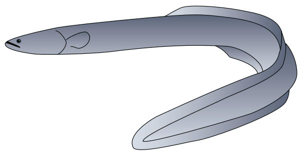
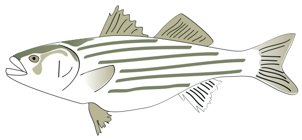
Since 1995, the RSI, a fish-monitoring network operated by the MFFP, collects a large quantity of standardized and reproducible data regarding fish and their habitats in the fluvial section of the St. Lawrence. Through the use of an index of biotic integrity (IBI) and other methods, those data are used to evaluate the health of fish communities. The IBI uses 12 descriptors, including the diversity of species, their abundance relative to certain trophic levels (e.g. insectivore, omnivore, piscivore, etc.), the contribution of species that tolerate or do not tolerate pollution, and the prevalence of external anomalies on fish (La Violette et al. 2003).

The results of the IBI suggest that the health of fish communities in the fluvial St. Lawrence has remained stable overall since 1995, within low-to-moderate values (Figure 10). A detailed analysis of the indicator shows a high level of variability between the various sections of the river, showing some improvements or deteriorations locally in the health of fish communities.

It is important to note that the IBI integrates an amalgam of information and thus provides an overview of the state of fish communities in the St. Lawrence River. To refine that evaluation, a detailed analysis by species remains essential to shed light on certain highly contrasting trends between species and sectors (Table 2). For instance, an increase in the abundance of Lake Sturgeon has been observed in the St. Lawrence River over the last decade. As well, the discovery of new spawning grounds and the return of the species to certain abandoned spawning grounds confirms that the Lake Sturgeon' situation is improving in the St. Lawrence. The reintroduction of the Striped Bass following its disappearance from the estuary in the late 1960s is also well underway and the species is reproducing naturally (see the indicator for the Striped Bass). On the other hand, the American Eel has seen a significant decline in the St. Lawrence in recent years. Between 1983 and 2000, in the upstream portion of the St. Lawrence, the number of young eel running toward the Great Lakes fell by 99.8% at the fishway at the Moses-Sunders Dam in Cornwall. Since that time, the abundance has increased at that location and now varies between 40 000 to 50 000 young fish per year. The loss of fluvial rearing habitat due to the construction of dams, mortality due to hydroelectric plant turbines, and fisheries operations are some examples of factors that have contributed to the decline in the eel population.

Table 2. State of the stocks of some fish species in the St. Lawrence River and a non-comprehensive list of the pressures and disturbances they face

Fish species	Trend	Main pressures	Management measures
Lake Sturgeon 		• Habitat fragmentation • Over-exploitation • Destruction of spawning grounds	• Monitoring of commercial fishing • Implementation of new rules for commercial and sport exploitation • Development of spawning grounds
Walleye 	* 	• Over-fishing • Habitat degradation	• Development of an action plan • Implementation of a range of sizes exploited (37 to 53 cm) applicable to sport and commercial fishing
Yellow Perch (Lake Saint-Pierre) 		• Habitat degradation • Loss of spawning grounds • Over-fishing	• Five-year moratorium on sport and commercial fishing • Close monitoring of the state of stocks • Development of a joint action plan

Fish species	Trend	Main pressures	Management measures
American Eel 		• Habitat fragmentation • Over-fishing	• Implementation of an action plan • Reduction of commercial exploitation rates by 50% by redeeming permits • Installation of fishways
Striped Bass 		• Over-fishing	• Reintroduction program • Stocking of young fish and larvae • Identification and monitoring of spawning grounds and critical habitats

*Findings from 2010, before the management plan took effect.

A decrease in the abundance of Yellow Perch (*Perca flavescens*) and several other species of fish associated with the flood plain and aquatic-grass beds was also noted in Lake Saint-Pierre. Yellow Perch in Lake Saint-Pierre have seen a significant decrease over the past two decades. From 2002 to 2013 alone, the abundance of the population fell by 68%. Although fishing initially contributed to this reduction, Yellow Perch also suffered from the deterioration of its habitats. The modification of communities of aquatic plants and the proliferation of benthic cyanobacteria caused a cascade of effects leading to a reduction in the growth of young Yellow Perch, their potential for survival, and the failure of recruitment (Figure 11) [see the section on Issues and perspectives].

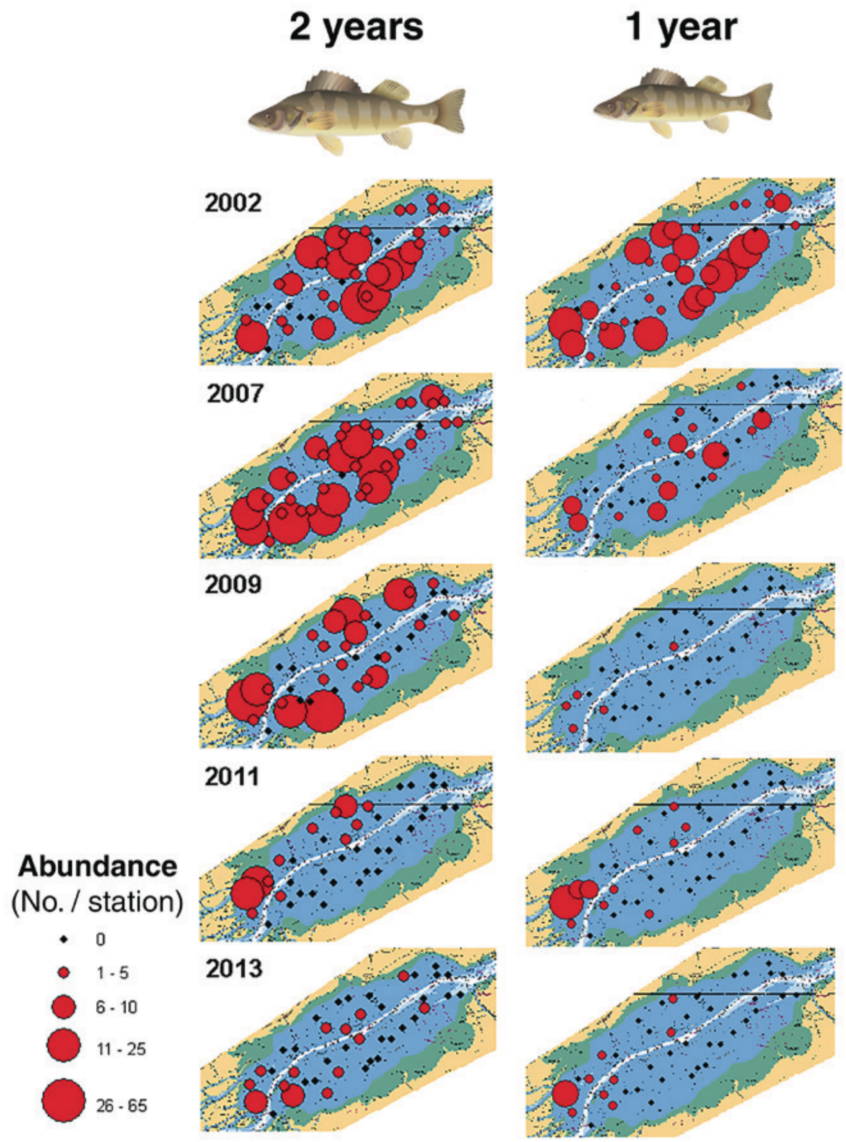


Figure 11. Spatial and temporal evolution of the abundance of Yellow Perch in Lake Saint-Pierre from 2002 to 2013

The abundances measured by means of gill net are presented for various age groups in order to shed light on the failure to recruit the species. It should be noted that a five-year moratorium on the commercial and sport fishing of Yellow Perch was ordered for Lake Saint-Pierre in 2012.

The status of Yellow Perch is very different upstream, for instance in lakes Saint-François and Saint-Louis, near Montréal, where Yellow Perch are abundant and support sustainable sport fishing. In Lake Saint-Louis, Yellow Perch have been re-established, particularly over the past 20 years, and particularly on the south shore, where efforts to reduce industrial emissions seem to have been successful. The findings between the various sections of the river are explained by the fact that there is additional pressure on fish populations in Lake Saint-Pierre. The decline of the Yellow Perch population, which occurred despite several strict management measures aimed at reducing and then eliminating fish mortality, now suggests the need for an examination of other possible solutions in order to return to the support capacity that existed in the past.

The state of Walleye stocks evaluated in 2010 indicates a decline in populations in the St. Lawrence River. In Lake Saint-François and downstream from the Laviolette bridge in Trois-Rivières, populations are declining due to the modification of the habitat and pressure from fishing. However, the Walleye population in Lake Saint-Louis is in good health. The species is considered to be at risk in Lake Saint-Pierre, where an increase in the mortality rate and decrease in the abundance of mature females have been noted. A management plan for the species was implemented in 2011 throughout Québec in order to improve the state of stocks and the quality of fish. That plan sets forth, for the St. Lawrence River, the release of Walleye measuring less than 37 cm and more than 53 cm for sport and commercial fishing in order to protect recruits and spawners.

In short, certain species of fish show encouraging signs of reestablishment, suggesting that key pressures have lessened over time. Fish communities in the St. Lawrence, however, remain very fragile. In some sectors of the St. Lawrence, particularly in Lake Saint-Pierre, there are numerous indicators of deterioration of the ecosystem and the situation has become critical for some species of fish. Major challenges thus remain to ensure that fish in the St. Lawrence have a healthy environment, which will require the restoration of habitats in the flood plains and large areas of aquatic-grass beds, the improvement of water quality, and the improvement of connectivity between habitats.

Reference:

LA VIOLETTE, N., D. FOURNIER, P. DUMONT AND Y. MAILHOT. *Caractérisation des communautés de poissons et développement d'un indice d'intégrité biotique pour le fleuve Saint-Laurent, 1995 1997*. Société de la faune et des parcs du Québec, Direction de la recherche sur la faune, 237 pp. (2003)

Wetlands

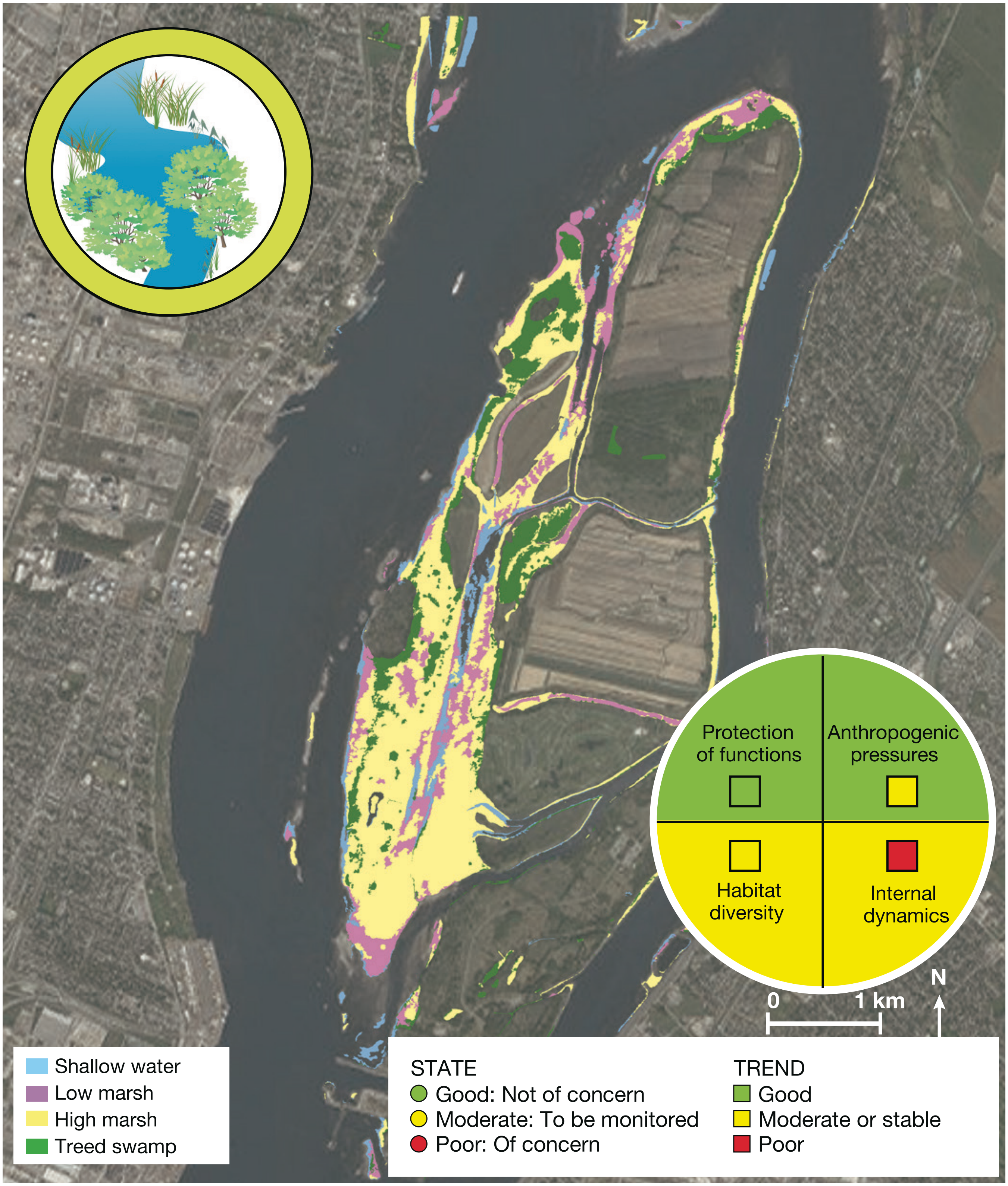


Figure 12. Map of wetlands on the Boucherville Islands in 2010

The indicator for size of freshwater wetland areas was modified to incorporate four aspects: direct anthropogenic pressures on coverage, the internal dynamic of the wetlands, the diversity of wet habitats, and the protection of wetlands against external stressors. The sectors of the Boucherville islands and Lake Saint-Pierre were examined. The general state of the wetlands in those sectors is qualified as moderate-good and the general trend is stable.

