ST. LAWRENCE
Action Plan 2011–2026

Overview of the State of the St. Lawrence 2024

Canada

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Québec

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1. State of the St. Lawrence Monitoring Program

1 State of the St. Lawrence Monitoring Program

1.1 The St. Lawrence hydrographic system, one of the largest in the world

The St. Lawrence River has its origins in the Great Lakes, at the heart of one of the most important industrial regions in North America. The river's drainage basin covers a surface area of 1.6 million km^2, making it the third largest in North America, after that of the Mississippi and Mackenzie rivers. It drains more than 25% of the world's freshwater reserves and influences environmental processes across the entire North American continent.

Figure 1.1 Hydrographic regions of the St. Lawrence: fluvial section, fluvial estuary, upper estuary, lower estuary and Gulf of St. Lawrence

1.2 The St. Lawrence: a rich and complex ecosystem

The St. Lawrence ecosystem is complex, consisting of a series of fluvial lakes interspersed with fluvial reaches that make up the fluvial section, as well as a long estuary and a gulf that is marine in character (Figure 1.1). Its physical properties (currents, depths, water masses, salinity and tides) change from upstream to downstream, resulting in an extremely dynamic river system. The St. Lawrence contains a wide variety of freshwater, estuarine and marine habitats, and a rich diversity of flora and fauna (Figure 1.2). Since the natural physical characteristics of the St. Lawrence have a considerable influence on its biodiversity and habitats, it is important to take the former into account when assessing the river's state of health, and to make a clear distinction between natural impacts and those resulting from human disturbances.

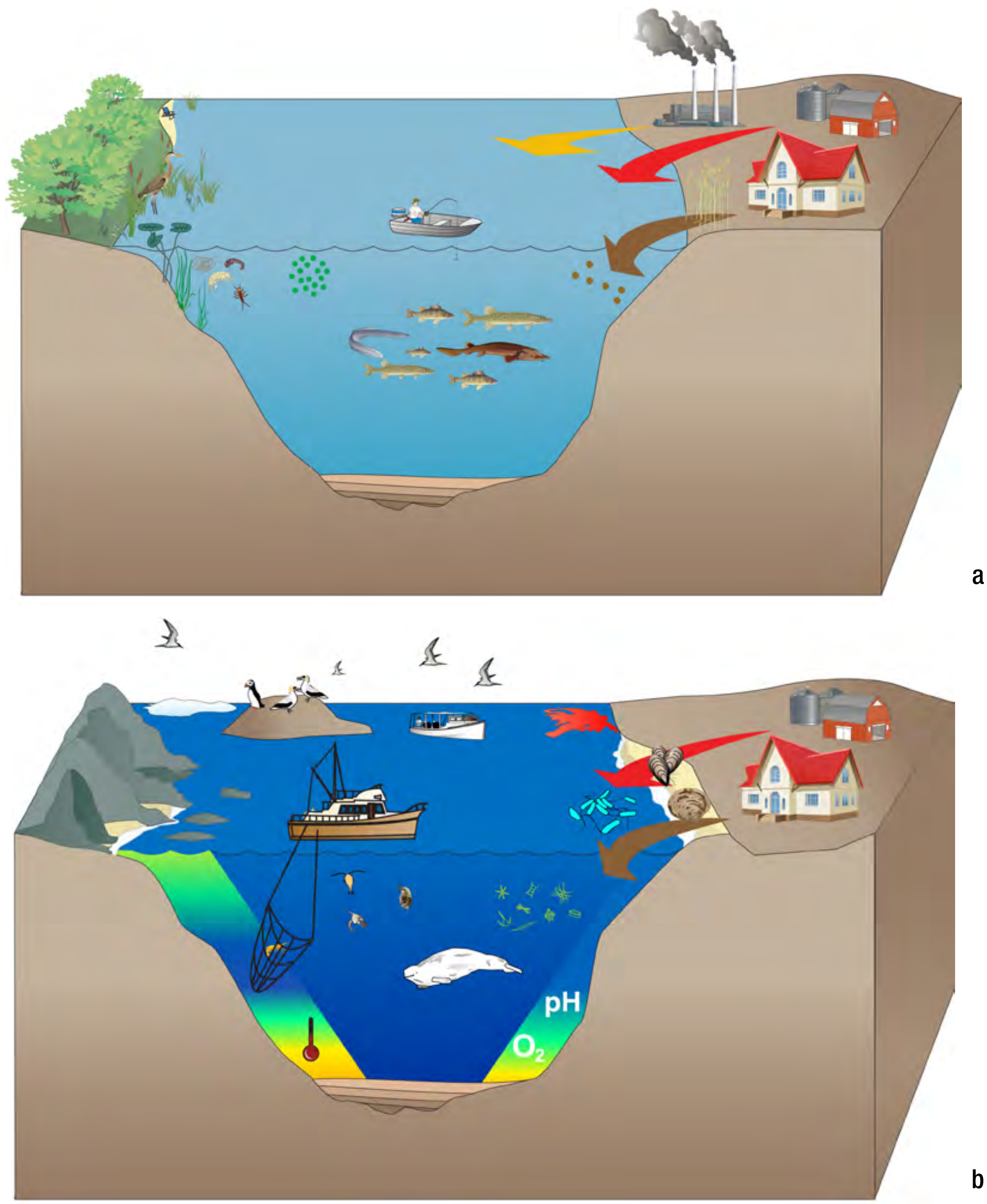


Figure 1.2 Ecosystems in (a) the fluvial section and (b) the estuary and Gulf of St. Lawrence

1.3 A partnership-based environmental monitoring program for the St. Lawrence established in 1988

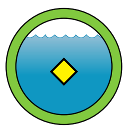
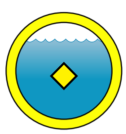
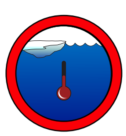
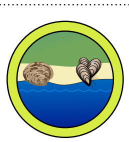
The *Overview of the State of the St. Lawrence 2024* is the fifth edition. This publication, which first appeared in 2003, is produced under the State of the St. Lawrence Monitoring Program, pursuant to the Canada–Quebec Agreement on the St. Lawrence 2011–2026 (St. Lawrence Action Plan 2011–2026). Various partners monitor a series of environmental indicators at regular intervals, over an area extending from the Quebec–Ontario border to the Gulf of St. Lawrence, to collect the data for the Overview. The data in the Overview of the State of the St. Lawrence 2024 typically cover the period from 2018 to 2022.

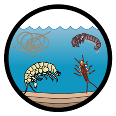
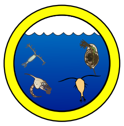
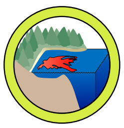
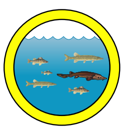
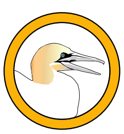
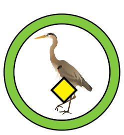
Diagnosis by environmental monitoring activity

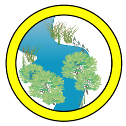
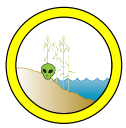
Poor	Moderate-poor	Moderate	Moderate-good	Good

Table 1.1 State of the St. Lawrence 2024 monitoring activities, grouped by element[1]

The status of the indicators monitored in these activities (which ranges from "good" to "poor") is based on a series of sub-indicators. Each indicator is portrayed by a pictogram, with the coloured circle around it representing its overall status.