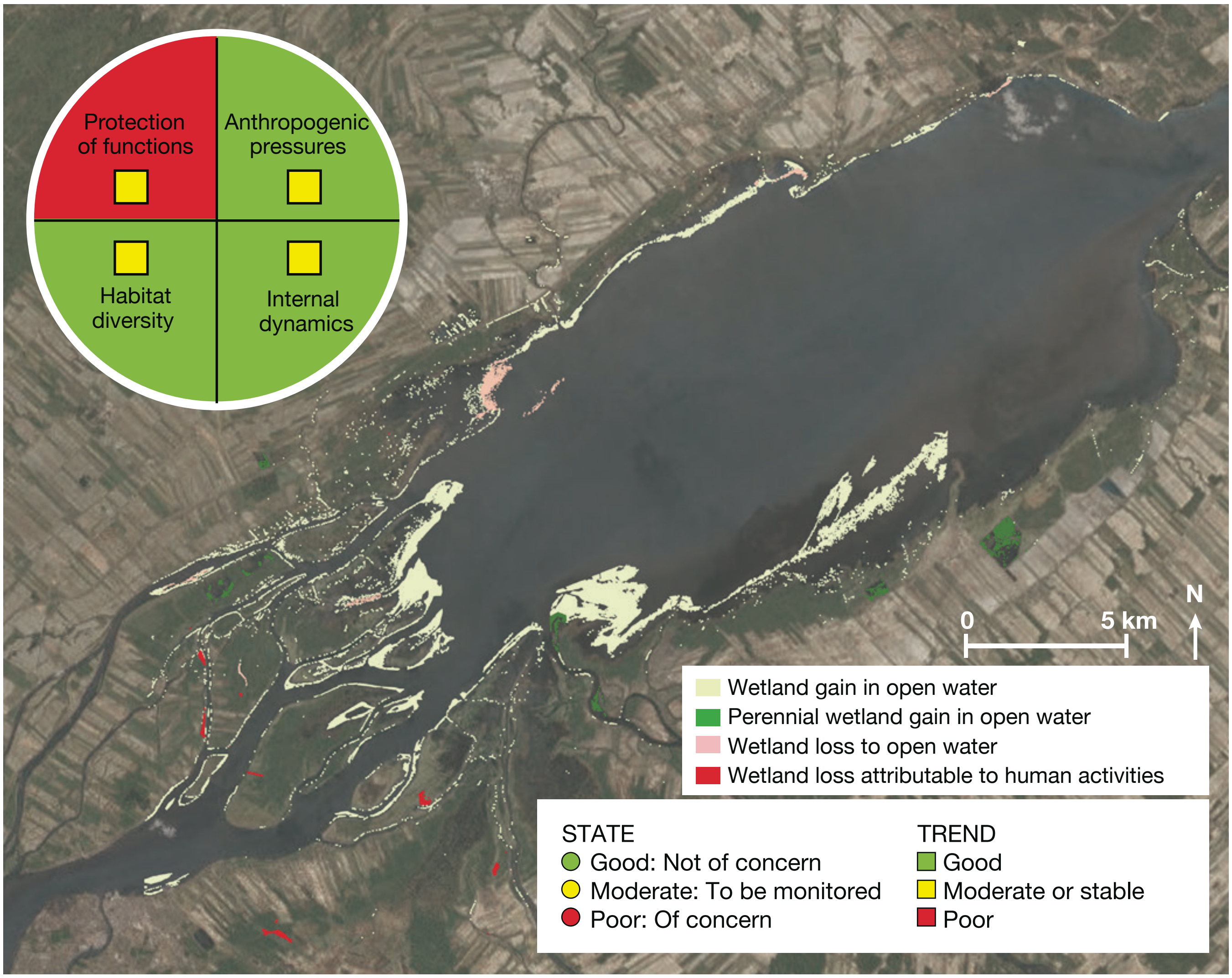


Figure 13. Map of wetland gains and losses in Lake Saint-Pierre from 2002 to 2010

Direct anthropogenic pressures on wetlands are estimated using the net gains and losses in size. Between 2002 and 2010, no net loss of wetland area caused by direct human activities was noted in the area of the Boucherville Islands. The net gains and losses are therefore nil and are primarily due to the park status conferred on this sector. A difference in area has been observed, but this is the result of a drop in water levels between the two dates. Regarding Lake Saint Pierre, there was a net increase of 64 ha of wetlands between 2002 and 2010. This is explained by the appearance of 101 ha of wetlands, minus 37 ha of wetlands that were lost to agriculture. For the period between 1990 and 2002, the trend is stable in the Boucherville Islands, as no additional losses or gains were observed. However, the fact remains that the 55 ha lost during that period were not recovered. In Lake Saint-Pierre, the net gain observed does not compensate for the losses to agriculture totalling 789 ha observed between 1990 and 2002. The trend for this sector can also be qualified as stable.

The internal dynamic of the wetlands is characterized by the ratio between the total areas that became drier and the total areas that present wetter conditions (Jean and Létourneau 2011). Between 2002 and 2010, in the Boucherville Islands area, the wetlands that dried up total three times the area of those places that became wetter. The transition from low marsh to high marsh represents the most significant internal change to the wetlands. For Lake Saint-Pierre, again between 2002 and 2010, the wetland areas that had dried total less than twice those that had become wetter. Here again, the transition from low marsh to high marsh represents the most significant change observed. Since the end of the 1970s, three successive periods of drying have been observed. On the other hand, no periods of wetting were detected based on the data available. The trend is deemed to be of concern (poor). Since the end of the 1970s, in Lake Saint-Pierre, a period of moderate wetlands wetting was observed, followed by two periods of slight drying. In this case, the trend is to be monitored (moderate).

The diversity of wetlands is evaluated by calculating the relative proportion of the five classes of wetlands present along the St. Lawrence (shallow water or aquatic-grass beds, low marshes, high marshes, shrub swamps, treed swamps). The evaluation of the relative proportion of classes of wetlands in the Boucherville Islands gives a moderate rating. The high marshes represent more than half of the wetland area in this sector, while shrub swamps are absent. However, the relative proportion of classes of wetlands in Lake Saint-Pierre is deemed to be good. The five classes of wetlands are well represented in this area. Since 1990, the trend is stable in the Boucherville Islands even though we observe an increased inequality of classes of wetlands. For Lake Saint-Pierre, during the same period, a slight increase was observed in the relative proportion of classes of wetlands. This temporal trend, however, is deemed to be stable.

The protection of wetlands from external stressors is evaluated using the presence of a protective zone 50 m wide, consisting of natural soil environments on the borders of wetlands. This protective zone was present over 76% of the limits of the wetlands in the Boucherville Islands sector in 2010. This finding is good. The largest proportion of this protective area is herbaceous. In Lake Saint-Pierre, this wetland protective zone is only present over 26% of the perimeter of wetlands and consists almost entirely of upland forests. This poor rating is attributable to the omnipresence of agricultural areas in the immediate area of the wetlands. Since 1990, we have seen an improvement in the protective zone in the Boucherville Islands sector, whereas the temporal trend for the protective zone in Lake Saint-Pierre is stable.

Reference:

JEAN M., AND G. LÉTOURNEAU *Changements dans les milieux humides du fleuve Saint-Laurent de 1970 à 2002*. Environment Canada, Science and Technology Branch, Water Quality Monitoring in Québec, Technical Report number 511, 302 pages. (2011)

JEAN, M. AND G. LÉTOURNEAU. *Les milieux humides en eau douce – 3rd edition*. Environment Canada, Science and Technology Branch. Fact sheet in the series "Monitoring the State of the St. Lawrence". St. Lawrence Action Plan. 9 pages. (2014)

Invasive species

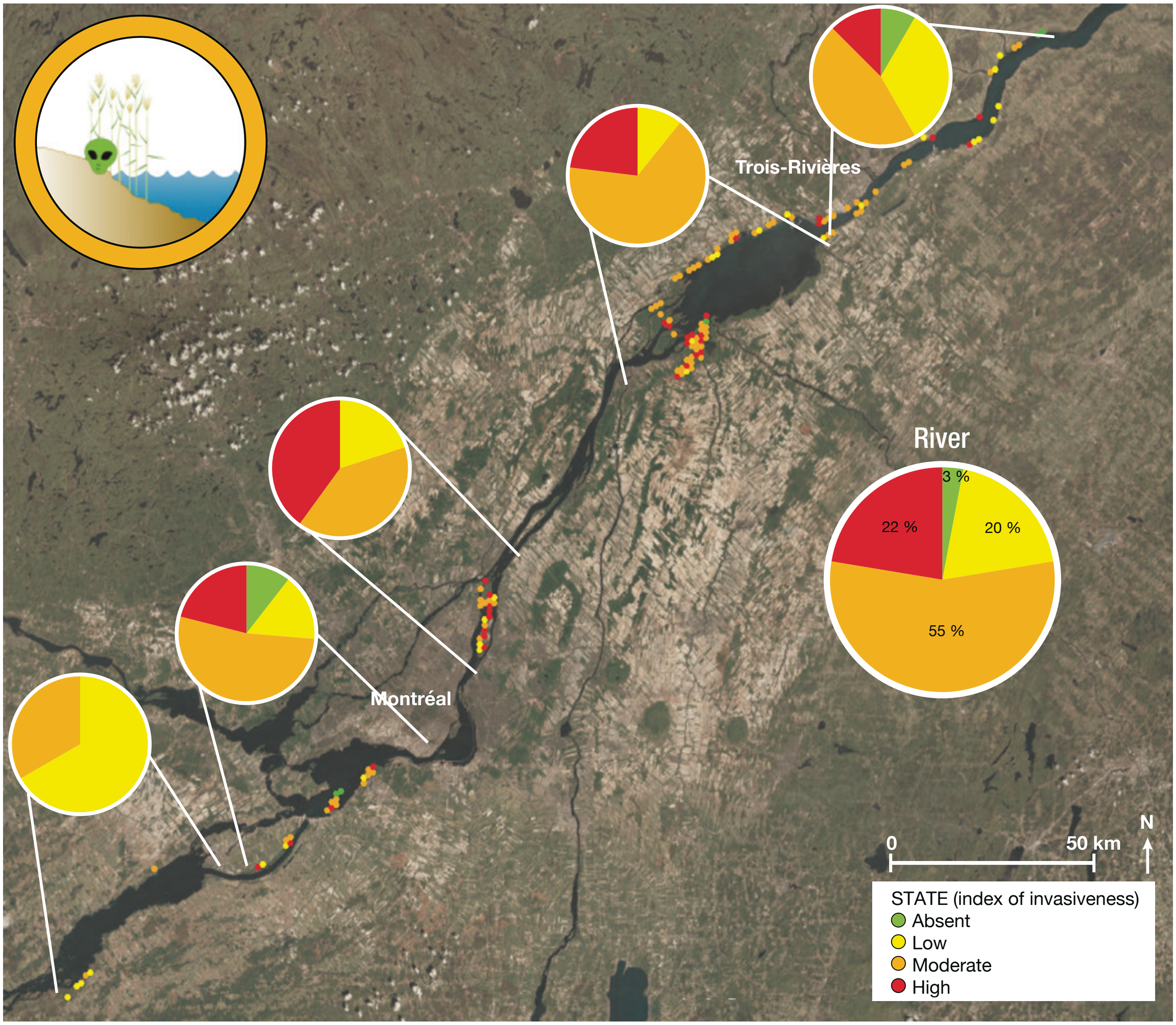


Figure 14: State of the indicator regarding invasive plant species

The monitoring, in cooperation with communities, of alien invasive plant species in the wetlands of the St. Lawrence continued between 2008 and 2010. During that period, the Haut-Saint-Laurent, Jacques-Cartier, Lake Saint Pierre and Deux Rives ZIP committees and the Société d'aménagement de la baie Lavallière visited close to 300 sites consisting of shallow water, high and low marshes, and shrub and treed swamps. The species monitored were the Reed Phalaris, the Flowering Rush, the European Frogbit, the Eurasian Water-milfoil, the Common Water Reed and the Purple Loosestrife.

The results obtained between 2008 and 2010 indicate that of all the sites visited, 246 were affected by the target species. Of those sites, 22% were highly invaded, 56% were moderately invaded and 19% were slightly invaded. The sectors most affected by alien invasive plant species are the sectors of Boucherville and Lake Saint-Pierre, while the sectors least affected are Lake Saint-François and the freshwater estuary. The dominant species observed are the Common Water Reed and the Reed Phalaris. Purple Loosestrife is the species most frequently observed in the wetlands studied.

However, it is rarely dominant at the sites visited. Most of the time, it is slightly or moderately represented. All the sites will be visited again between 2012 and 2014. It will then be possible to identify a trend regarding the evolution of invasion of wetlands in the St. Lawrence between 2005 and 2014.

1.2.2 Contamination by toxic substances through the various components of the ecosystem

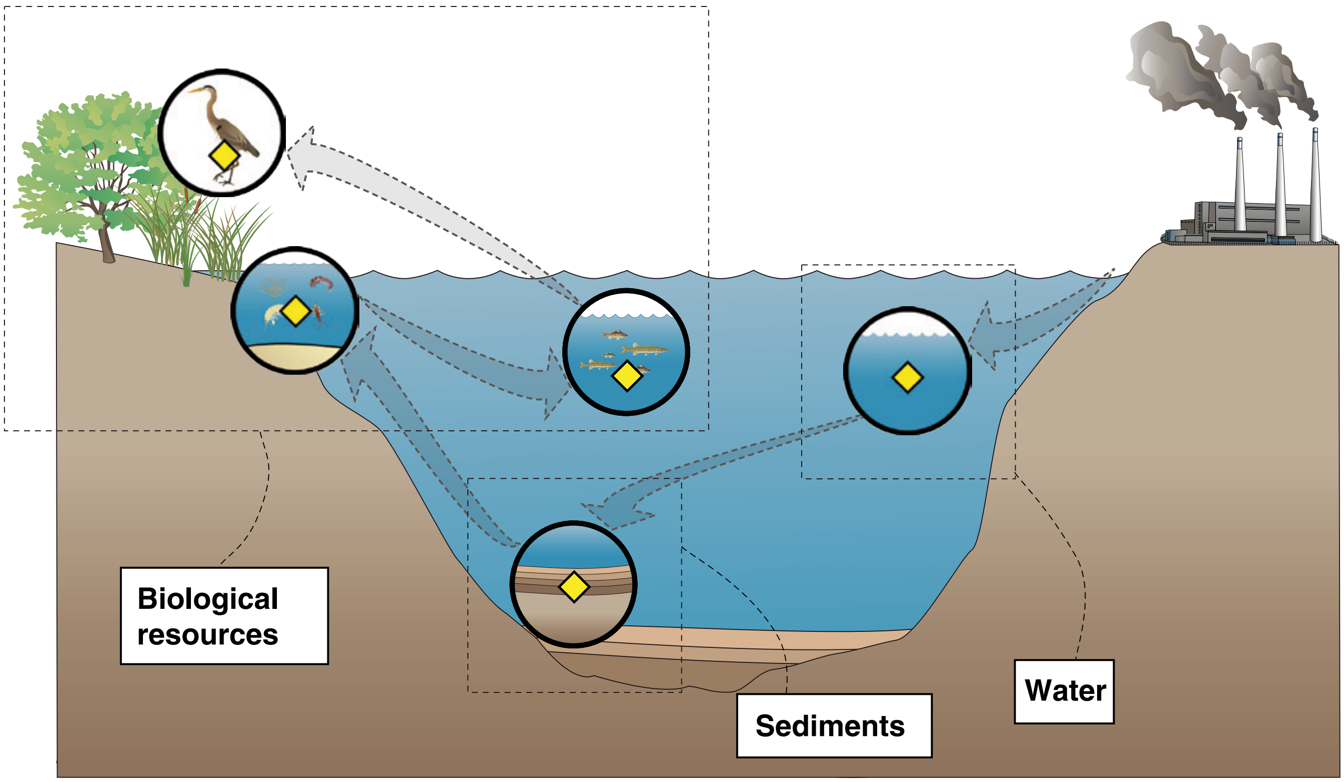


Figure 15. Conceptual diagram representing the path of toxic substances in freshwater

The presence of toxic contaminants in the aquatic ecosystem is an indicator of its disturbance and can be monitored through its various components, i.e. water, sediment and living organisms. In effect, certain contaminants, such as mercury and polychlorinated biphenyls (PCBs), are subject to bioaccumulation and biomagnification in the food chain, which can have significant negative impacts on living organisms. There are many sources of toxic contaminants: industrial waste, urban effluents, or runoff from farm land (pesticides). Contaminants can be transported in the water over very long distances depending on their solubility and physical factors such as flow. They are sometimes bound to particulates and settle in sediments where they can become trapped, where we see an accumulation of sediments, or remobilized where there is erosion and transport of sediment materials. Benthic organisms living on the interface of sediments can be affected by the presence of contaminants depending on their relative sensitivity and the concentrations of contaminants that are present. Benthic organisms serve as food for numerous other aquatic species, such as young fish, which can then be eaten by larger predators (fish, birds or mammals) and the toxic contaminants are thus transferred and biomagnified in the food chain.