ELEMENT	SYMBOL	ENVIRONMENTAL MONITORING ACTIVITY	LEAD ORGANIZATION	HYDROGRAPHIC REGIONS OF THE ST. LAWRENCE
Water		Contamination of river water by toxic substances	Environment and Climate Change Canada (ECCC)	Fluvial section and fluvial estuary
		Safety of potential swimming sites[2]	Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MELCCFP)	Fluvial section and fluvial estuary
		Pesticides in Lake Saint-Pierre[2]	Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MELCCFP)	Fluvial section
		Oceanographic processes: dissolved oxygen and acidity	Fisheries and Oceans Canada (DFO)	Lower estuary and Gulf of St. Lawrence
		Oceanographic processes: water temperature and sea ice	Fisheries and Oceans Canada (DFO)	Lower estuary and Gulf of St. Lawrence
		Shellfish water quality	Environment and Climate Change Canada (ECCC)	Lower estuary and Gulf of St. Lawrence

ELEMENT	SYMBOL	ENVIRONMENTAL MONITORING ACTIVITY	LEAD ORGANIZATION	HYDROGRAPHIC REGIONS OF THE ST. LAWRENCE
Biological resources		Benthic macroinvertebrate communities	Environment and Climate Change Canada (ECCC)	Fluvial section
		Phytoplankton communities	Fisheries and Oceans Canada (DFO)	Lower estuary and Gulf of St. Lawrence
		Zooplankton communities	Fisheries and Oceans Canada (DFO)	Lower estuary and Gulf of St. Lawrence
		Toxic algae	Fisheries and Oceans Canada (DFO)	Lower estuary and Gulf of St. Lawrence
		Striped Bass population	Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MELCCFP)	Fluvial section, fluvial estuary, and upper estuary
		Fish communities	Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MELCCFP)	Fluvial section, fluvial estuary, and upper estuary
		Beluga population	Fisheries and Oceans Canada (DFO)	Upper estuary and lower estuary
		Northern Gannet population	Environment and Climate Change Canada (ECCC)	Lower estuary and Gulf of St. Lawrence
		Contamination of the Great Blue Heron by toxic substances	Environment and Climate Change Canada (ECCC)	Fluvial estuary, upper estuary, lower estuary, and Gulf of St. Lawrence

ELEMENT	SYMBOL	ENVIRONMENTAL MONITORING ACTIVITY	LEAD ORGANIZATION	HYDROGRAPHIC REGIONS OF THE ST. LAWRENCE
		Seabird populations	Environment and Climate Change Canada (ECCC)	Lower estuary and Gulf of St. Lawrence
		Wetland area[2]	Environment and Climate Change Canada (ECCC)	Fluvial section
		Monitoring of invasive alien plant species	Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MELCCFP)	Fluvial section, fluvial estuary, and upper estuary

1. As a result of interruptions in data collection, some indicators have incomplete data and cannot be included in the 2024 Overview: invasive animal species, monitoring of land use, physicochemical and bacteriological parameters, contamination of sediments by toxic substances, contamination of freshwater fish by toxic substances, monitoring of marine aquatic invasive species, and flow. Details on these monitoring activities can be found on the St. Lawrence Action Plan website.

2. Indicator not included in the previous Overview (2019).

2. Overall state of the St. Lawrence and changes

2 Overall state of the St. Lawrence and changes

According to the synthesis of the results for the monitoring indicators for the 2018–2022 period, the overall assessment of the status of the St. Lawrence is “moderate,” based on the median value of the 2024 indicators. Among the latter, 35% are in the “moderate-good” and “good” categories; 41% are in the “moderate” category; and 24% are in the “moderate-poor” and “poor” categories.

This overall status therefore represents a slight deterioration relative to the 2019 Overview, in which the river’s overall status was rated as “moderate-good.” However, this decline may be related to the fact that four indicators rated as “moderate-good” in the 2019 report were omitted in the 2024 report. When only the indicators included in both overviews are considered, the overall status remains unchanged. A detailed analysis of the State of the St. Lawrence Monitoring Program indicators revealed the following results:

- Water quality in the St. Lawrence differed by sector. Although various toxic substances were detected in most river water samples, none were found in concentrations that exceeded the water quality guidelines, except for some samples from Lake Saint-Pierre, where levels of a few pesticides exceeded the guidelines. The safety of swimming areas in the river varied by location, with roughly half of the sites assessed as having good swimming potential. Shellfish water quality in the Magdalen Islands and on the Lower North Shore was excellent, although this was not the case in the Gaspé and Lower St. Lawrence regions where only 15% of sites have a good score, respectively. With respect to oceanographic processes, oxygen saturation and pH values reached their lowest levels on record, and the water in the deepest layers (below 300 m) is warming.
- The status of most of the biological resource indicators was similar to that in the 2019 Overview. In the lower estuary and Gulf of St. Lawrence, changes were observed in the phenology of phytoplankton and toxic algal blooms, as well as in phytoplankton and zooplankton biomass. The status of fish communities was variable. Some declines were observed, attributable to the degradation of aquatic habitats, among other factors. Encouragingly, 20 years after the launch of the Striped Bass reintroduction program, the species’ population continues to show signs of recovery. Although some metrics used to assess the health of the St. Lawrence Beluga population have improved, its overall status remains worrisome. Even though the species’ decline has been reversed, the increased mortality of adult females and newborns has continued since 2010. Contaminant levels in Great Blue Heron eggs have universally decreased relative to historical values. Among seabird populations, the Common Murre and Razorbill are doing well, the condition of the Atlantic Puffin is improving, and the Caspian Tern is making a tentative comeback. In contrast, the Herring Gull population has continued to decline.
- Lastly, the status of wetlands in the St. Lawrence has continued to deteriorate since 1990. The most significant pressures on these habitats are agricultural activities, water level fluctuations, and the presence of invasive alien plant species, with Reed Canarygrasss, Common Reed and Purple Loosestrife being the worst culprits.

2.1 Indicators of change

The wide diversity of indicators considered in this Overview make it possible to appreciate the complexity of the various environmental issues impacting the St. Lawrence River. For example, some water quality indicators—such as concentrations of pesticides and toxic substances, and bacteriological quality—are directly indicative of specific environmental stressors. Other indicators are more indirect, such as the spread of invasive plant species and toxic algae, and changes in wetland area and oceanographic processes in the estuary; these indicators reveal changes in the state of health of the St. Lawrence. Lastly, biological resource indicators reflect the combined impact of multiple stressors on St. Lawrence ecosystems.

However, all the indicators used to monitor the state of the St. Lawrence will be impacted by climate change. For example, modifications in ocean currents driven by climate change will affect water temperatures and oxygen levels in the estuary. Climate change will also have an impact on phytoplankton production, the timing and frequency of algal blooms, and the growth and composition of zooplankton communities. In addition, shifts in fish distribution and abundance will likely affect the availability of food for seabirds. Climate change is also altering wetland dynamics, which will have consequences on the important role of wetlands in maintaining water quality and in mitigating erosion and the effects of flooding.

Each monitoring activity, along with its associated indicator, is outlined in the following section, beginning with a summary of its status and how it has changed over time. The environmental issues that the indicators specifically target and how climate change could affect the indicators are also discussed. Further details on these monitoring activities are provided in fact sheets available on the St. Lawrence Action Plan website.

Contamination of river water by toxic substances

Lead organization: Environment and Climate Change Canada (ECCC)
Study area: fluvial section and fluvial estuary

Status: good in 2018–2022
Trend: unchanged since 2004

The 2019 Overview focused on metals, pesticides and polybrominated diphenyl ethers (PBDEs) to assess the status of this indicator. However, since PBDEs have shown a continued overall downward trend, less effort has been expended on monitoring these compounds. Instead, the 2024 Overview targets perfluoroalkyl compounds and bisphenols, along with metals and pesticides, to evaluate contaminants in the river's waters. It should be noted that the data are incomplete for the period between January 2020 and September 2022, due to the suspension of sampling activities during the pandemic.

Pesticides: status "good" in 2018–2022, trend unchanged since 2004

No values exceeding the water quality guidelines were observed for the 45 organophosphate, triazine and carbamate pesticides analyzed, or for their degradation compounds.

Samples from the Châteauguay monitoring station had the highest concentrations of linuron (240 ng/L), metolachlor (570 ng/L) and metribuzin (300 ng/L), three herbicides commonly used on field crops. Across all sites, 13 of the 45 compounds analyzed were detected in over 80% of the samples in 2022, including atrazine and two of its degradation compounds, as well as butylate, chlorpyrifos, diazinon, dimethenamid, dimethoate, ethyl dipropylthiocarbamate (EPTC), metolachlor, metribuzin, propazine and simazine. Significant downward trends were observed in simazine and cyanazine concentrations, while atrazine and metolachlor concentrations remained stable between 2004 and 2020.