Contamination By Toxic Substances In The Water

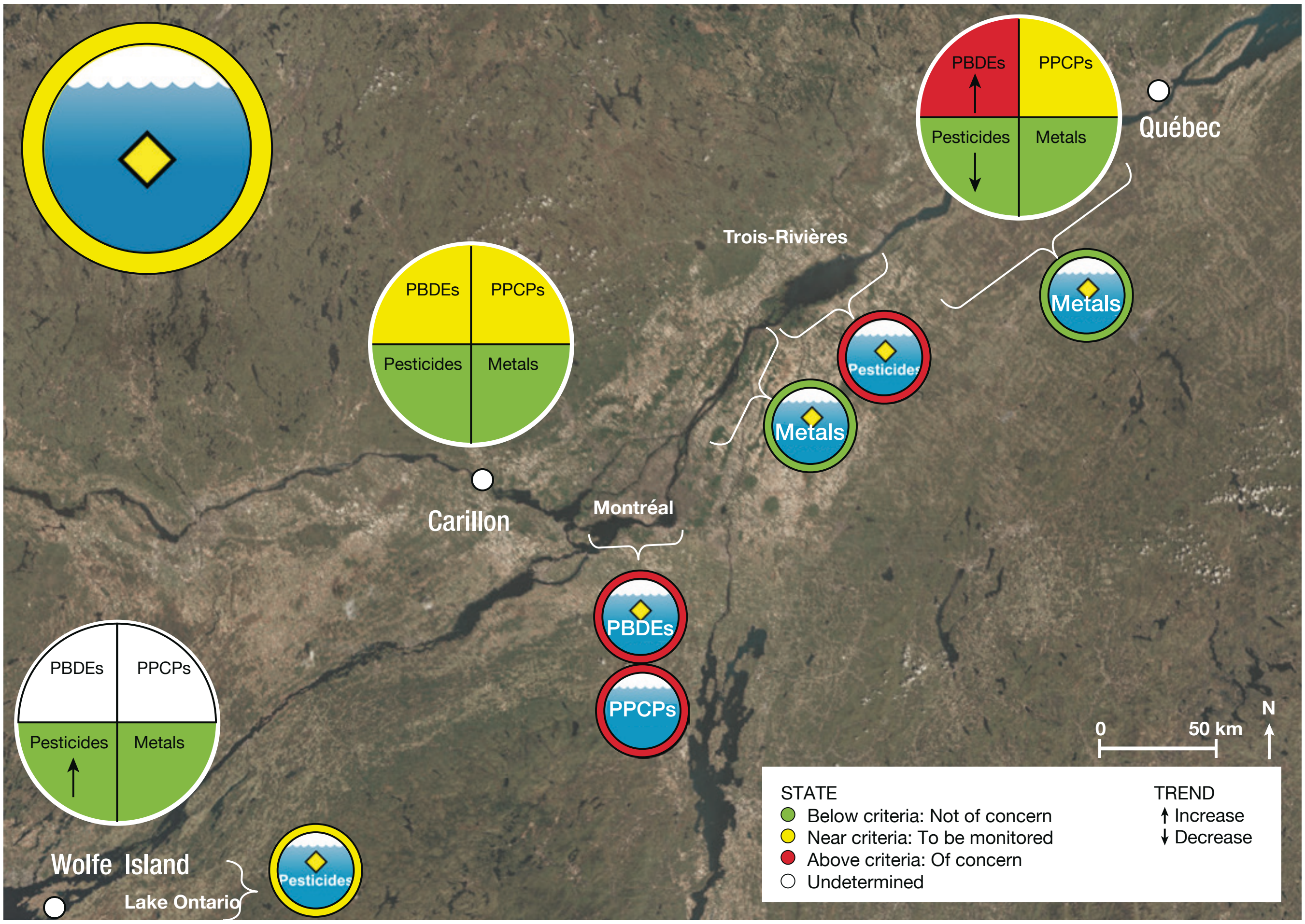


Figure 16. State of the water toxic substances indicator at Wolfe Island, Carillon and Québec stations

The quantity of a contaminant released into an ecosystem has a direct influence on its concentration in the aquatic environment. Similarly, the origin of a contaminant determines in part the variations of its concentration in the aquatic environment. Metals are naturally present in watercourses. It is only when concentrations exceed a certain threshold that we can conclude that there was a significant contribution by human activities. Concentrations of metals in the St. Lawrence do not exceed the water quality criteria for protection of aquatic life. In general, concentrations of pesticides in the river are on the same scale as those measured at Wolfe Island, at the outlet of Lake Ontario. However, at the Québec City station, higher concentrations are observed in the summer due to the spreading of pesticides on crops located in the St. Lawrence lowlands, particularly in the Lake Saint-Pierre basin. From 1995 to 2012, we saw a net decrease (around 50%) in the input of pesticides to the estuary. The same decrease was not observed in the Great Lakes, but was substantial in Québec tributaries, suggesting that the decrease observed in the river at Québec City is the result of the decrease in the tributaries. It must be noted, however, that this decrease is undoubtedly attributable to a change in the type of pesticide, as modern pesticides are effective in smaller quantities. The maximum concentrations of polybrominated diphenyl ethers (PBDEs) and pharmaceuticals and personal care products (PPCPs) are found downstream from the Montréal region. Since 1995, concentrations of PBDEs have increased considerably at the outlet of the river, at Québec City. Although we cannot evaluate the trend for pharmaceutical products, the number and sometimes the concentrations (e.g. for hormones) are areas of concern.

Although the water in the St. Lawrence comes primarily from Lake Ontario, the same is not necessarily true for contaminants. In the St. Lawrence, it is the affinity of contaminants with suspended solids that will dictate, in large part, the source of contaminants. Thus, since Lake Ontario acts as a vast settling pond, contaminants associated with particulates will tend to remain in the lake in the form of sediments. In the St. Lawrence, suspended particles and the related contaminants (metals and PBDEs) are not from the Great Lakes, but instead from erosion, urban or industrial effluents, and the river's tributaries. However, more soluble contaminants, such as pesticides, are, to a significant degree, from Lake Ontario, while pharmaceutical products are from urban effluents.

Contamination By Toxic Substances In Sediments

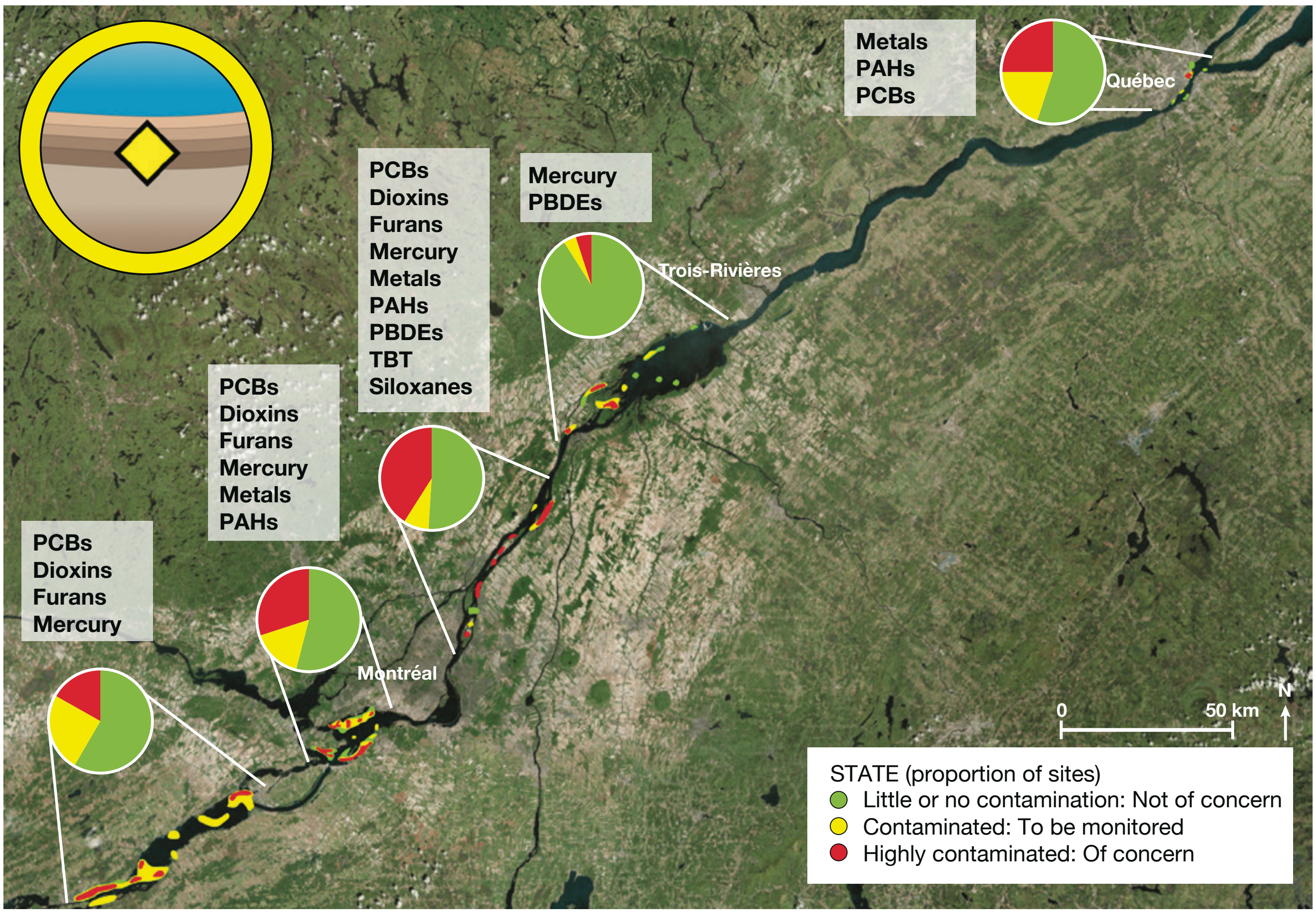


Figure 17. State of the contaminated sediments indicator

The areas of the river in green, yellow and red indicate areas where contamination is present at three levels (slightly contaminated, contaminated and highly contaminated). The non-contaminated zones are not illustrated on the map but are calculated in the pie charts. Contaminants in the boxes are those that exceed the criteria in each section of the river.

The indicator for monitoring the quality of sediments aims to regularly record changes in the levels of their contamination in the St. Lawrence River. It allows us to report on the presence of various toxic substances and identify long-term trends. Data gathered over the last few years show a substantial decrease in the concentration of contaminants left behind by industrialization in the mid-20th century, also known as historical contaminants (see the Issues and perspectives section), such as PCBs, metals, polycyclic aromatic hydrocarbons (PAHs), mercury, dioxins and furans. Recent results identify new sources of contamination for old and new organic substances that may be harmful to the aquatic ecosystem, such as PBDEs, siloxanes, and tributyltin (TBT).

The creation of industrial and urban rehabilitation programs and numerous mitigation measures for sources of contamination has had noticeable and fast repercussions on the concentrations of toxic contaminants in sediments. Thirty years ago, all sediments in the fluvial lakes were contaminated by metals, mercury, PCBs and PAHs. Today, these contaminants do not represent a real threat, except in certain sectors, such as upstream from Lake Saint François, the southern part of Lake Saint-Louis, the sector downstream from Montréal, the Sorel delta, Lake Saint Pierre, and the ports of Montréal and Québec City. Finally, recent work shows an increase in the concentrations of new substances, such as flame retardants (PDBEs), and the presence of emerging substances from urban effluents, such as siloxanes.