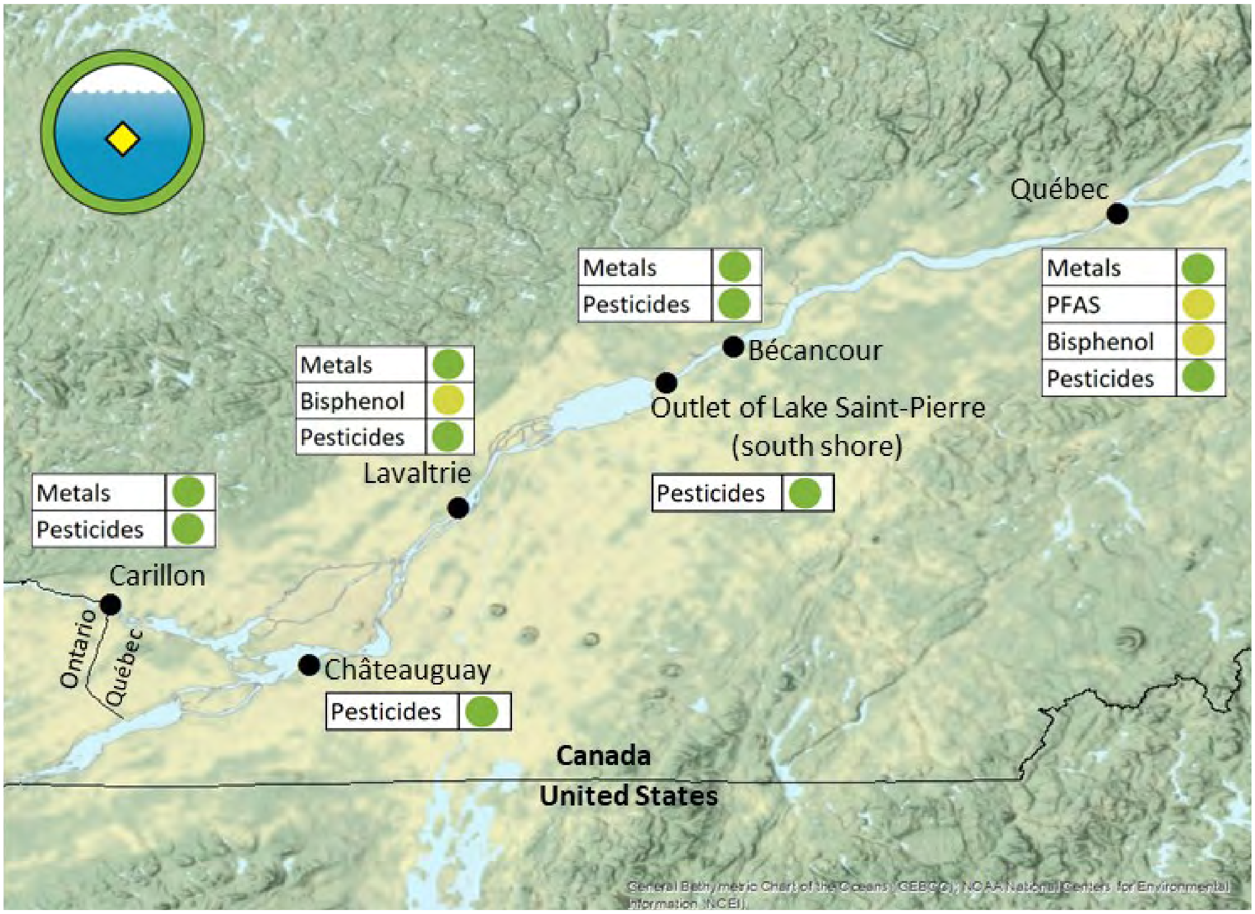


Figure 2.1 Status of water contamination by pesticides, metals, perfluoroalkyl compounds and bisphenols at water quality monitoring stations

Two neonicotinoids – clothianidin and thiamethoxam – were detected in 100% of the samples, but all concentrations were below the water quality criteria for the protection of aquatic life (MELCC, 2020; RIVM, 2014). The highest neonicotinoid concentration was observed at the Bécancour station, for clothianidin (3.4 ng/L).

The highest glyphosate levels were measured at the Châteauguay station (996 ng/L) and the station located on the south shore of Lake Saint-Pierre (62.2 ng/L). Although maximum concentrations are generally observed in June, they meet Canadian water quality guidelines of 800 µg/L (CCME).

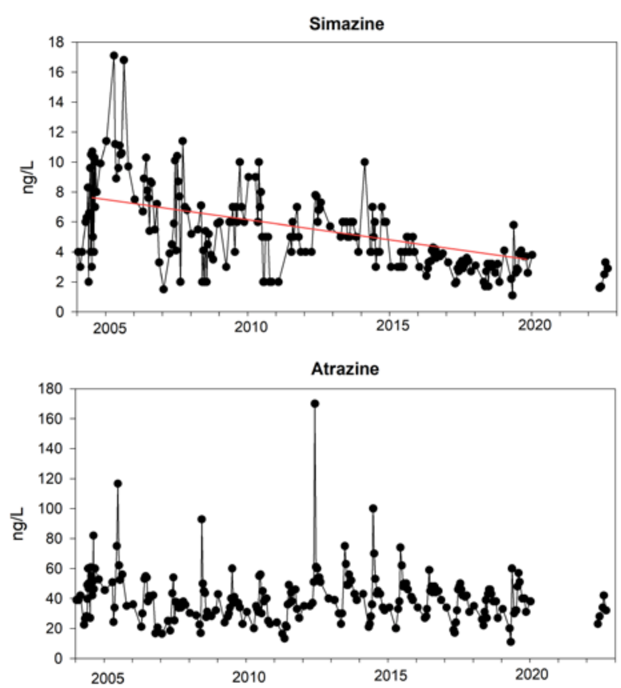


Figure 2.2 Simazine and atrazine concentrations (ng/L) at the Quebec City sampling station between 2004 and 2022

Metals: status "good" in 2018–2020, unchanged since 2004

No values exceeding the water quality guidelines were observed for metals, including arsenic, silver, cadmium, copper, iron, mercury, nickel, lead and zinc.

Although metals were detected in over 98% of samples collected between 2018 and February 2020, metal concentrations never exceeded the water quality guidelines for the protection of aquatic life (CCME; U.S. EPA 1998). No spatial gradients were observed in contaminant levels, except in arsenic and cadmium, whose concentrations increased from west to east (i.e. from the Carillon station to the Quebec City station).

Over the past 15 years, significant declines have been observed in cadmium and copper concentrations. However, iron concentrations have increased significantly at the Carillon, Lavaltrie and Quebec City stations, although they remain within the guidelines.

Perfluoroalkyl compounds and bisphenols: status "good" in 2022

A number of perfluoroalkyl substances (PFAS)—i.e. PFBA, PFPeA, PFHxA, PFOA and PFOS—were detected in 100% of the samples taken at the Quebec City station.

The values observed for PFOS and PFOA are below the water quality guideline of 6.8 µg/L (ECCC 2022). These low concentrations are likely attributable to the enactment of a regulation in 2008 prohibiting the use, sale, offer for sale or import of these two compounds.

PFBA, PFPeA and PFHxA, which were detected in concentrations ranging from 0.93 ng/L to 7.79 ng/L, were still unregulated as of 2022 and no guidelines for the protection of aquatic life have been established to date. These substitute products are being used by industry to replace regulated PFAS, and will require increased monitoring and studies to establish criteria to protect the aquatic environment.

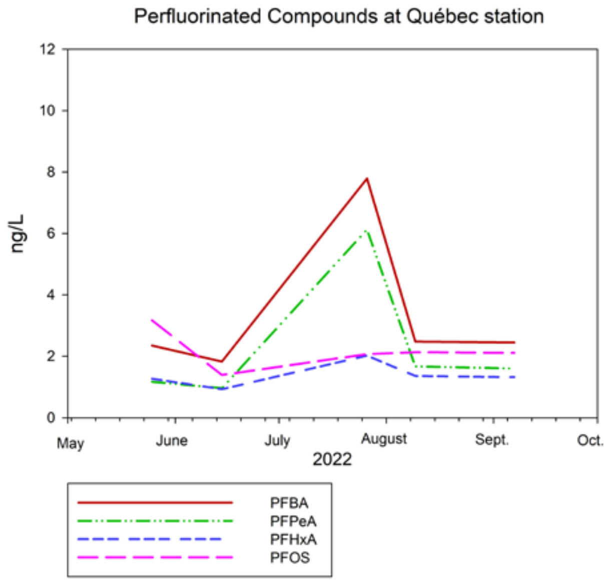


Figure 2.3 Concentrations (ng/L) of five perfluoroalkyl compounds at the Quebec City sampling station from May to September 2022

The situation for bisphenols was similar. Although bisphenol A was below the detection limit in all samples, bisphenol S was detected in 50% of samples from the Quebec City station in the spring and summer of 2022. Indeed, bisphenol S is increasingly being used as a substitute for bisphenol A, which was classified as a toxic substance in Schedule 1 of the *Canadian Environmental Protection Act, 1999* (CEPA) (Government of Canada 2010). In addition, bisphenol A is covered in the existing water quality guidelines, but bisphenol S is not, although recent research suggests that bisphenol S can be equally harmful (Wu et al. 2018). Therefore, continuing to monitor this compound in the aquatic environment is extremely important.

What does this indicator tell us about the environmental issues affecting the St. Lawrence River?

The water quality monitoring program in the St. Lawrence targets environmentally persistent substances, such as metals, pesticides and certain organic compounds. Some of these substances may be bioaccumulative, and therefore are likely to contaminate the food web, through urban, industrial and agricultural wastewater discharges and runoff. Although metals occur naturally in the environment in low concentrations, human activities can cause them to increase.

■ **How is this indicator affected by climate change?**

Lower water levels in the St. Lawrence River due to climate change could worsen water quality by decreasing the dilution of contaminants, resulting in increased concentrations in the water. In addition, changes in the river's flow regime could disturb contaminated sediments, and remobilize the contaminants. Furthermore, the flow of the St. Lawrence River plays an important role in transporting contaminants.

For more information

LAFRANCE, Myriame, and Caroline ROBERT, 2020. Contamination of water by toxic substances. Fact sheet. State of the St. Lawrence Monitoring Program. Environment and Climate Change Canada.

References

CANADIAN COUNCIL OF MINISTERS OF THE ENVIRONMENT (CCME), *Canadian Environmental Quality Guidelines*. [Online], https://ccme.ca/en/resources (consulted in April 2023).

ENVIRONMENT AND CLIMATE CHANGE CANADA (ECCC), 2022. *Federal Environmental Quality Guidelines (FEQGs)*. [Online], https://www.canada.ca/en/health-canada/services/chemical-substances/fact-sheets/federal-environmental-quality-guidelines.html (consulted in January 2023).

GOVERNMENT OF CANADA, 2010. Order Amending Schedule I to the Hazardous Products Act (bisphenol A). *Canada Gazette*, Part II, Vol. 144, No. 7, pp. 413–426.

MINISTÈRE DE L'ENVIRONNEMENT ET DE LA LUTTE CONTRE LES CHANGEMENTS CLIMATIQUES (MELCC), 2020. *Recommandation de critères de qualité de l'eau du chlorantraniliprole pour la protection de la vie aquatique*, Direction générale du Suivi de l'État de l'Environnement.

RIVM (Rijksinstituut voor Volksgezondheid en Milieu), 2014. *Water quality standard for imidacloprid, Proposal for an update according to the framework directive*, Ministry of Health, Welfare and Sport, Netherlands, National Institute for Public Health and the Environment. 92 pp.

U.S. ENVIRONMENTAL PROTECTION AGENCY (U.S. EPA), 1998. National Recommended Water Quality Criteria; Republication, Notices, *Federal Register*, Vol. 63, No. 237, pp. 68354–68364.

WU, Liu-Hong, Xue-Mei ZHANG, Fei WANG, Chong-Jing GAO, Da CHEN, Jillian R. PALUMBO, Ying GUO, and Eddy Y. ZENG, 2018. "Occurrence of bisphenol S in the environment and implications for human exposure: A short review," *Science of The Total Environment*, Vol. 615, pp 87–98.

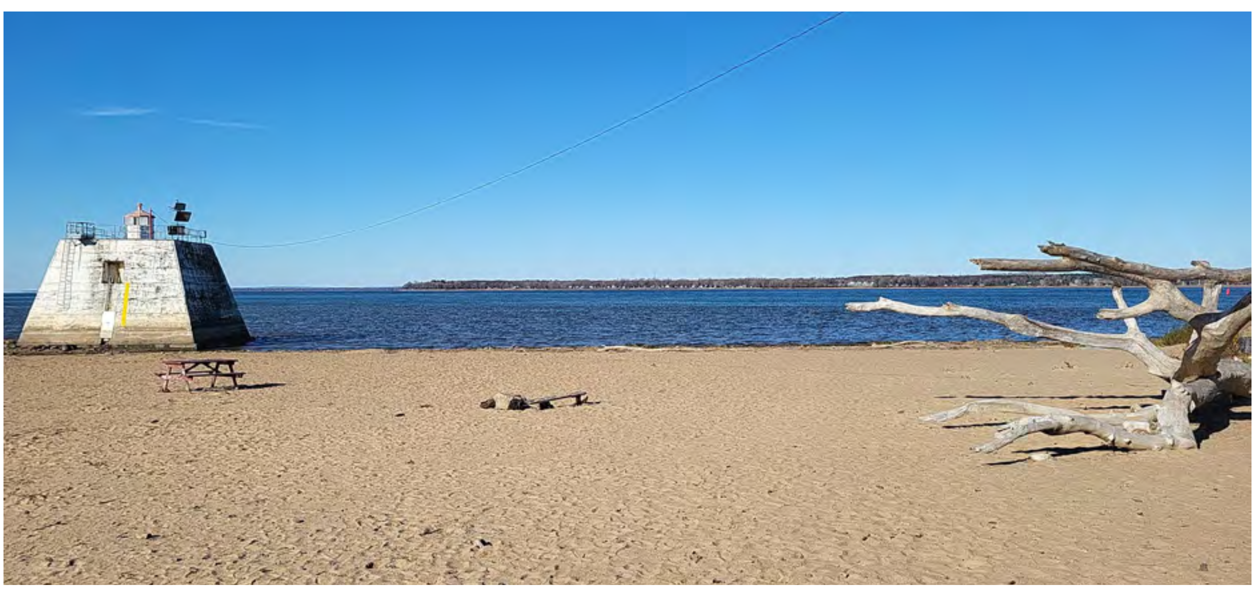
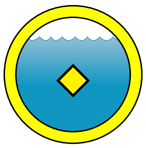


Photo: Laurie Mercier, ECCC

Pesticides in Lake Saint-Pierre

Lead organization: Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MELCCFP)
Study area: fluvial section (Lake Saint-Pierre)



Status: moderate in 2017–2021
Trend: improvement since 2014–2015

Lake Saint-Pierre's abundant wetlands and aquatic grass beds support significant biological diversity, leading to its designation as a Biosphere Reserve by UNESCO. Pesticide monitoring in Lake Saint-Pierre is part of concerted efforts by researchers and governments to understand certain changes in the lake's ecosystem, such as the decline in the Yellow Perch population and changes to the Lake's aquatic grass beds.

A range of pesticides detected

Sampling was carried out during the summers of 2017 to 2021 at three stations in the shallow waters on the south shore of the lake to ascertain the number of pesticides present and the frequency with which Quebec's chronic aquatic life toxicity criteria (critères de vie aquatique chroniques, or CVAC) were exceeded. Among the 100 or so pesticides monitored, 23 products were detected (Figure 2.4). Products intended generally for corn and soybean crops were the ones most commonly detected.

Herbicides: Atrazine and S-metolachlor were ubiquitous, detected in 97% and 93% of samples, respectively. Several other herbicides, such as glyphosate, imazethapyr and 2,4 dichlorophenoxyacetic acid (2,4-D), were also present, as were the degradation products of atrazine (deethylatrazine [DEA] and deisopropylatrazine [DIA]) and glyphosate (aminomethylphosphonic acid [AMPA]).

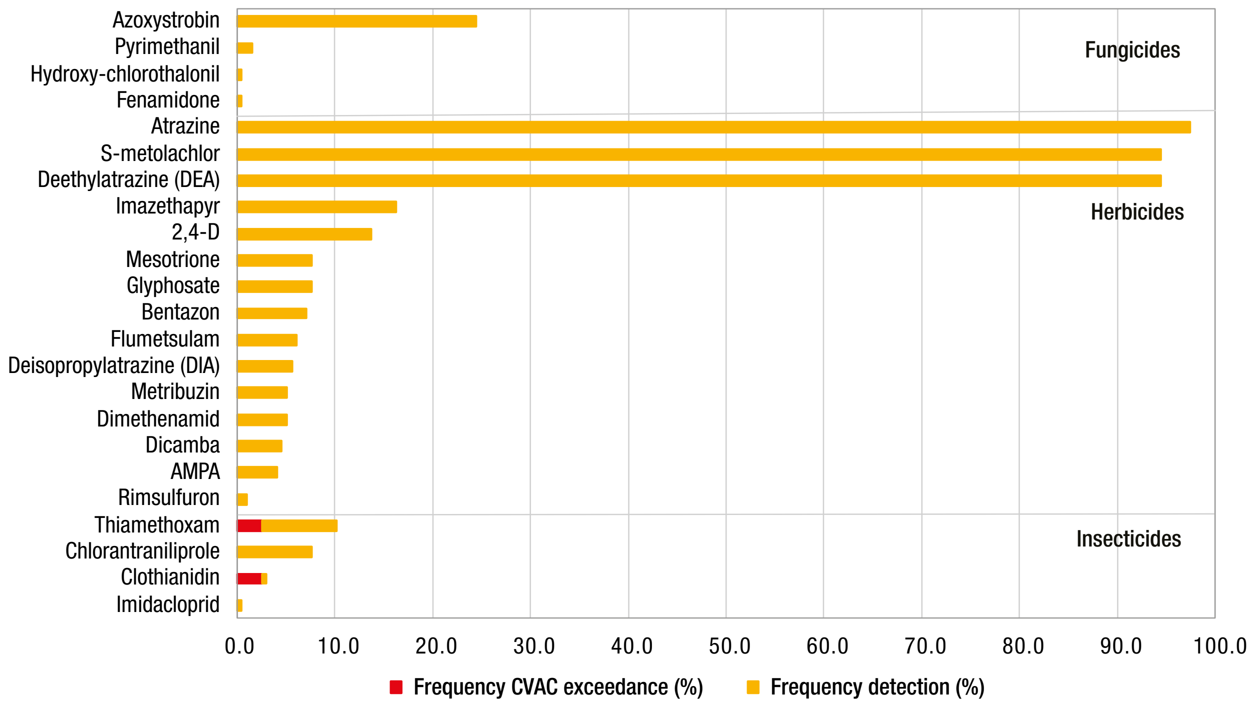


Figure 2.4 Frequency of detection of various pesticides and their CVAC exceedance in Lake Saint-Pierre between 2017 and 2021 (%)

Fungicides: Among the fungicides detected, azoxystrobin was the most common, found in 24% of samples. This fungicide is used as a seed treatment.