Contamination Of Fish

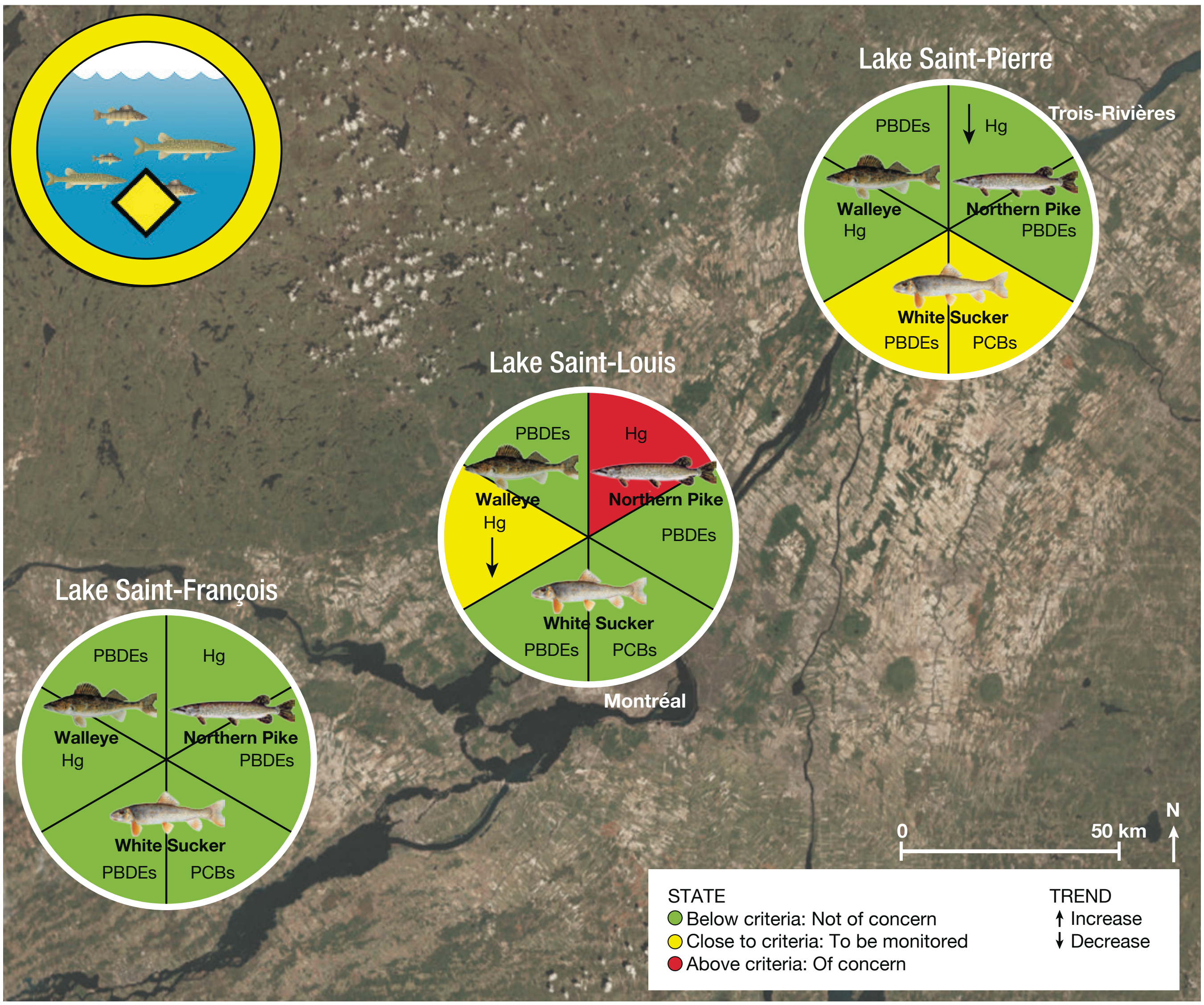
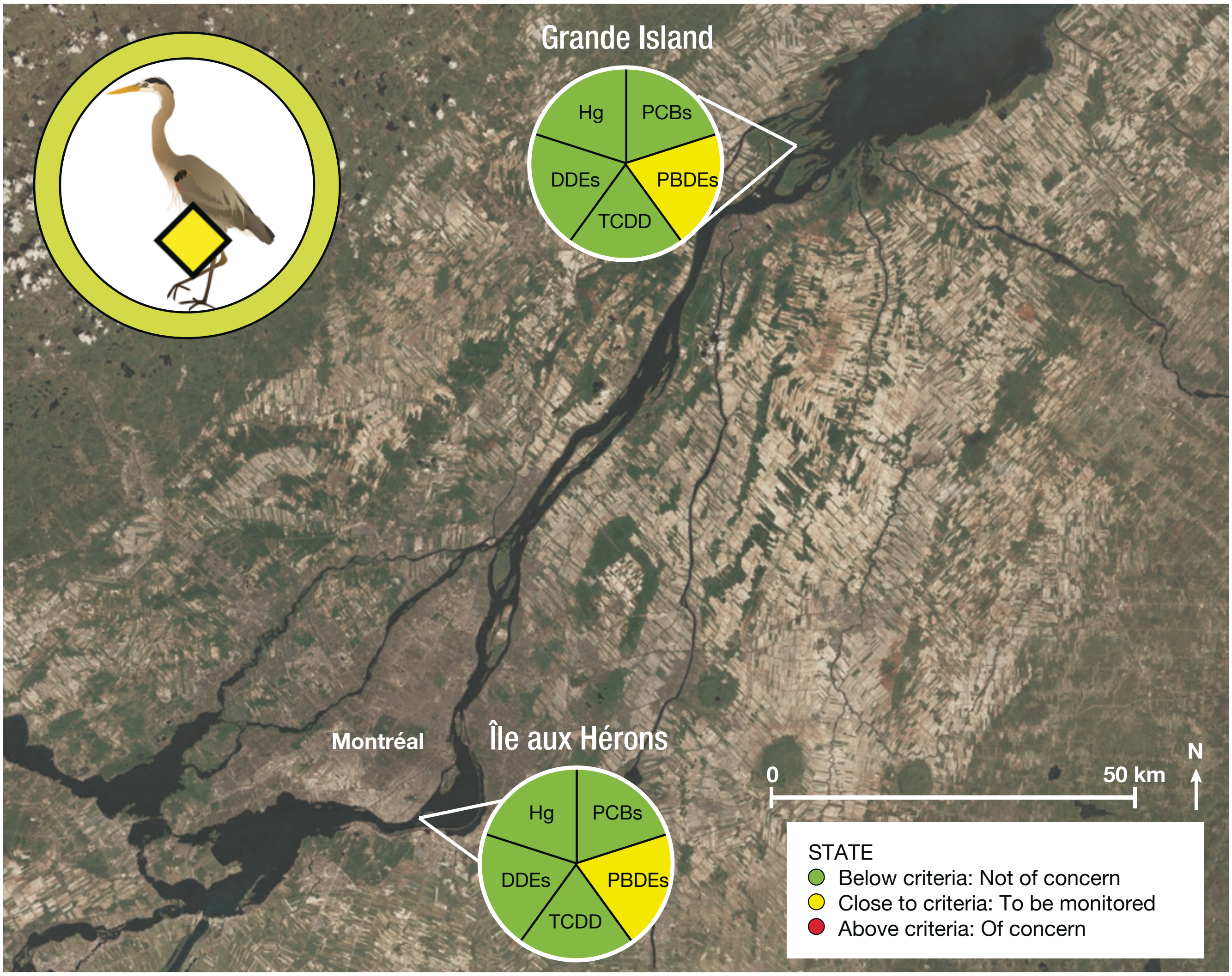


Figure 18. State of the indicator for contamination of fish

The indicator for contamination of fish more specifically examines three species: the Walleye, the Northern Pike and the White Sucker, in the river's three fluvial lakes. The average concentrations of mercury (Hg) in Walleye are less than the Health Canada directive of 0.5 mg/kg at the 3 sites, but concentrations at Lake Saint-Louis are very close to the criteria, despite a decrease since the last findings in 2008. Since then the average concentrations of mercury in Northern Pike are lower than the Health Canada directive of 0.5 mg/kg in Lake Saint-François and Lake Saint-Pierre, but exceed the directive in Lake Saint-Louis. Mercury concentrations in Northern Eel are lower in 2011 in Lake Saint-Pierre. PCB concentrations in whole White Suckers measured in 2009 and 2011 do not differ much from those measures in the past in lakes Saint-François, Saint-Louis and Saint-Pierre. Average concentrations of PCB in whole White Suckers are higher in Lake Saint-Pierre than in Lake Saint-François. The average PCB levels in white suckers are below the criteria for fish-eating wildlife in lakes St. Francis and St. Louis but slightly higher in Lake Saint-Pierre. PBDE concentrations in the flesh of Walleyes and Northern Pikes in the three lakes are below the criteria for piscivorous wildlife (44 µg/kg and 13 µg/kg for tetra-BDEs and penta-BDEs respectively). In whole White Suckers, PBDE concentrations are below the criteria for piscivorous wildlife in lakes Saint François and Saint-Louis, but are very close to the criterion for Lake Saint-Pierre.

Contamination Of The Great Blue Heron



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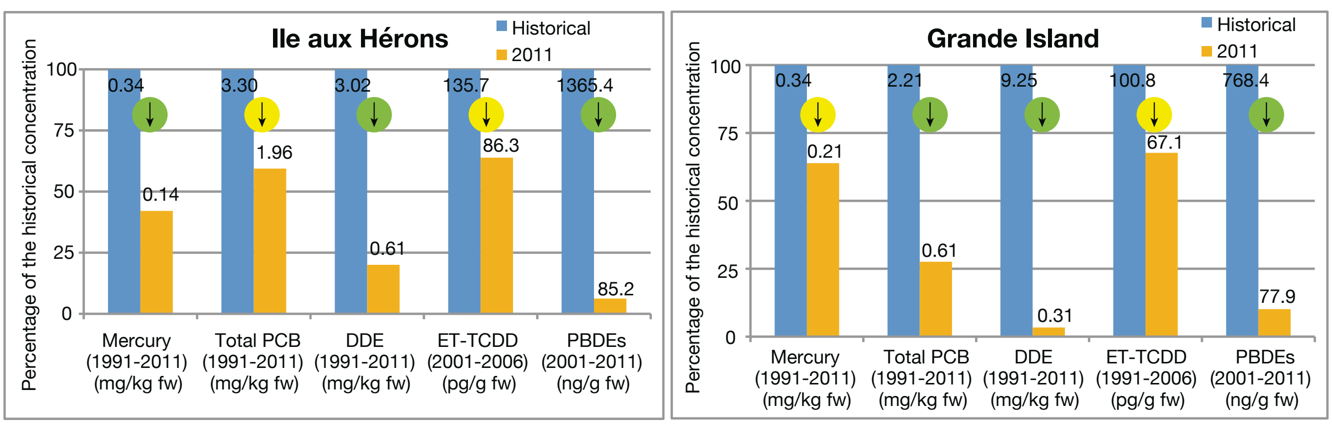


b

STATE
- Significant decrease: Not of concern
- Slight decrease: To be monitored
- Increase: Of concern

TREND
- ↑ Increase
- ↓ Decrease

Figure 19. a) State of the contamination indicator of the Great Blue Heron in freshwater; b) Comparison of concentrations of contaminants in the eggs of the Great Blue Heron between historical and recent values

The values above each bar represent the concentrations.

The most recent concentrations of mercury, PCBs, DDEs, ET-TCDD and PBDEs were compared with historical data (histograms) and to toxicity criteria or thresholds taken from scientific literature (pie charts). These five contaminants or groups of contaminants are the most abundant and of most concern in the eggs of the Great Blue Heron. These contaminants all decreased since monitoring started, both at Île aux Hérons and at Grande Island. The average decrease is 62% (36% to 94%) at Île aux Hérons and 66% (33% to 97%) at Grande Island. The pie charts on the map indicate that concentrations of all the contaminants except penta-BDE are lower than the criteria in the two colonies.

In general, in the fluvial corridor, contamination indicators all show a decrease in historical contaminants (metals PCBs, DDTs). We no longer see these substances exceed the criteria for protecting aquatic life in water and very little in sediments and living organisms. Most trends are downward. The finding is different for emerging contaminants. For instance, contamination by PBDEs sometimes exceeds the criteria and we have seen an increase in concentrations in water and sediments over the last decade.

1.3 The estuary and the Gulf

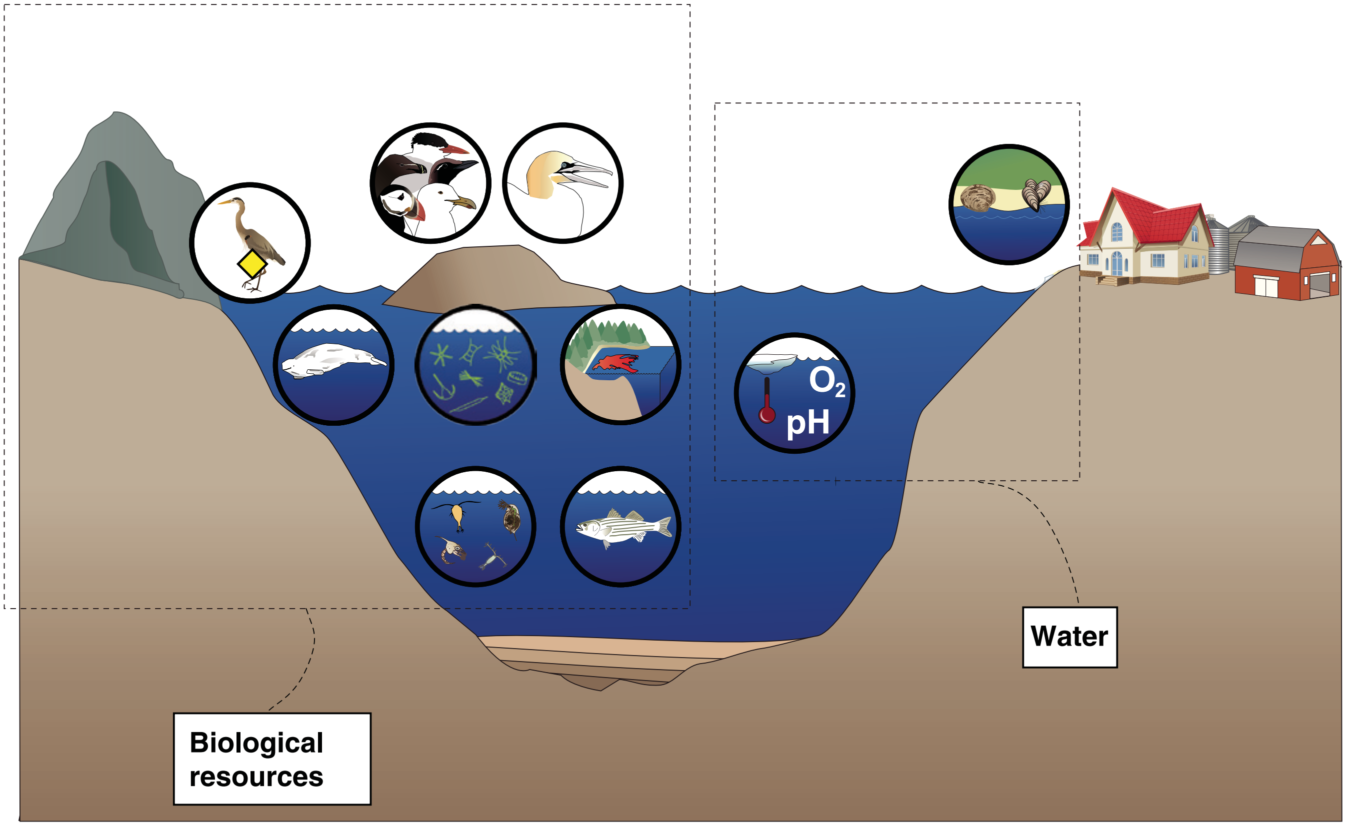
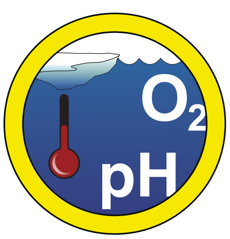


Figure 20. Conceptual diagram representing the environmental indicators monitored in saltwater

1.3.1 The physical, chemical and bacteriological parameters of the water and their effects on the ecosystem

Oceanographic Processes



The Atlantic Zone Monitoring Program (AZMP) monitors the evolution of oceanographic variables in the lower estuary and the Gulf of St. Lawrence by gathering data on physical (e.g. temperature, salinity, ice cover, freshwater runoff), chemical (e.g. dissolved oxygen, nutrients, pH) and biological (e.g. chlorophyll, zooplankton) parameters.

The lower estuary and the Gulf of St. Lawrence exhibit strong vertical temperature and salinity stratification that follows a seasonal cycle. Freshwater runoff in the estuary has a major influence on stratification and on the intensity of the estuarine circulation. Since 1974, the average annual freshwater runoff has decreased by 10%. Furthermore, after the mild winters of 2010 and 2012 the spring freshet was both smaller and occurred earlier than normal.

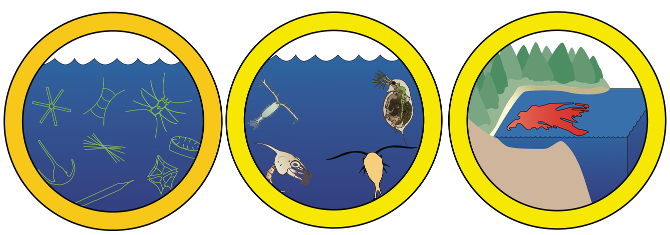
Summer surface water temperatures in the Gulf have increased following the rise in air temperature, which has progressed at a rate of 0.9°C per century since 1873, but which has risen more quickly over the past 20 years. Summer temperatures broke heat records in 2006, followed closely by 2012. From another standpoint, the seasonal maximum area and volume of sea ice reached during winter and the length of the sea ice season have been decreasing in the Gulf since 1990. The almost complete lack of sea ice in 1969, 2010 and 2011 coincide with the only 3 winters that saw air temperatures 2°C to 3°C above the seasonal norm, which may be a preview of future conditions in 50 years, based on climate change scenarios.