Insecticides: Overall, neonicotinoids were detected in 10% of samples: thiamethoxam (10% of samples) was the most common, followed by clothianidin (3%) and imidacloprid (0.5%). The insecticide chlorantraniliprole was found in 8% of samples. Only thiamethoxam and clothianidin (3% of samples) exceeded Quebec's CVAC values.

Similar concentrations in Lake Saint-Pierre and its major tributaries

Pesticide concentrations measured in Lake Saint-Pierre were generally lower than those in its smaller tributaries, which drain cultivated fields (Giroux 2018), but were similar to those measured in the mouths of its main tributaries, such as the Yamaska, Saint-François and Nicolet rivers (Giroux 2022). Similar concentrations of atrazine and S-metolachlor were detected at site A and at site C, located approximately 7 km downstream (Figure 2.5).

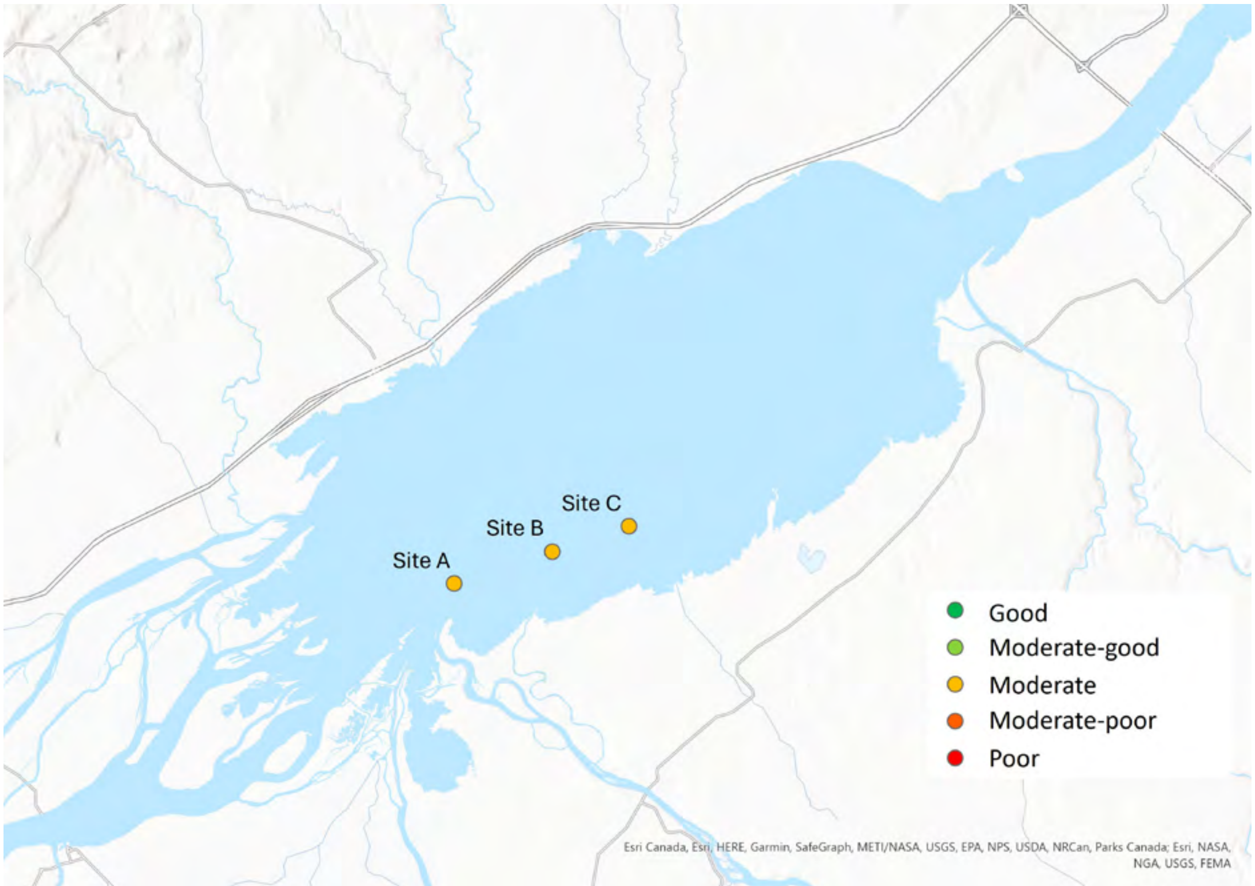


Figure 2.5 Sites sampled in Lake Saint-Pierre for pesticides during the summers of 2017 to 2021

Overall improving trend

Similar sampling operations were carried out in the summers of 2014 and 2015 to document the presence of pesticides in Lake Saint-Pierre (Giroux 2018). An improving trend can be observed for neonicotinoid insecticides between the results in 2017–2021 and those obtained in 2014 and 2015, as their frequency of detection and CVAC exceedance decreased between the two study periods (Figure 2.6). The number of pesticides detected and the pervasiveness of the herbicides atrazine and S-metolachlor were, however, very similar between both sampling campaigns.

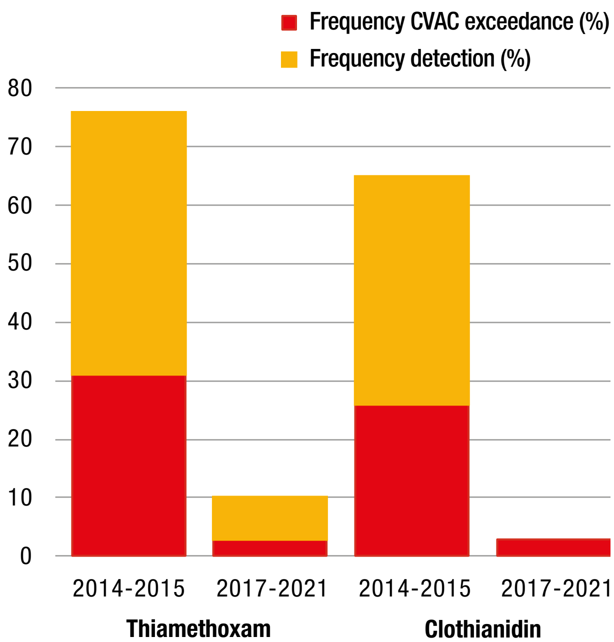


Figure 2.6 Comparison of frequency of detection and CVAC exceedance of two neonicotinoids in Lake Saint-Pierre in 2014–2015 and 2017–2021 (%)

- Thiamethoxam was detected in 76% of samples in 2014 and 2015, compared with 10% from 2017 to 2021. The frequency of detection of clothianidin decreased from 65% in 2014–2015 to 3% in 2017–2021. A similar comparison cannot be made for imidacloprid, which was not analyzed in 2014–2015.
- In 2014–2015, thiamethoxam and clothianidin concentrations exceeded CVAC values in 31% and 26% of samples, respectively, compared with 3% in 2017–2021.

The positive impact of new regulations

Beginning in 2018, new provincial regulations were gradually phased in, requiring an agronomic justification and prescription for the sale and use of the highest-risk pesticides (atrazine, chlorpyrifos, thiamethoxam, imidacloprid and clothianidin).

The implementation of these regulations and the resulting reduction in pesticide use likely explains, at least in part, the decreased frequency of detection and CVAC exceedance of neonicotinoids. In 2020, areas planted in corn and soybean using neonicotinoid-treated seeds probably made up less than 1% of all corn and soybean cropland, compared with 100% in 2015 (MELCC 2022).