The summer cold intermediate layer (CIL) is a vestige of the winter cooling of the surface layer that is slowly eroded and warmed, but nevertheless keeps temperatures in some areas below 1°C for the rest of the year. Its average minimum temperature has experienced significant interannual variations, with a long period of intense cold from 1986 to 1998. Since then, there has been an increase in CIL minimum temperatures, but the average in 2003 was as low as those observed during the cold period; 2003 was also the year in which the highest volume of sea ice was observed in the Gulf (including sea ice exported onto the Scotian Shelf) since 1969. In the summer of 2012, the average CIL minimum temperature was the highest since the record of 1980.

The waters of the deep layer in the lower estuary, located below the CIL (> 150 m), come from the continental slope, having circulated upstream with little mixing with shallower waters in 3 to 4 years between Cabot Strait and the head of the lower estuary. In doing so, concentrations of dissolved oxygen decrease due to pelagic and benthic respiration. The lowest concentrations of dissolved oxygen are therefore observed in the deep waters of the lower estuary, which were briefly hypoxic in the early 1960s, and have been so consistently since 1984.

At the same time as the reduction in oxygen, the pH of the deep water (> 170 m) fell by 0.2 to 0.3 units between 1934 and 2010, an increase in acidity of approximately 100%. This acidification results in a reduction in calcium carbonate, which is needed to develop the shells and skeletons of many organisms, including mollusks, crustaceans and corals. The accumulation of anthropogenic carbon dioxide (CO_2) from the atmosphere, the origin of the water masses and the decomposition of organic matter in the deep waters are apparently responsible for the acidification of the St. Lawrence.

Phytoplankton, Zooplankton And Toxic Algae



Changes are observed in the phytoplankton communities (e.g. increase in flagellum and dinoflagellata) and zooplankton (e.g. increase in the abundance of species of small calanoids, modified phenology), and the finding is that biological conditions have been responding to the environmental variations in the ecosystem noted over the last few years. Thus, we see unusually early bloom of phytoplankton in the Gulf of St. Lawrence, more specifically in 2010 and 2012, two warm years when the ice was out early in the year. These changes in the environment also create an increased risk of toxic algal bloom. Regarding species of copepods indicative of arctic waters, we see a decrease in their abundance during the period from 2008 to 2012 compared with the 1990s. Finally, the changes noted in the phenology of the secondary production cycle in the St. Lawrence in the mid 2000s seem to be in response to the warming of the ecosystem and the early bloom of phytoplankton. These changes in plankton production can have consequences on recruitment processes and the productivity of higher trophic levels, including species of commercial value. These variations in the production dynamic are therefore added to the direct impact of conditions such as hypoxia and acidification on organisms.

Shellfish Water

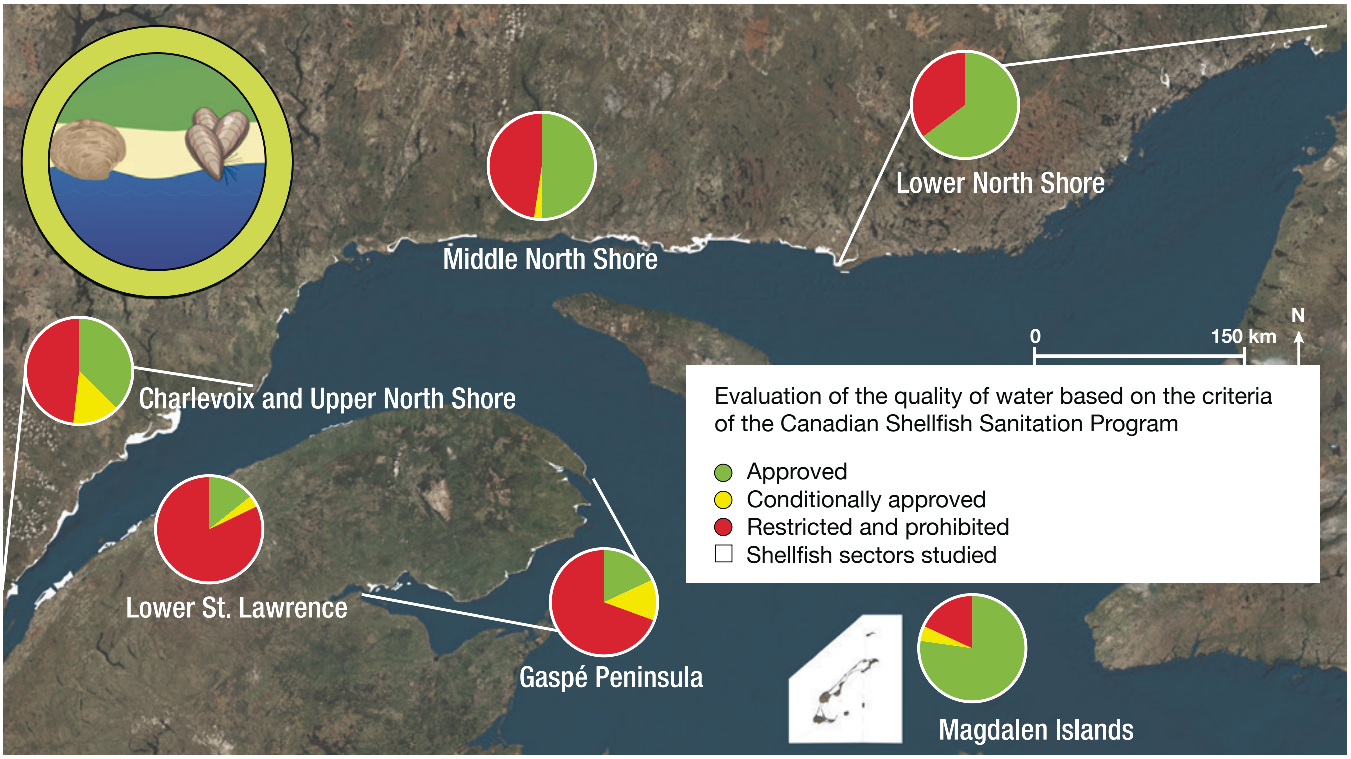


Figure 21. State of the shellfish water quality indicator

Overall, for all the portions of shoreline evaluated, the quality of water is moderate-good. In the Magdalen Islands, more than three quarters of the sectors evaluated meet the criteria for an approved or conditionally approved sector, and most of those meet the criteria for an approved sector. The quality of water is therefore excellent. On the Lower North Shore, close to two thirds of the sectors evaluated meet the criteria for an approved sector. This region has a large proportion of coast not defined in sectors, but where the anticipated quality of water appears to be excellent, given the absence of nearby sources of contamination. Overall, the quality of the water in this region is excellent. In the regions of the Upper North Shore / Charlevoix and Middle North Shore, about half of the sectors evaluated meet the criteria for an approved or conditionally approved sector, and the other half of the sectors do not meet those criteria and are prohibited from gathering shellfish. In the Gaspé Peninsula, about a third of the sectors evaluated meet the criteria for an approved or conditionally approved sector. Two thirds of the sectors evaluated do not meet these two criteria. In the Lower St. Lawrence, more than three quarters of the sectors evaluated do not meet the criteria for an approved or conditionally approved sector, and are prohibited from gathering shellfish.

The coastal waters are highly vulnerable to the impact of human activities and we saw the same trend in 2013 as in 2008. Anthropogenic bacterial contamination is still causing the loss of use, such as gathering softshell clams and mussels. This problem remains more serious in the Gaspé Peninsula and the Lower St. Lawrence than in the Magdalen Islands and along the North Shore. As in the fluvial portion, it is wastewater from municipalities or remote residences and the presence of agricultural activity that are the main sources of bacteriological contamination. Little variation in water quality was measured for the priority shellfish sectors between 2008 and 2013, and none of the 53 priority sectors was reopened during that period. However, there were improvements regarding the sources of contamination in certain sectors in the Gaspé Peninsula and the Upper North Shore. Water quality has probably improved in two sectors of the North Shore following the construction and commissioning of a wastewater treatment plant (secondary treatment) in Portneuf-sur-Mer in 2011. In Gaspé Bay, ongoing efforts have been made to improve the existing wastewater treatment plant.

Over the long term, an improvement could be seen in water quality with the implementation of the *Wastewater Systems Effluent Regulations* under the Fisheries Act, which favours the implementation and improvement of wastewater treatment plants.

Striped Bass

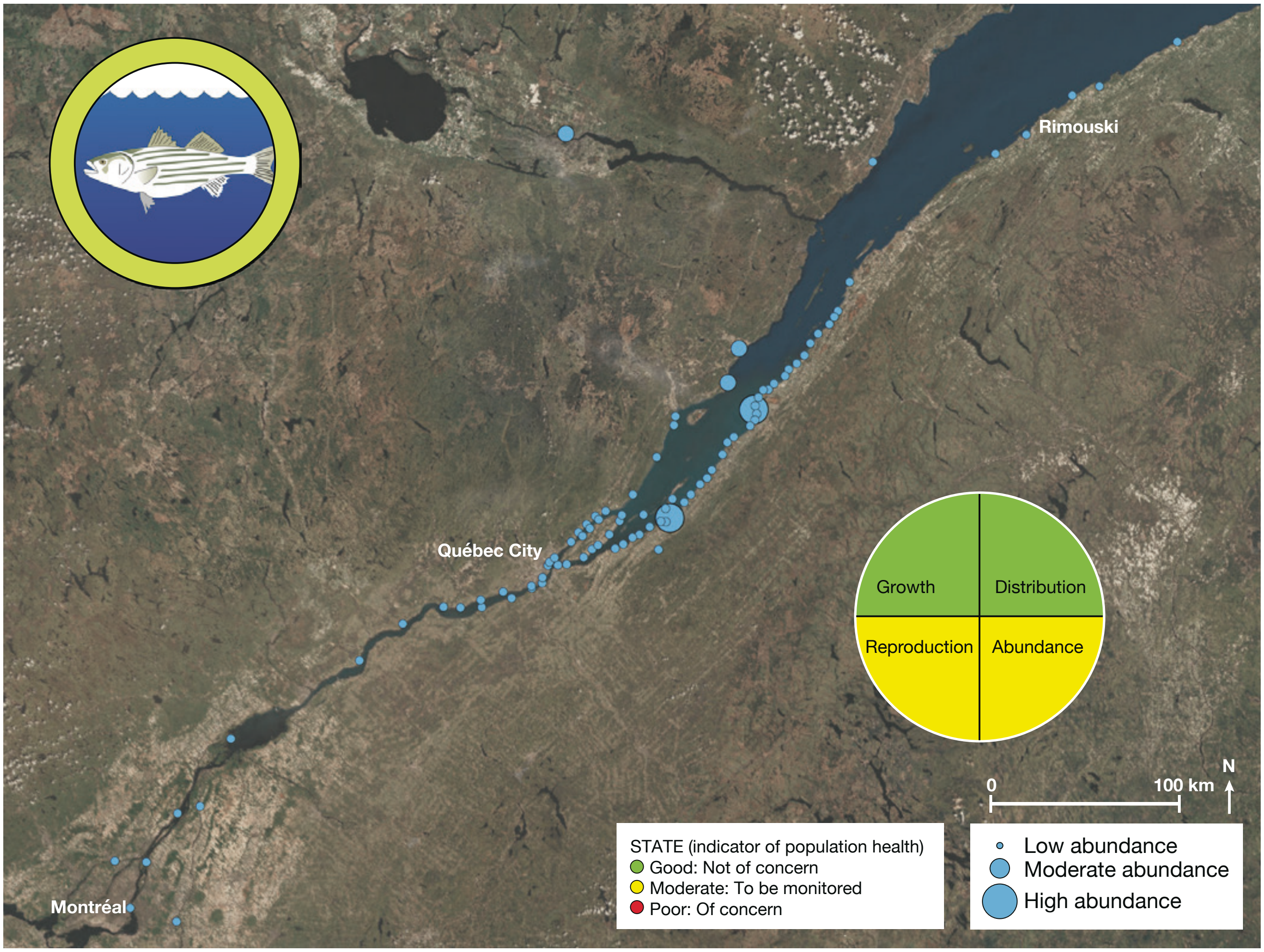


Figure 22. State of Striped Bass indicator and its observed abundance

Historically, the Striped Bass was primarily present between Lake Saint-Pierre and Kamouraska. Currently, following efforts to reintroduce the species, we note the presence of Striped Bass in the entire river, between Montréal and Rimouski (Figure 22). The Striped Bass that currently make up the population in the St. Lawrence are growing more rapidly than those of the former population. It seems that the food and fluvial rearing habitats in the St. Lawrence River are not limiting for the current level of abundance of the new population of Striped Bass. The capture of young of the year in 2008, when no seeding at that stage of development had been carried out in the river, confirmed the presence of natural reproduction. This observation was followed by the location in 2011 of a first breeding site at the mouth of the Rivière du Sud at Montmagny, followed by the location of a second breeding site in 2013 at the mouth of the Ouelle River at Rivière Ouelle (Figure 23). Since 2010, there has been an exponential increase in the abundance of juveniles. However, they are concentrated in a few areas and their abundance remains low. The distribution area is larger than it was in the past and is probably related to the exploratory behaviour of a species that is settling into a new environment.

The abundance of the Striped Bass in the St. Lawrence River has considerably increased since the last finding, although it remains low. Maintenance of this new population remains precarious. The state of the indicators used does not yet allow for sampling or sustainable use of the resource.

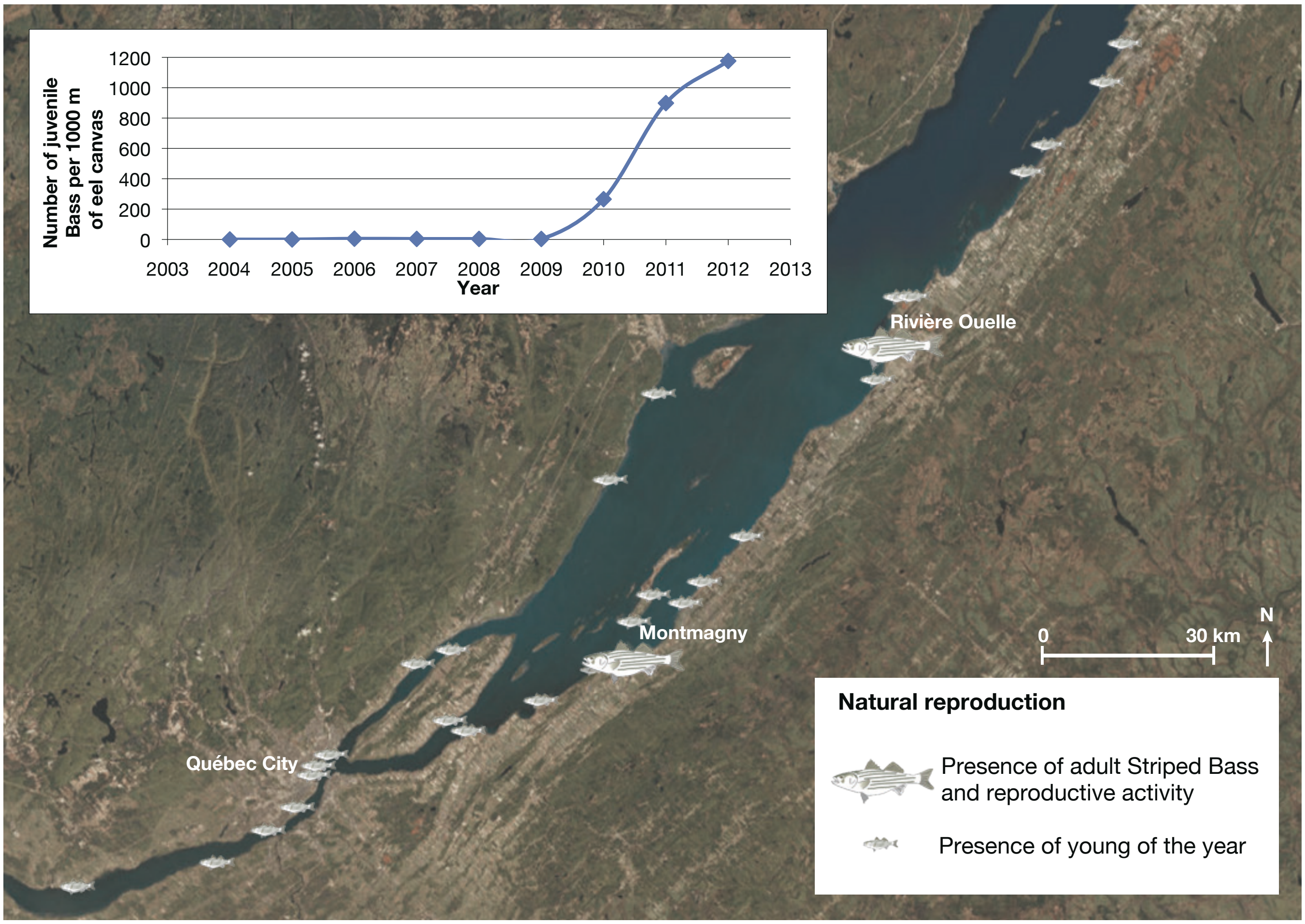


Figure 23. Indicators of natural reproduction of Striped Bass

Seabirds And Northern Gannets populations

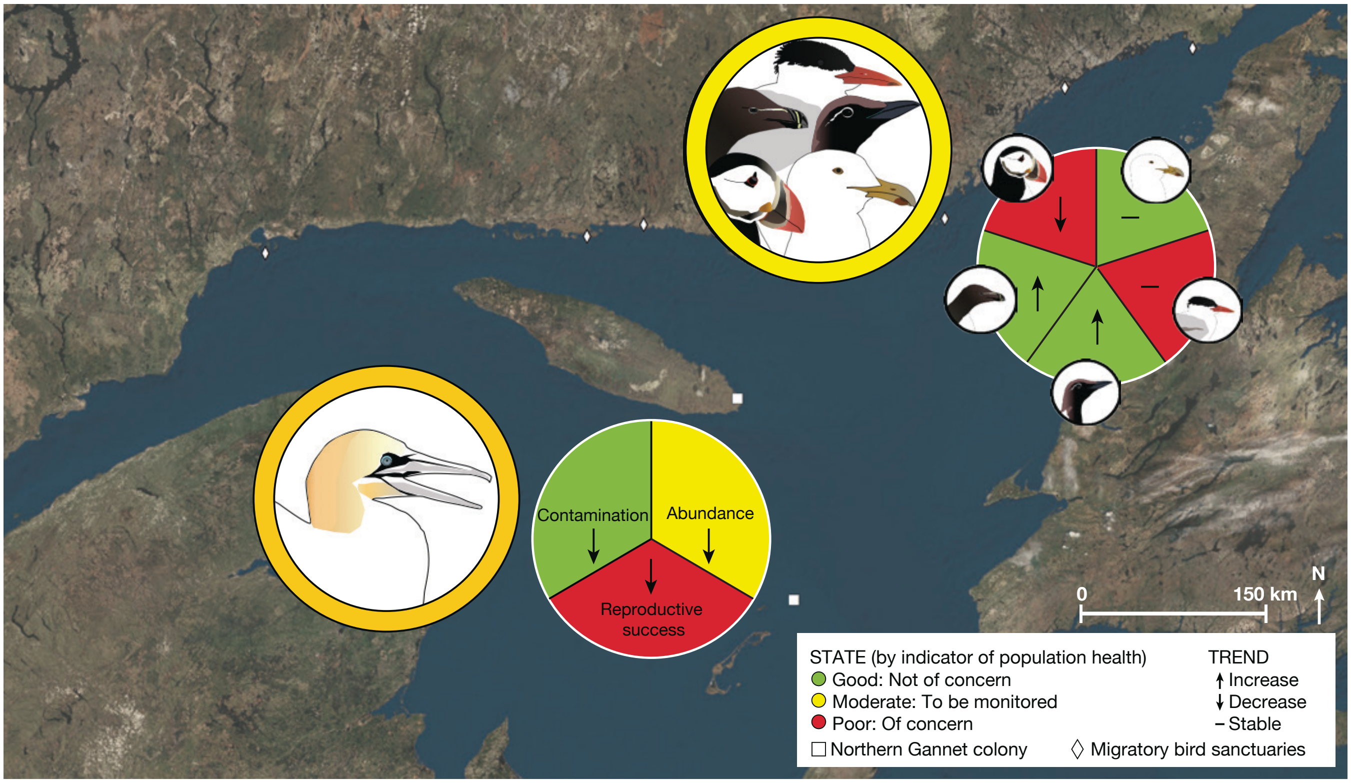


Figure 24. State of indicators for seabirds and Northern Gannets

Seabirds in the pie chart at the right, clockwise starting at the top : Herring Gulls, Caspian Terns, Common Murres, Razorbills and Atlantic Puffins.

Seabirds

Using 2005 and 2010 inventories, while taking into consideration the 5-year inventory data collected since 1925, the most recent trends were analyzed for the populations of each species in the sanctuaries. The Herring Gull population has remained stable; the Caspian Tern is still present, but again with only 3 individuals; the number of Common Murres increased significantly between 2005 and 2010 (+77%) and the population is currently at a fairly high level. There was another impressive increase in the Razorbill population in the sanctuaries between 2005 and 2010 (+61%) and that growth has been almost steady since 1977. The Atlantic Puffin declined moderately (-15%) between the last 2 inventories, but that is the third consecutive drop in its numbers, giving a decline of 54% since 1993, such that the estimated population in 2010 was the second smallest since 1925.

In the previous overview (following the 2005 inventory), it was found that the population of Herring Gulls in the refuges had stabilized after 1993, and that finding did not change in 2010. Three Caspian Terns were found in 2005, while the species was absent in the 2 previous inventories. This reappearance is encouraging, but the status of the species remains worrisome. Without population growth, the status of the species remains excessively precarious. Following a worrisome decline of 51% between the years 1998 to 1999 and 2005, the number of Common Murres rebounded in 2010 to a high level, close to the maximums of 1993 and 1998 to 1999. The finding for this species therefore changed from to be monitored in 2005 to good in 2010. The steady growth in the population of Razorbills since 1977 explains why the good finding remained the same in 2005 and 2010. With this third consecutive decrease in the number of Atlantic Puffins in the sanctuaries, the population trend appears to be strongly downward and its population level is increasingly low, which explains why the finding went from moderate (in 2005) to poor (in 2010).

Northern Gannet

The size of the population is large and is only 13% lower than the maximum recorded in 2009, but the signs of decline after 2009 follow a long period (approximately 30 years) of population growth. Reproductive success has been declining at a worrisome rate since 2009 and is currently too low to maintain the colony. Supplementary studies have shown that the birds seem to be having trouble finding their food and must travel very far from their colony to feed, which would affect their reproductive success.

In the previous finding, the three indicators were increasing and the situation was very positive. Since then, however, although the levels of contaminants have continued to drop in general, reproductive success has dropped sharply to reach the lowest levels ever observed on Bonaventure Island in 2011 and 2012. Such low reproductive success can only result in a decline of the reproductive population over the long term (with a delay of five or six years, the age at which birds begin to reproduce). After 2009, the growth of the population stopped, with the size of the two main colonies showing variations edging toward decline. Countering this trend would require that the reproductive success climb back up to 67% (percentage of young born in a particular year and that survive to first flight).

Belugas population

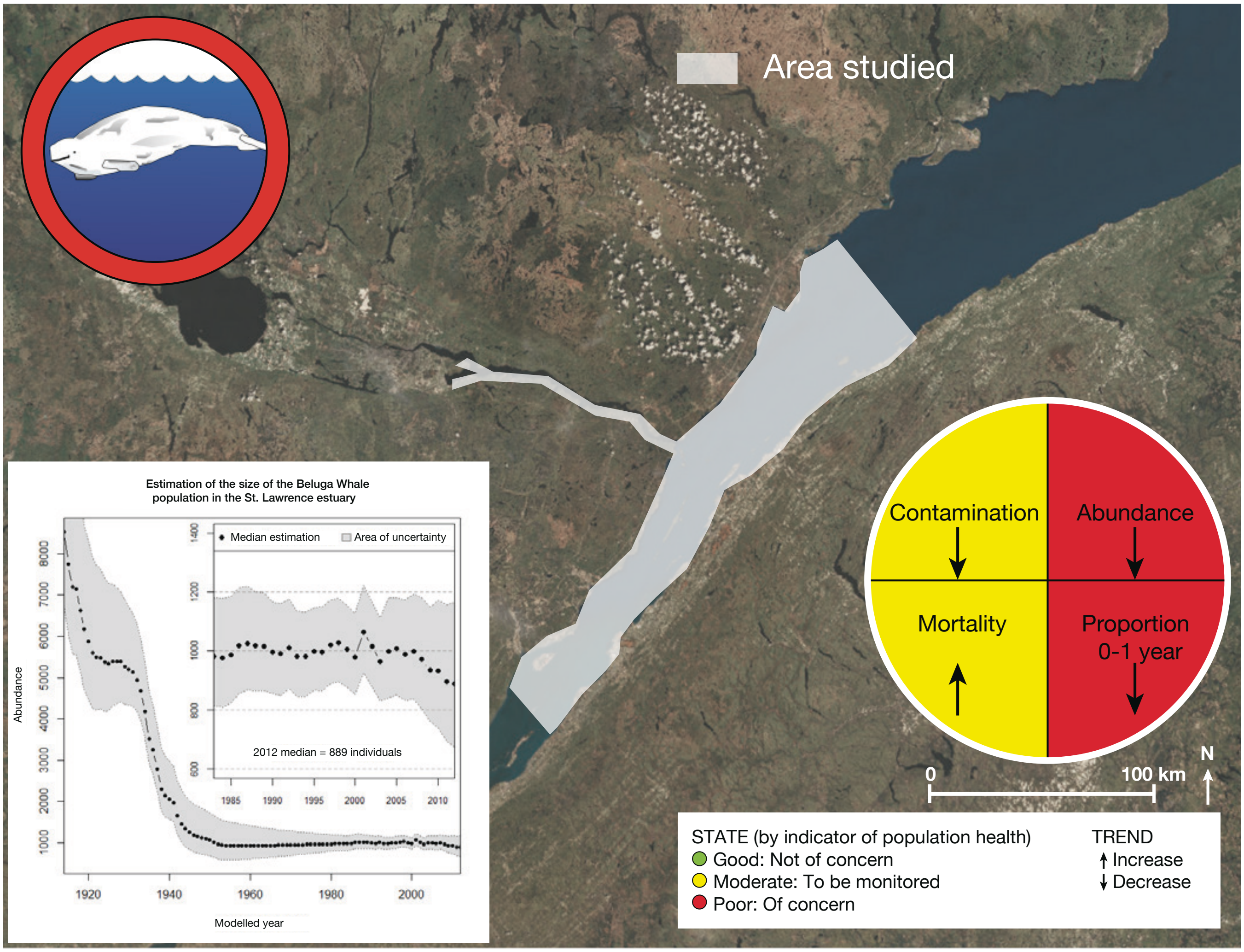


Figure 25. State of the Beluga Whales indicator and graphic showing the estimated size of the Beluga Whale population in the estuary

Integrating data up to 2012, the model used to monitor the Beluga Whale population in the St. Lawrence estimates that the population was stable or increasing slightly from the end of hunting in the 1960s until the early part of the 2000s, reaching approximately 1000 individuals in 2002, then declined since that time to 889 individuals (IC 95%: 672-1,167) in 2012. Again according to the model, changes in vital parameters and in age structure seem to have occurred in the Beluga Whale population in the St. Lawrence estuary. We are therefore seeing a transition from a period of relative stability in vital parameters prior to 1998, characterized by cycles of three-year intervals between maximums in reproduction, to a period of instability characterized by a two-year reproductive cycle, resulting from increased variability in mortality rates among newborns and gestation rates and a decline in the proportion of newborns and immature births in the population. Beluga Whales are exposed to noise and disruption from maritime traffic, recreational activities and the whale-watching industry. An analysis of 28 indicators describing the ecosystem showed that conditions have changed in the Gulf of St. Lawrence since the end of the 1990s. Analysis of chemical markers in Beluga whale carcasses from 1988 to 2012 indicates a change in the sources of the carbon (probably related to diet) used by adult males and females since 2003. An unusually high number of Beluga Whale carcasses found in 2008, including 8 newborns and a range of other species, coincided with a proliferation of the dinoflagellate *Alexandrium tamarense*, which produces paralyzing toxins (saxitoxins) and it has been shown that several dead animals had been exposed to saxitoxins. The number of carcasses of newborns in 2010 and 2012 was 8 and 16 times higher than the median number observed since 1983 and was likely the result of a combination of an increase in the production of young and a decrease in the survival of those young. This mortality occurred during a period of long-term below-average icy conditions and higher water temperatures in 2012.

1.3.2 Contamination by toxic substances through the various components of the saltwater ecosystem

Beluga Whales

The Beluga Whale in the St. Lawrence remains one of the most contaminated marine mammals and, although some components have decreased over the last decade (PCBs, DDT), others have increased (PBDEs). Concentrations of classic or historical persistent organic pollutants (POPs) have remained constant or have decreased slightly. Concentrations of PBDEs have continued to increase among male adults, but the rate of increase has fallen slightly since the early 2000s (series ending in 2008). Among adult females and newborn, concentrations of PBDEs have not increased since the end of the 2000s (series ending in 2012 for both groups).