These regulations may have also had an impact on the atrazine concentrations measured in Lake Saint-Pierre. Although the frequency of detection of this herbicide was similar in the two study periods, the concentrations measured in 2017–2021 were significantly lower than those measured in 2014–2015 (Wilcoxon-Mann-Whitney test, $p < 0.05$). In addition, no CVAC exceedances were observed for atrazine in 2017–2021, compared with a 5% frequency in 2014–2015. A significant decline (96%) in atrazine sales has been recorded since the implementation of the agronomic justification and prescription requirement.

However, the drier conditions in recent growing seasons may also be a contributing factor in these decreases. In addition, the various initiatives to conserve and restore the shorelines of Lake Saint-Pierre and encourage sustainable agricultural practices may have also played a part.

What does this indicator tell us about the environmental issues affecting the St. Lawrence River?

Lake Saint-Pierre is under intense pressure from agricultural activities. According to the results obtained for this indicator, pesticides used in watersheds upstream are transported downstream into Lake Saint-Pierre through its tributaries. Although the situation has improved for some pesticides, a significant amount of uncertainty still surrounds the potential additive and synergistic effects of pesticides on aquatic organisms, given the number of products detected in the shallow waters of the lake.

How is this indicator affected by climate change?

Rising water temperatures and changes in the frequency and severity of hydrological events (e.g. flooding and low water levels), as well as increasing growing season length, could have an impact on water quality in the tributaries and, consequently, on that in Lake Saint-Pierre itself (Ouranos 2015; Dulude 2016). According to some researchers (Dulude 2016), climate change will likely lead to the disappearance of certain habitats and increase pollutant concentrations (nitrogen, phosphorus, pesticides, etc.) in the lake.

Water sampling in Lake Saint-Pierre. Photo: MELCCFP

For more information

GIROUX, Isabelle, 2018. État de situation sur la présence de pesticides au lac Saint-Pierre. Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques, Direction de l'information sur les milieux aquatiques, Quebec.

References

DULUDE, Anne-Marie, 2016. Impacts du réchauffement climatique sur le lac Saint-Pierre. Coopérative de solidarité de la réserve de la biosphère du lac Saint-Pierre.

GIROUX, Isabelle, 2022. Présence de pesticides dans l'eau au Québec : Portrait et tendances dans les zones de maïs et de soya – 2018 à 2020. Quebec, Ministère de l'Environnement et de la Lutte contre les changements climatiques, Direction de la qualité des milieux aquatiques.

MINISTÈRE DE L'ENVIRONNEMENT ET DE LA LUTTE CONTRE LES CHANGEMENTS CLIMATIQUES, 2022. *Bilan des ventes de pesticides au Québec – Année 2020*. Direction des matières dangereuses et des pesticides.

OURANOS, 2015. *Vers l'adaptation : synthèse des connaissances sur les changements climatiques au Québec*, 2015 edition. Synthèse 2015 – La science du climat scrutée à la loupe | Ouranos.

Safety of potential swimming sites

Lead organization: Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MELCCFP)
Study area: fluvial section and fluvial estuary

Status: moderate in 2019–2021
Trend: unchanged since 2003

The overall status of this indicator was rated "moderate" for the 2019–2021 period. Nearly 56% (i.e. slightly over one out of two) of the 16 sites monitored had "good" or "very good" swimming potential on average, meaning that they were swimmable at least 70% of the time, and had annual quality ratings during the 2019–2021 period ranging from A (excellent) to C (fair). In addition, almost 40% of the sites were classified as "quality sites"—corresponding to annual ratings of "excellent" or "good" (A or B). In total, 63% of the days monitored at all sites combined were swimmable.

Bacteriological quality varied by study site (Figure 2.7), with significant differences in *E. coli* concentrations found. This suggests that the sources of contamination or their effects also varied between the sites studied. The highest values for the 2019–2021 period, approximately 1,500 CFU/100 ml, were recorded at two sites located in the stretch between Lanoraie and the Sorel islands (Îles de Sorel). In contrast, *E. coli* concentrations of only 30 CFU/100 ml were detected at the Parc de l'Île Charron site (in the Longueuil to Varennes stretch), which had significantly better water quality than most of the other sites.

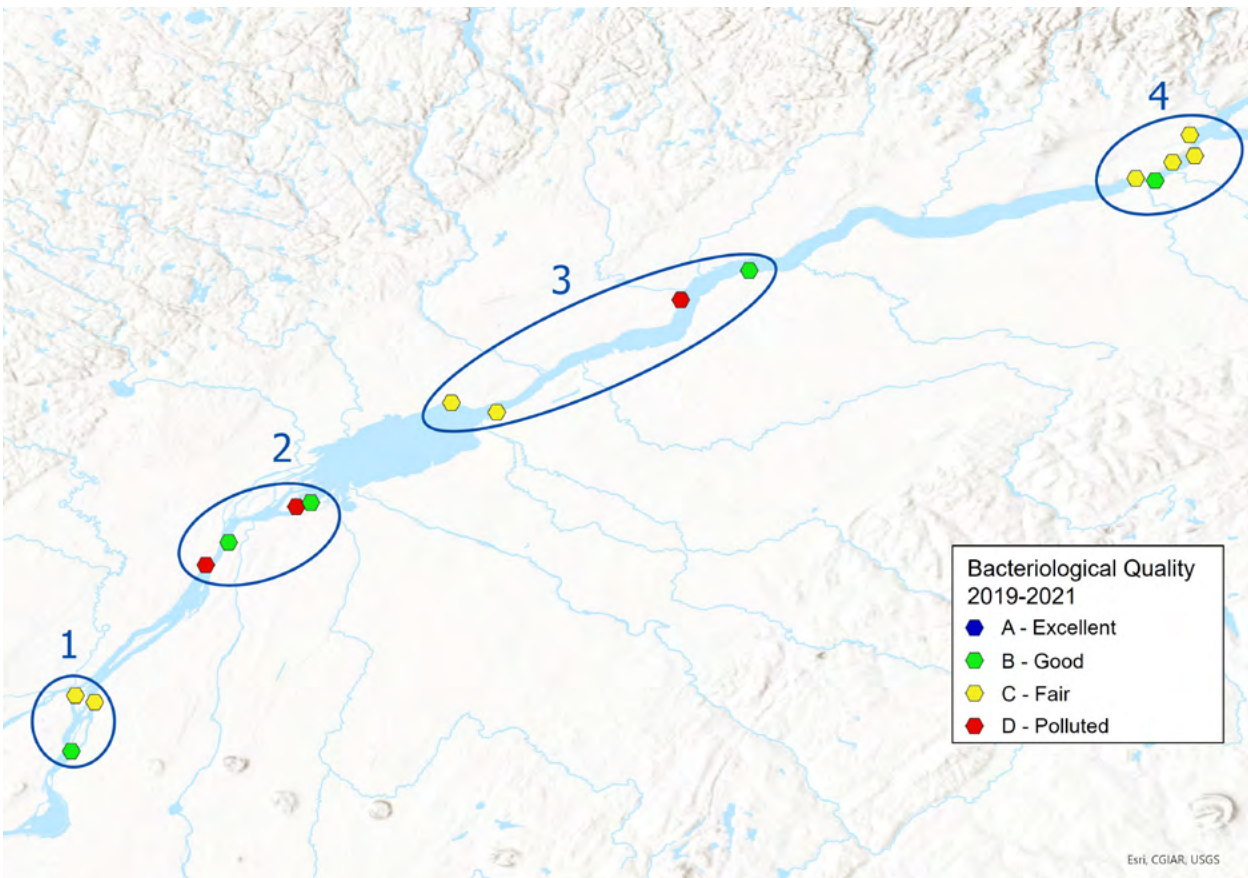


Figure 2.7 Bacteriological quality at potential freshwater swimming sites in the St. Lawrence River in 2019-2021

The four stretches sampled are circled and numbered from 1 to 4: (1) Longueuil to Varennes; (2) Lanoraie to the Îles de Sorel; (3) Francheville to Deschaillons; and (4) Quebec City–Lévis.

An analysis by stretch shows that bacteriological quality deteriorated immediately downstream of the Montreal urban agglomeration. The proportion of “poor” ratings (D ratings) increased from 26% to 53% in the stretches upstream and downstream, respectively, of the outlet of Montreal’s wastewater treatment plant, which discharges wastewater that is not disinfected (Figure 2.8). This deterioration in bacteriological quality was also reflected in the percentage of sites with “good” ratings, which dropped from 66.7% upstream of the Montreal discharge point to 50% downstream.