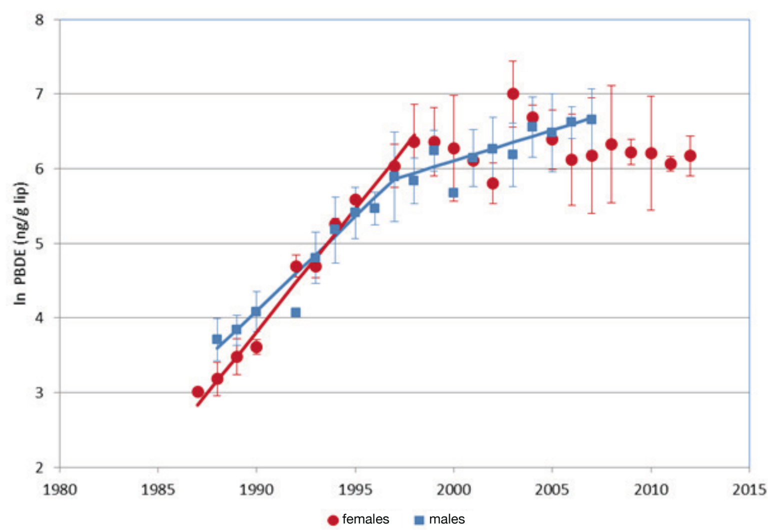


Figure 26. Temporal trend in PBDE contamination among male Beluga Whales (blue) and female Beluga Whales (red)

The vertical lines represent the standard deviation. Significant trends are identified by the line segments. Modified from Lebeuf et al. (2014 a,b)

Reference:

LEBEUF, M., MEASURES, L., NOËL, M., RAACH, M., TROTTIER, S. A twenty-one year temporal trend of persistent organic pollutants in St. Lawrence Estuary beluga, Canada. Science of the Total Environment, 485-486, 377-386. (2014a)

LEBEUF, M., RAACH, M., MEASURES, L., MÉNARD, N., and HAMMILL, M. Temporal trends of PBDEs in adult and newborn beluga (Delphinapterus leucas) from the St. Lawrence Estuary. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/120. v + 11 p. (2014b)

Northern Gannet

The most recent concentrations of mercury, PCBs, DDE, ET-TCDD and PBDEs were compared with historical data (histograms) and to toxicity criteria or thresholds taken from scientific literature. These contaminants have all decreased in the eggs of Northern Gannets on Bonaventure Island since monitoring started, except ET-TCDD, which increased between 2004 and 2009. The average decrease is 52% (13 to 99%). Concentrations of all contaminants are below the criteria.

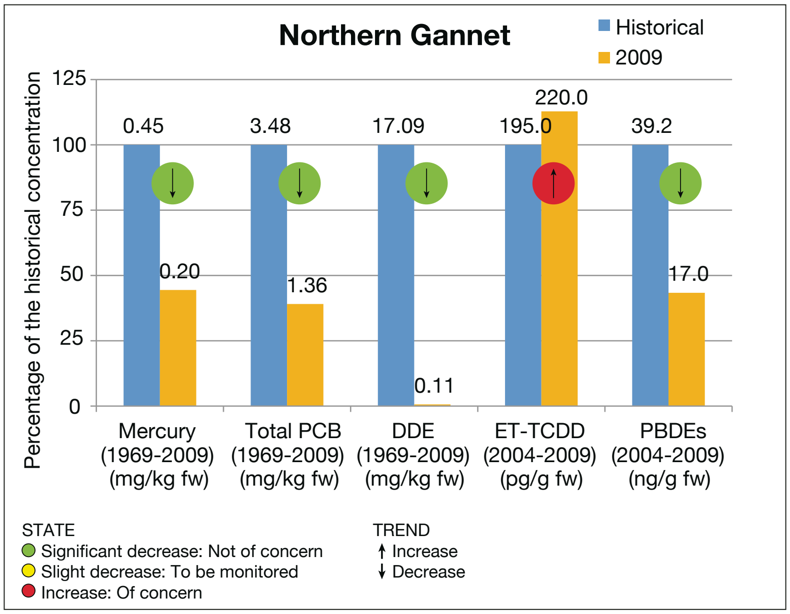


Figure 27. Comparison of concentrations of contaminants in Northern Gannet eggs between historical and recent values

The values above each bar represent the concentrations

Great Blue Heron

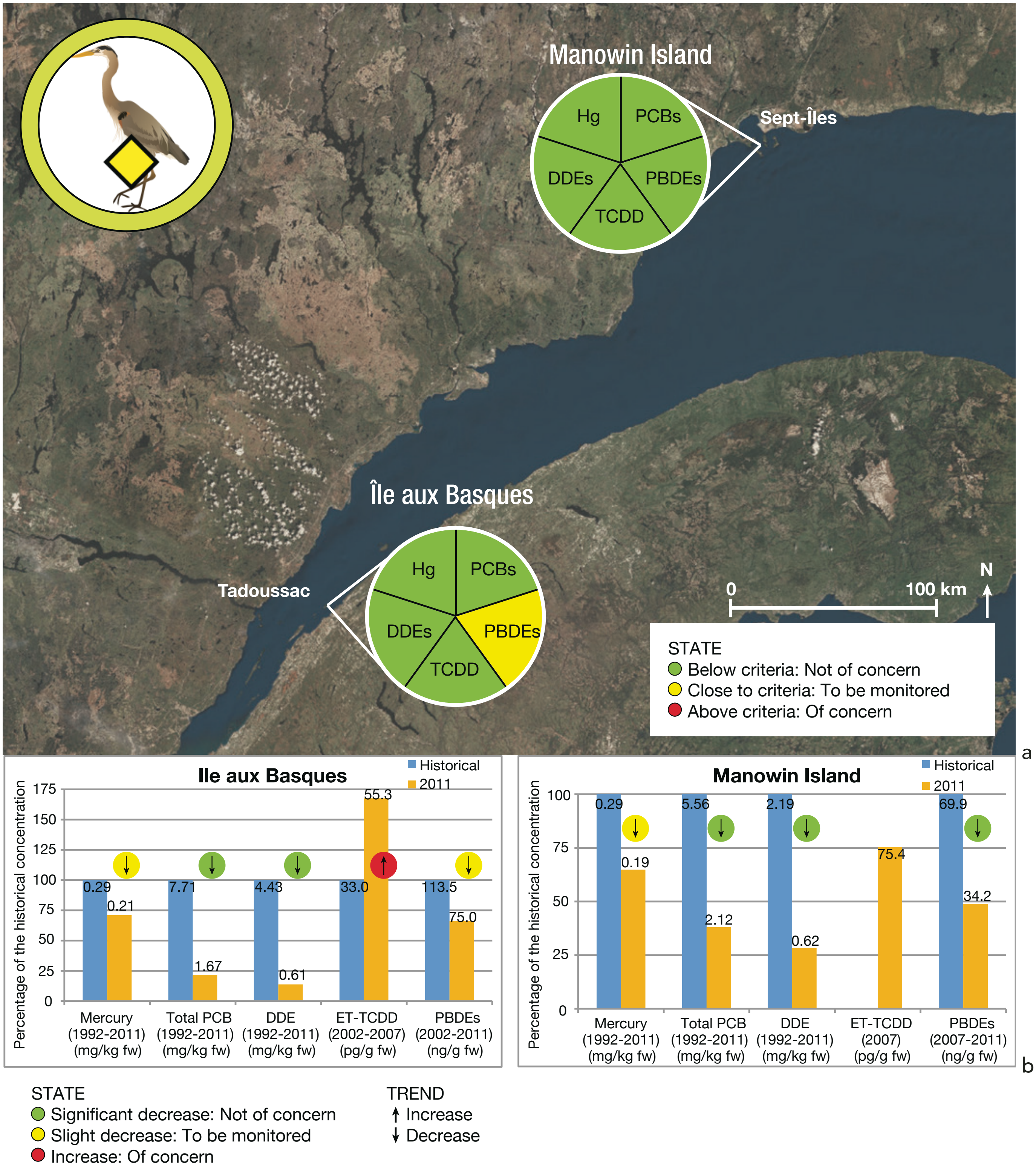


Figure 28. a) State of the contamination indicator of the Great Blue Heron in saltwater; b) Comparison of concentrations of contaminants in the eggs of the Great Blue Heron between historical and recent values

The values above each bar represent the concentrations.

The most recent concentrations of mercury, PCBs, DDE, ET-TCDD and PBDEs were compared to historical data (histograms) and to toxicity criteria or thresholds taken from scientific literature (pie charts). These contaminants have all decreased in the two colonies since monitoring started, except ET-TCDD on Île aux Basques. The average decrease is 32% (-68% to 86%) at Île aux Basques and 55% (34% to 72%) at Manowin Island. The concentrations of all contaminants are below the criteria at both colonies, except penta-BDE on Île aux Basques. For dioxins, despite an increase compared to 2002 at Île aux Basques, concentrations have remained below the criterion value.

Like the fluvial corridor, indicators of contamination in the estuary and the Gulf all show a decrease in historical contaminants (metals, PCBs, DDT). ET-TCDD, although in concentrations below the criterion, is higher in the eggs of the Northern Gannet than in the eggs of the Great Blue Heron in the fluvial corridor. With regards to emerging contaminants, PBDEs have increased among the Beluga Whale and decreased among birds, although penta-BDE exceeds the criterion at Île aux Basques.

2.1 Problem at Lake Saint-Pierre: Loss of ability to support the habitat and declining Yellow Perch

Lake Saint-Pierre is one of the major elements of the St. Lawrence ecosystem. This region was designated a Ramsar site in 1998 under the Convention on Wetlands of International Importance, and a World Biosphere Reserve by UNESCO in 2001. Its archipelago, in the upstream portion of the lake, has about a hundred islands and channels and up to 40% of all wetlands in the St. Lawrence, which are home to an exceptional wealth of plants and wildlife. Although its territory remains for the most part natural, Lake Saint-Pierre has undergone numerous changes since the 19th century due to human activities, including in its flood plain.

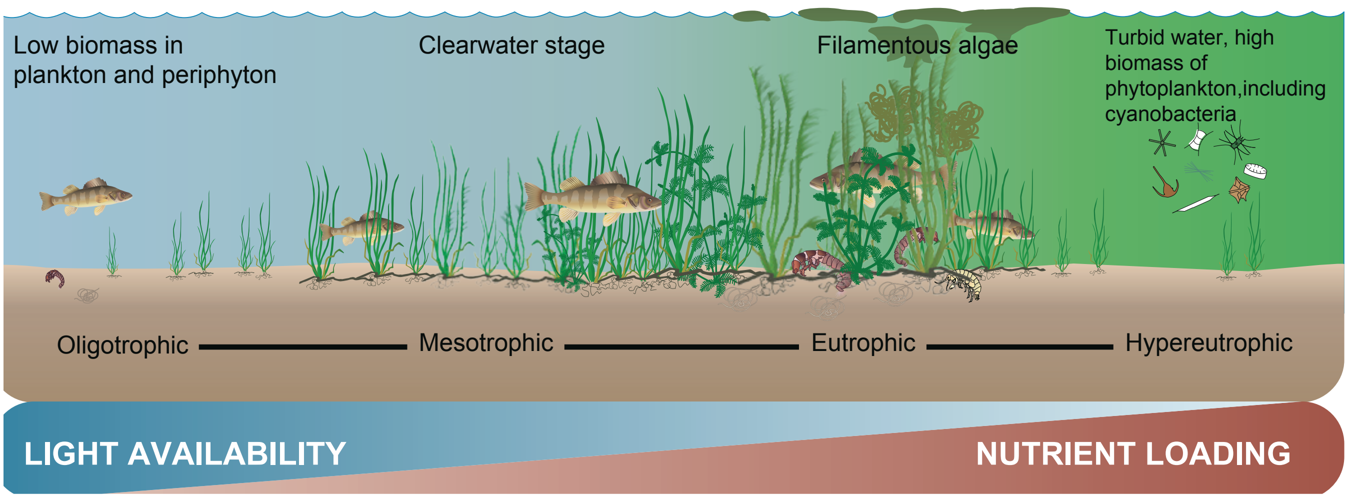


Figure 29. Changes that occur in an aquatic ecosystem as a result of changes in the supply of nutrients (adapted from Hudon et al. 2012)

Submerged aquatic plants constitute a major element of the fish habitat, providing them with shelter from predators and physical support for the algae and invertebrates that they eat. In their original state, shallow environments support low biomasses of algae and submerged plants (Figure 29). Enrichment by nutrients promotes the growth of aquatic vegetation and increases biological productivity, which increases the capacity to support fish habitats. However, beyond a certain critical threshold, excessive enrichment and turbidity in the water hampers the growth of submerged vegetation, thus causing a deterioration of the fish habitat. The passage of the enriched water of the Yamaska and Saint-François rivers through dense vegetation at the mouth of the rivers in Lake Saint-Pierre illustrates the link between nutrients, aquatic plants, invertebrates and fish along the south shore of Lake Saint-Pierre (Hudon et al. 2012). After the water from the tributaries goes through the vegetation, several phenomena occur:

- The dissolved nitrogen/phosphorous ratio is unbalanced and the organic nitrogen disappears.
- This change induces a decrease and the eventual disappearance of macrophytes, filamentous algae and epiphytes.
- These nutrient conditions and the disappearance of competitors foster the development of benthic cyanobacteria.

Carpets of cyanobacteria represent a habitat that is less complex and less rich in prey for fish, which results in a decrease in growth and survival among young Yellow Perch and in the number of adult fish species. Prior to this change, the area thus affected represented a vast area of reproduction, fry rearing, shelter and growth for a wide range of fish species. The presence of *Lyngbia wollei* and *Gleotrichia pisum* (two cyanobacteria) can therefore serve as an indicator of the effect of eutrophication on the aquatic ecosystem of the St. Lawrence.

Yellow Perch in Lake Saint-Pierre saw a major decline as of the mid-1990s. The situation became so critical that, in 2012, the Government of Québec decreed a 5-year moratorium on commercial and sport fishing. A recent study of the situation (De la Chenelière et al. 2014) found that, although fishing contributed to the collapse, Yellow Perch also suffered from the deterioration of its habitats since the 1950s. The analysis of land use based on aerial photography, combined with modelling of the best reproduction habitats in the littoral zone, indicates that 5000 ha of spring habitats were altered in a negative manner by a number of anthropogenic activities, primarily agricultural. The disappearance of vegetation and the proliferation of benthic cyanobacteria in the growth areas of young Yellow Perch, the decrease in the connectivity between the lake and the littoral zone, the climate, the introduction of competitive alien species and the introduction of a new avian predator (cormorant) have contributed to the failure in recruitment and the decline in Yellow Perch. Findings regarding the deterioration of Lake Saint-Pierre indicate that the situation will only improve once the species are able to reproduce and develop in a healthy environment, which will require the restoration of habitats and the improvement of water quality and connectivity between the lake and the littoral zone to allow for the partial or total recovery of the environment's historical capacity for support. The precarious state of the Yellow Perch, an important link in the aquatic communities of Lake Saint-Pierre, must be interpreted as one of many indicators of the deterioration of this exceptional ecosystem.