Site quality was variable in the stretch between Francheville and Deschaillons, although the number of D ratings decreased gradually, to 35% fewer than in the stretch upstream. Although local sources of contamination must be taken into account, the bacterial plume from the Montreal agglomeration may also occasionally affect some of these sites (Working Group on the State of the St. Lawrence Monitoring 2019).

Lastly, quality improved slightly towards the Quebec City–Lévis sector, with the percentage of D ratings falling to 33%. However, this sector had more rainfall at the time of monitoring visits (lower percentage of dry weather; Figure 2.8).

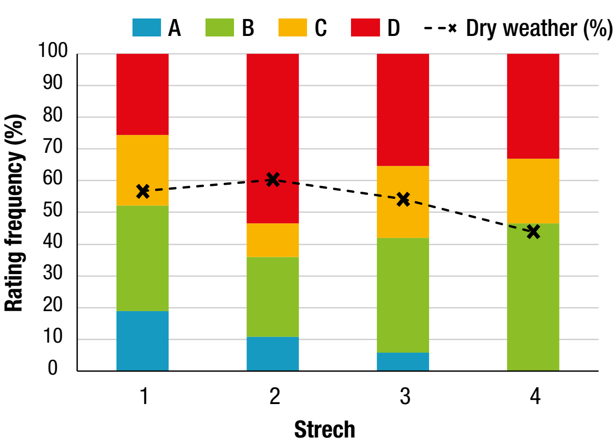


Figure 2.8 Distribution of quality ratings and dry weather by stretch from 2019 to 2021

Percentages of ratings and dry weather are compiled using data obtained by date of visit for each site in the sector.1) Longueuil to Varennes; 2) Lanoraie to the Îles de Sorel; 3) Francheville to Deschaillons; 4) Quebec City-Lévis

In addition, non-disinfected discharge from the Montreal, Longueuil and Repentigny wastewater treatment plants adversely affects recreational uses (direct and indirect contact) in a portion of the river. Although a few outliers with “good” bacteriological quality were present in 2019–2021 (Figure 2.7), none of the sites received an “excellent” rating during the study period.

No trend since 2003

The overall status of potential swimming sites in the river ranged from “moderate-poor” to “moderate-good,” depending on the monitoring year (Figure 2.9). The status of the different quality indicators also varied significantly from year to year (Figure 2.10).

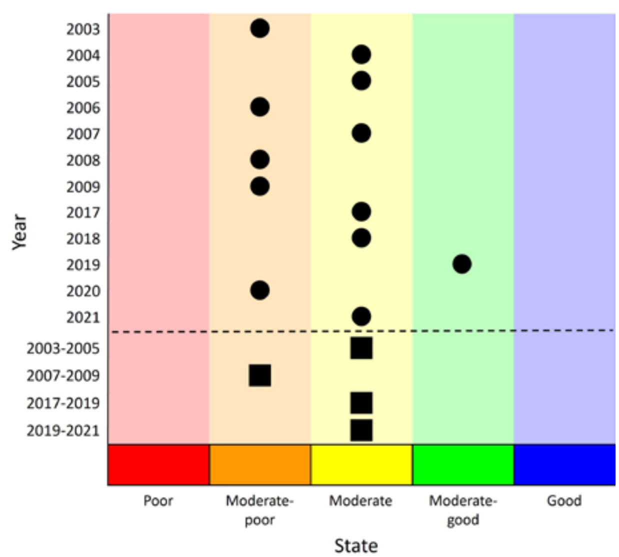


Figure 2.9 Changes in the overall status of potential freshwater swimming sites in the St. Lawrence River between 2003 and 2021

In order to reduce the effects of interannual variability and assess changes over time, the trend was evaluated by comparing groups of three consecutive years. The overall trend between the start of monitoring (2003–2005) and recent years (2019–2021) was unchanged, with the maintenance of “moderate” status. However, the lower percentages of quality sites, swimmable days, and sites with “good” swimming potential in the 2007–2009 interval resulted in “moderate-poor” status. Subsequently, the monitoring program was temporarily halted between 2010 and 2016 to await the completion of major sanitation operations. When monitoring began again, the same overall status rating was obtained for the 2017–2019 and 2019–2021 intervals.

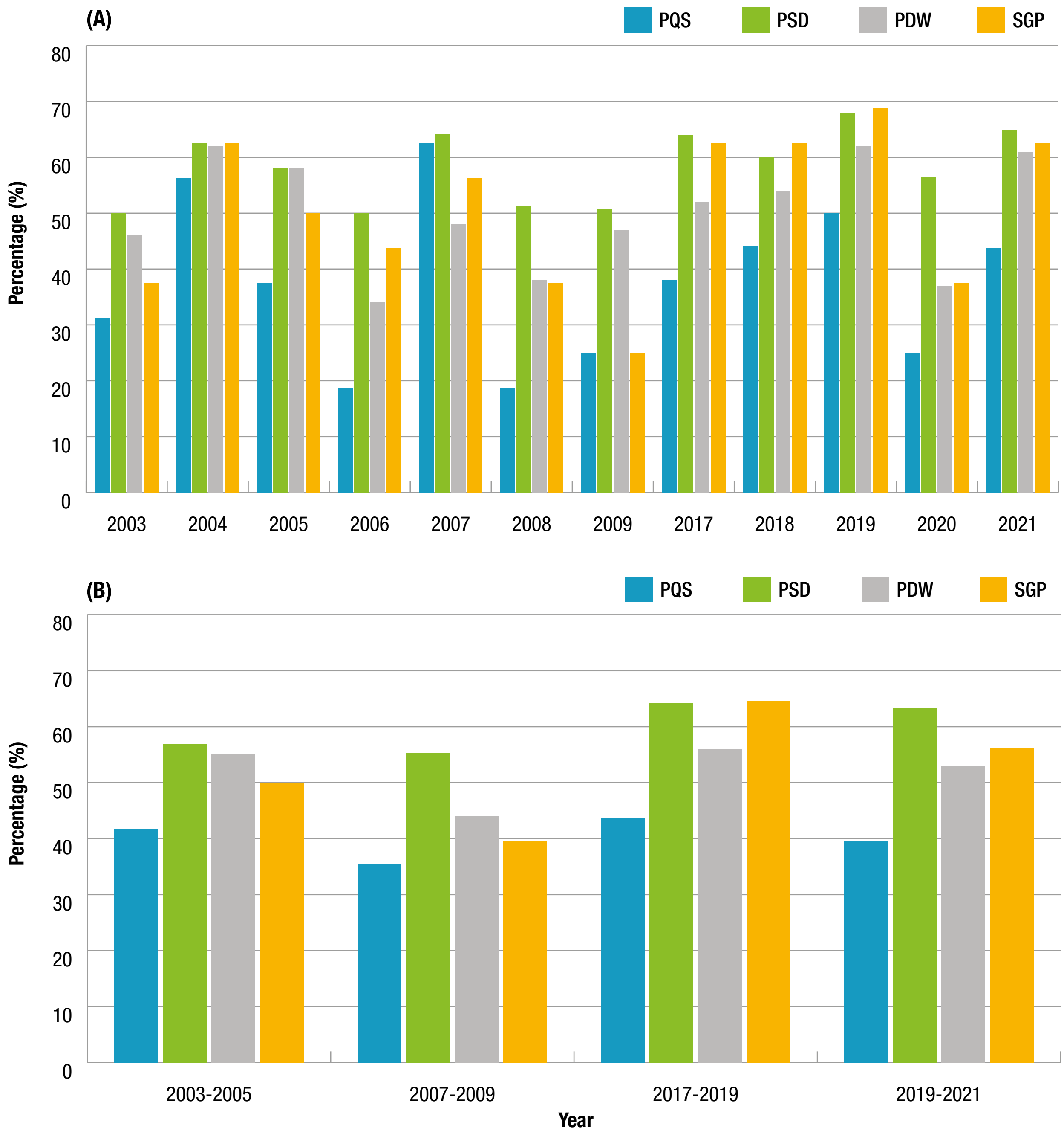


Figure 2.10 Changes in the value of the quality indicators for potential swimming sites (A) between 2003 and 2021 and (B) by three-year intervals, i.e. 2003–2005, 2007–2009, 2017–2019 and 2019–2021

The quality indicators of the sites are the percentage of quality sites (PQS), the percentage of swimmable days (PSD), the percentage of sites with good potential (SGP), as well as the percentage of dry weather (PDW).

Interannual variability in bacteriological water quality can be partly explained by the presence of dry or wet weather. Years characterized by more sampling during dry weather (percentage of dry weather [PDW]) had a greater percentage of quality sites, swimmable days, and sites with good potential.