Reference:

HUDON, C., A. CATTANEO, A. M. TOURVILLE POIRIER, P. BRODEUR, P. DUMONT, Y. MAILHOT, J. P. AMYOT, S. P. DESPATIE AND Y. DE LAFONTAINE. “Oligotrophication from wetland epuration alters the riverine trophic network and carrying capacity for fish”. Aquatic Sciences, vol. 74, nº. 3, p. 495-511. (2012)

DE LA CHENELIÈRE, V., P. BRODEUR AND M. MINGELBIER. “Restauration des habitats du lac Saint-Pierre : un prérequis au rétablissement de la perchaude”. Le Naturaliste canadien, vol. 138, nº. 2, p. 50-61. (2014)

2.2 Historical and emerging contamination

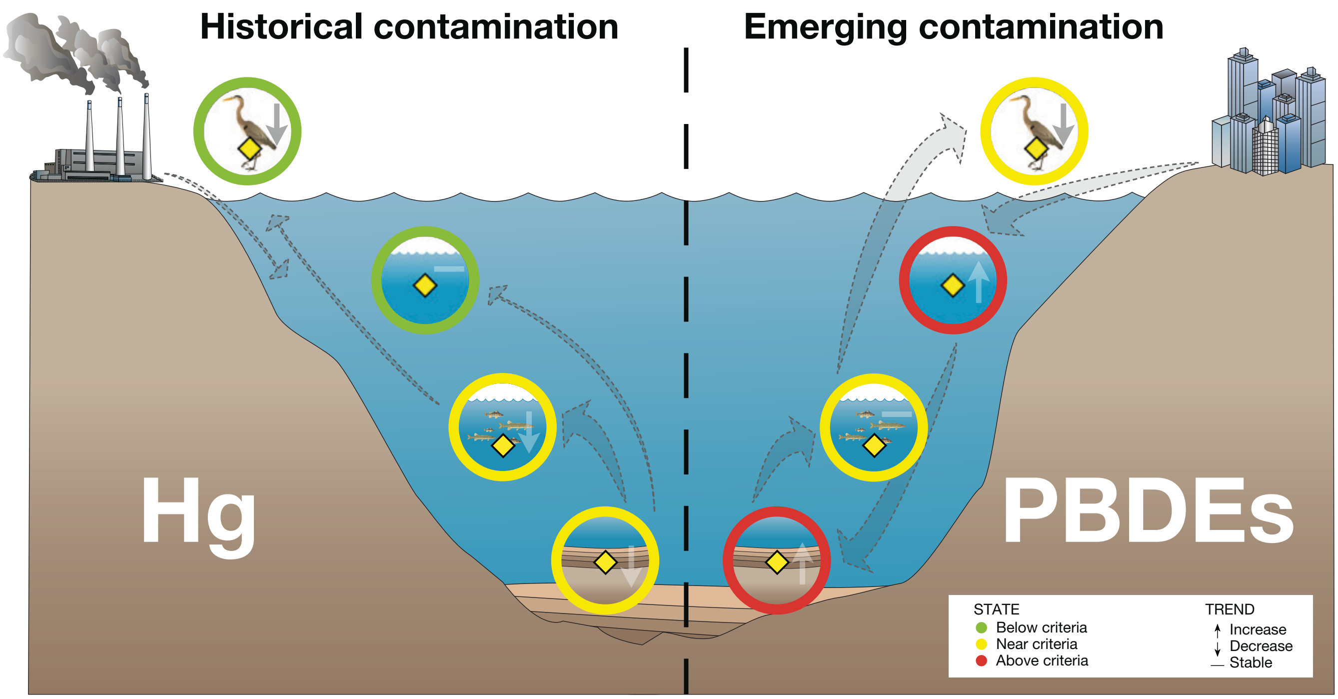


Figure 30. Comparison of historical contamination dating to the industrial era and emerging contamination, representing new substances entering the ecosystem

Regarding contamination by toxic substances in the St. Lawrence, we can see two groups of substances: historical contamination, i.e. that left by the industrial revolution, and emerging contamination, which is progressing and corresponds more to a sign of recent urban and industrial development. Historical contamination corresponds to metals, such as mercury, and other contaminants, such as organochlorine pesticides and PCBs. Emerging contamination consists of numerous groups of substances, such as PBDEs and PPCPs. PBDEs are fire retardants that have been used in polyurethane foam, electronic products, textiles and plastics since the 1970s. PPCPs include medications (hormones, antidepressants, etc.) and hygiene and beauty products. Although these products have been present in the environment for a long time, the development of analytical methods sensitive enough to detect them is more recent. When these two groups of substances are observed separately, we see different findings regarding their state and the trends observed in the environment. For historical contamination, we no longer see these substances exceed the criteria for protecting aquatic life in water and very little in sediments and living organisms, and most trends are downward. On the other hand, emerging contamination, such as PBDEs, often exceeds the criteria for aquatic life and we have seen an increase in concentrations over the last decade. It may be relevant to consider these groups of substances separately in the various indicators for contamination in order to not dilute the findings and obtain an average or moderate mark regarding the overall finding for them.

Some PDBEs have potential for bioaccumulation and may cause harmful effects in animals. Since the 1990s, various measures have been taken, including voluntary withdrawal of certain products by manufacturers and restrictions in Canada and other countries, and reductions have been observed in environmental concentrations, particularly in the eggs of the Great Blue Heron and the Northern Gannet in the Gulf and the St. Lawrence River.

Those restrictions, however, have resulted in an increase in the use of alternative fire retardants, which are also in the ecosystem and the potential effects of which are not known. A number of these products, such as hexabromocyclododecane (HBCDD), polybrominated biphenyl (PBBS), hexabromobenzene (HBB) and decabromodiphenyl ethane (DBDPE), are now commonly measured in scientific studies and certain monitoring programs. Once in the environment, several products degrade under the effect of factors such as light, or are metabolized by organisms, thus forming new products than can also be measured. For instance, hydroxylated PCBs (OH-PCBs) and methylsulfonyl PCBs (MeSO2-PCBs), products of the degradation of PCBs, are found in the tissue of birds. These products are just a few examples of emerging contaminants that could be measured as part of the monitoring program over the coming years.

Reference:

CHEN, D., R.J. LETCHER, N.M. BURGESS, L. CHAMPOUX, J.E. ELLIOTT, C.E. HEBERT, P. MARTIN, M. WAYLAND, D.V. CHIP WESELOH, L. WILSON. "Flame Retardants in Eggs of Four Gull Species (Laridae) from Breeding Sites Spanning Atlantic to Pacific Canada." Environmental Pollution 168: 1-9. (2012)

2.3 Secondary production in the estuary and Gulf

Zooplankton works as a major element of the ecosystem in the estuary and the Gulf of St. Lawrence by acting as a chain of transmission between primary production and higher links in the food chain. The survival of larvae from a wide range of invertebrate and fish species of commercial value depends on the availability of adequate zooplankton prey in sufficient quantities, which could contribute to the success of recruitment and to the productivity of such species in the St. Lawrence. Moreover, pelagic fish species such as Capelin, Sand Lance, Herring and Mackerel are primarily planktivores and therefore represent an important link between the secondary production system and large piscivorous predators.

Changes in the abundance and composition of zooplankton and in the seasonality of their production cycle have been observed over the past two decades (Plourde et al. 2013), resulting in various environmental systems characterized by considerable changes in the dynamic of the ecosystem (Plourde et al. 2013). The changes to the base of the ecosystem could therefore have a significant impact on the productivity of species of major economic value and on the dynamic of large predators such as the St. Lawrence Beluga Whale and other species of marine mammals. It is therefore essential to monitor the evolution of these changes to the base of the ecosystem in the future in order to anticipate the effect of climate change on the St. Lawrence ecosystem.

Reference:

PLOURDE, S., P. GALBRAITH, V. LESAGE, F. GRÉGOIRE, H. BOURDAGE, J. F. GOSSELIN, I. MCQUINN AND M. SCARRATT. “Ecosystem perspective on changes and anomalies in the Gulf of St. Lawrence: a context in support to the management of the St. Lawrence Beluga whale population”. Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, Research document 2013/129, v + 30 p. (2013)

2.4 An Evolving Program

Since its launch in 2001, the State of the St. Lawrence Monitoring Program has been modified to consider new scientific knowledge regarding the St. Lawrence ecosystem. Thus, over time, specific efforts have been made to focus the collection of data on ecologically sensitive areas that are subject to considerable anthropogenic pressure based on the ecosystem elements being considered. Particular attention has also been given to substances of interest and to emerging environmental issues in order to consider the concerns raised and to better report on the situation. The partners involved have also ensured that their monitoring activities optimized the resources available for implementing the program. Maintaining a comparable series of relevant monitoring activities over the long term nonetheless remains a constant challenge. Engagement, cooperation and the complementarity of activities planned as part of the program and distributed among partners remain key factors for the success of this process in a spirit of continuity.

To maintain a dynamic program that is useful in decision making regarding the St. Lawrence, we face several challenges. In the near future, in addition to integrating new knowledge that will, among other things, allow for the development and amelioration of environmental indicators, the links between monitoring the state of the St. Lawrence and environmental forecasting must be explored and reinforced to help the users of the information generated. The same applies to the complementarity between the results generated by this program, the more systematic evaluation of pressures on the ecosystem, and the responses put forth to improve the state of the St. Lawrence, which explain to a great degree the state of the St. Lawrence and the trends observed there.

In a context of integrated management of the St. Lawrence, the State of the St. Lawrence Monitoring program is a key support tool for decision making. It requires constant vigilance by all players involved so the pooling of scientific expertise and resources among various organizations can continue, with the ultimate goal of disseminating information regarding the health of this complex ecosystem. The various resulting information products will continue to be available on a regular basis, to emphasize the integration of results, and to foster the development of environmental policies aimed at saving this great river, which is an unparalleled source of collective wealth.

GLOSSARY

Bioaccumulation: Increase in concentrations of toxic contaminants in an organism over time.

Biomagnification: Increase in concentrations of toxic contaminants upwards in the hierarchical levels of the food chain.

DDE (or p,p'-DDE): The most persistent and most toxic product of DDT degradation.

DDT (dichlorodiphenyltrichloroethane): Approved for the first time as a pesticide under the Pest Control Products Act (PCPA) in the 1940s. Although it was never manufactured in Canada, it was widely used in pest control products in the 1960s. To address growing concerns regarding the environment and safety, most Canadian uses of DDT were progressively eliminated by around the mid-1970s. Registration of all uses of DDT was eliminated in 1985 on condition that existing stocks be sold, used or disposed of no later than December 31, 1990.

Dioxins and furans (polychlorinated dibenzodioxins and polychlorinated dibenzofurans): These persistent and bioaccumulative toxic compounds, resulting primarily from human activities, are found in the components of ecosystems, including air, water, soil, sediments, animals and food. Dioxins and furans enter the environment as complex mixtures from four main sources: commercial chemical products (e.g., pentachlorophenol); incinerators; pulp mills, where chlorine is used to bleach pulp; fires; and accidental spills that release polychlorinated biphenyls (PCBs, which contain furans as their main contaminants).

ET-TCDD (toxic equivalent (ET) of 2,3,7,8-TCDD): The most toxic of dioxins and furans. Toxic equivalent is a measurement calculated based on the relative toxicity of a group of substances compared with that of 2,3,7,8-TCDD. 2,3,7,8-TCDD is recognized as being the most toxic chemical composite currently known on earth.

Mercury: Mercury is a naturally occurring element found in the earth's crust in natural deposits, usually in the form of a vermillion red mineral known as cinnabar. Approximately half of the mercury currently present in the environment is from human activities (such as carbon combustion and the incineration of waste), while the other half can be attributed to natural sources or processes. Mercury is persistent and accumulates in living organisms (it is bioaccumulative). Mercury is currently on the List of Toxic Substances under the provisions of the Canadian Environmental Protection Act, 1999.

Metals: Metals are among the elements that make up the earth's crust and are therefore naturally present in watercourses. It is only when their concentrations exceed a certain threshold that we can conclude that there is a significant contribution by human activities. Some metals, such as iron, zinc or copper, are essential trace elements for many organisms. Conversely, other metals are not essential elements that make up living matter and, when absorbed by an organism, they can prove toxic. Such is the case, for example, for lead and cadmium.

Organochlorine pesticides: Organochlorine pesticides were the first synthetic pesticides to appear on the market in the 1940s. They are generally insecticides that, given their persistent, bioaccumulative and toxic nature, are current prohibited or limited in use. They are divided into five groups based on their chemical structure: DDT and associated compounds, benzene hexachloride (BHC), cyclodienes and associated compounds, mirex and toxaphene

PAHs (polycyclic aromatic hydrocarbons): PAHs released into the Canadian environment are from natural and anthropogenic sources. Forest fires alone are one of the most significant natural sources of PAHs in Canada. There are many anthropogenic sources that produce PAH emissions in all environments. The largest sources of atmospheric releases of PAHs are residential wood heat and aluminum smelters. The main sources of PAH releases into water and soil include products treated with creosote, spills of petroleum products, metal manufacturing plants and coking plants, as well as fallout of PAHs of the atmosphere.

PBDEs (polybrominated diphenyl ethers): A group of 209 chemical products (varying from mono-PBDEs to deca-PBDEs depending on the number of bromine atoms) widely used as fire retardants (that slow down ignition and the spread of flames) in polyurethane foam, electronic products, textiles, plastics and other materials. Since 2006, the use of commercial mixtures of penta-BDEs and octa-BDEs has been progressively eliminated both internationally and in Canada.

PCBs (polychlorinated biphenyls): A group of 209 chemical products (from mono-PCBs to decachloro-PCBs, depending on the number of chlorine atoms) used as dielectrics in electrical transformers and condensers, in coolants, in paint additives and in plastics, cutting oils and ink. In 1977, concern regarding the effects of PCBs on the environment led to a ban on their manufacture and import into North America. However, that ban did not apply to PCBs already in use in electrical applications; such PCBs are being gradually eliminated.

Penta-BDEs: See PBDEs.

POPs (persistent organic pollutants): A general term that includes organochlorine pesticides, industrial chemical products (PCBs and benzene hexachloride) and sub-products and contaminants (dioxins and furans). Persistent organic pollutants are toxic substances released into the environment by various anthropogenic activities. They have negative effects on the health of ecosystems, wildlife species and people.

PPCPs (pharmaceuticals and personal care products): These include medication (hormones, antidepressants, etc.) and hygiene and beauty products. They have been measured in wastewater and surface water for about 15 years. These products include ibuprofen and triclosan.

p,p'-DDE: See DDE.

Siloxanes (or silicones): These compounds, which are exclusively anthropogenic, are produced industrially on a large scale. They are compounds of an alkane chain and of groups of oxygen and silica. Their properties depend on the length of the Si-O chain. They can be cyclical or linear. They are widely used in the cosmetics and personal care industry, where they are known as methicones. They are also used as lubricants, cleaners, in construction materials, as antifoaming agents, etc. They are often highly volatile. Generally, they are very stable compounds, which make them persistent in the environment.

TBTs (tributyltins): These are part of a group of substances known as organotins, which are used primarily in the processing of PVC (a type of plastic) and pesticides. The use of TBTs in antifouling paint (used to cover hulls of boats to prevent sea organisms from attaching themselves to them) to finish the hulls of ships is now prohibited in Canada. TBTs have been added to the list of toxic substances (June 2011) in Schedule 1 of the Canadian Environmental Protection Act, 1999.

Tetra-BDE: See PBDEs.

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