In terms of the temporal trend, the percentage of dry weather during the 2019–2021 period was similar to that in the 2017–2019 and 2003–2005 periods, contrasting with the lower percentage of dry weather during the 2007–2009 period, which could explain the slight decline in the indicator's overall status during the latter period.

- **What does this indicator tell us about the environmental issues affecting the St. Lawrence River?**

The discharge of non-disinfected wastewater from the Montreal treatment plant is a major issue affecting the St. Lawrence River. The Ville de Montréal is working to install an ozonation plant to disinfect its wastewater, and monitoring this indicator will be useful in assessing the resulting improvement in bacteriological water quality.

- **How is this indicator affected by climate change?**

Climate change can:

- alter the flow regime, and the distribution of water masses and bacterial plumes;
- increase water contamination through overflows resulting from increasingly frequent extreme rainfall events;
- concentrate contaminants during more severe low water events, and favour bacterial survival due to warmer water temperatures resulting from the projected increase in air temperatures (MELCC 2020).

Given that the number of extreme rainfall events is expected to increase, combined with higher temperatures that will make Quebecers more inclined to cool off by swimming (Rousseau et al. 2004; Fortier 2013; Ouranos 2015), measures such as installing disinfection equipment, reducing wastewater overflows and minimizing microbial transport in runoff in aquatic environments will be essential.

How is the safety of potential freshwater swimming sites in the St. Lawrence River assessed?

The Parc de l'Île Charron, although close to Montreal (seen in the background), has good bacteriological water quality. Photo: Caroline Anderson, MELCCFP

Two composite samples are prepared for each site from the various individual samples taken. Photo: Caroline Anderson, MELCCFP

Bacteriological quality indicators

Four sub-indicators are used to interpret water quality in greater detail: percentage of quality sites (PQS), percentage of swimmable days (PSD), percentage of sites with good potential (SGP) and percentage of dry weather (PDW) (Anderson 2021).

Quality ratings and overall status

The bacteriological quality of 16 sentinel sites in the St. Lawrence River is assessed based on *E. coli* concentrations (CFU/100 ml) in the water. The overall status of the indicator is determined by the percentage of sites with “good” or “very good” potential (Anderson 2021).

For more information

ANDERSON, Caroline, 2021. Safety of potential freshwater St. Lawrence River swimming sites – 3rd edition. Fact sheet. State of the St. Lawrence Monitoring Program. Minister of Environment and Climate Change Canada, 17 pp.

References

FORTIER, Claudine, 2013. *Impact des changements climatiques sur les débordements des réseaux d'égouts unitaires*. Université du Québec, Institut National de la Recherche Scientifique – Centre Eau Terre Environnement. Thesis presented as part of a master's degree in water sciences, 125 pp. and 6 appendices.

MINISTÈRE DE L'ENVIRONNEMENT ET DE LA LUTTE CONTRE LES CHANGEMENTS CLIMATIQUES, 2020. Rapport sur l'état des ressources en eau et des écosystèmes aquatiques du Québec. 2020 edition, Ministère de l'Environnement et de la Lutte contre les changements climatiques, 480 pp.

OURANOS, 2015. Sommaire de la synthèse des connaissances sur les changements climatiques au Québec. 2015 edition, Montreal, Quebec, Ouranos, 13 pp.

ROUSSEAU, Alain, Alain MAILHOT, Michel SLIVITZKY, Jean-Pierre VILLENEUVE, Manuel J. RODRIGUEZ, and Alain BOURQUE, 2004. "Usages et approvisionnement en eau dans le sud du Québec," *Canadian Water Resources Journal*, Vol. 29, No. 2, pp. 121–134.

WORKING GROUP ON THE STATE OF THE ST. LAWRENCE MONITORING, 2020. Overview of the State of the St. Lawrence 2019. St. Lawrence Action Plan. Environment and Climate Change Canada, Ministère de l'Environnement et de la Lutte contre les changements climatiques du Québec, Ministère des Forêts, de la Faune et des Parcs, Parks Canada, Fisheries and Oceans Canada, and Stratégie Saint-Laurent, 60 pp.

Oceanographic processes: dissolved oxygen and acidity

Lead organization: Fisheries and Oceans Canada (DFO)
Study area: lower estuary and Gulf of St. Lawrence (near Rimouski)

Status: moderate-poor in 2018–2022
Trend: deterioration since the 1930s

Status of dissolved oxygen: poor

- **Dissolved oxygen at an all-time low in 2022**

Although the overall status of the oceanographic processes indicator is considered "moderate-poor," the dissolved oxygen results received a "poor" rating (an annual mean oxygen saturation level of less than 15% is considered poor). In 2018–2019, the observed saturation values were around 17%, or comparable to those observed in 2013–2017. However, dissolved oxygen has decreased significantly since 2020, reaching a record low of 11.4% in 2022.

Photo: Peter Galbraith, DFO

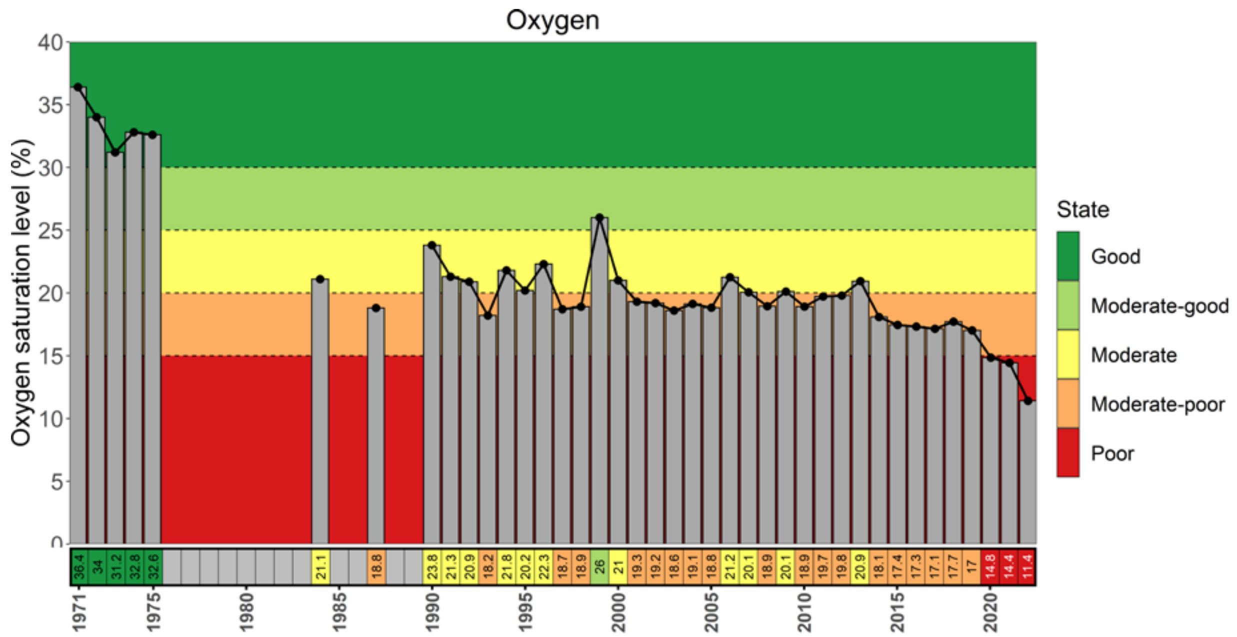


Figure 2.11 Oxygen saturation levels in the deep waters of the estuary from 1971 to 2022

Dissolved oxygen is essential for the maintenance of aquatic life. Hypoxia, caused by a lack of available dissolved oxygen, is a phenomenon that is observed in the deep waters of the estuary and the Gulf of St. Lawrence. Few marine organisms can tolerate oxygen saturation levels below 20%. Although 30% oxygen saturation marks the threshold of hypoxic conditions, more sensitive organisms may experience adverse effects as soon as oxygen saturation falls below 70%.

Status of water pH: moderate-poor

- **Water pH at its lowest level in 2022**

The data indicate that water pH, which received a "moderate-poor" rating for the 2018–2022 period, could very well deteriorate further. In 2022, the pH reached a record low level of 7.5. Although the decrease of roughly 0.03 units between 2018 and 2022 may seem insignificant, the pH scale is logarithmic, so this change represents an increase in environmental acidity of more than 8%.

Photo: Aude Boivin-Rioux, MPO

These findings indicate a significant degradation of the environment. The increase in acidity should serve as a warning about the current state of the environment and the potential consequences for both the ecosystem itself and the economic sectors that depend on it.

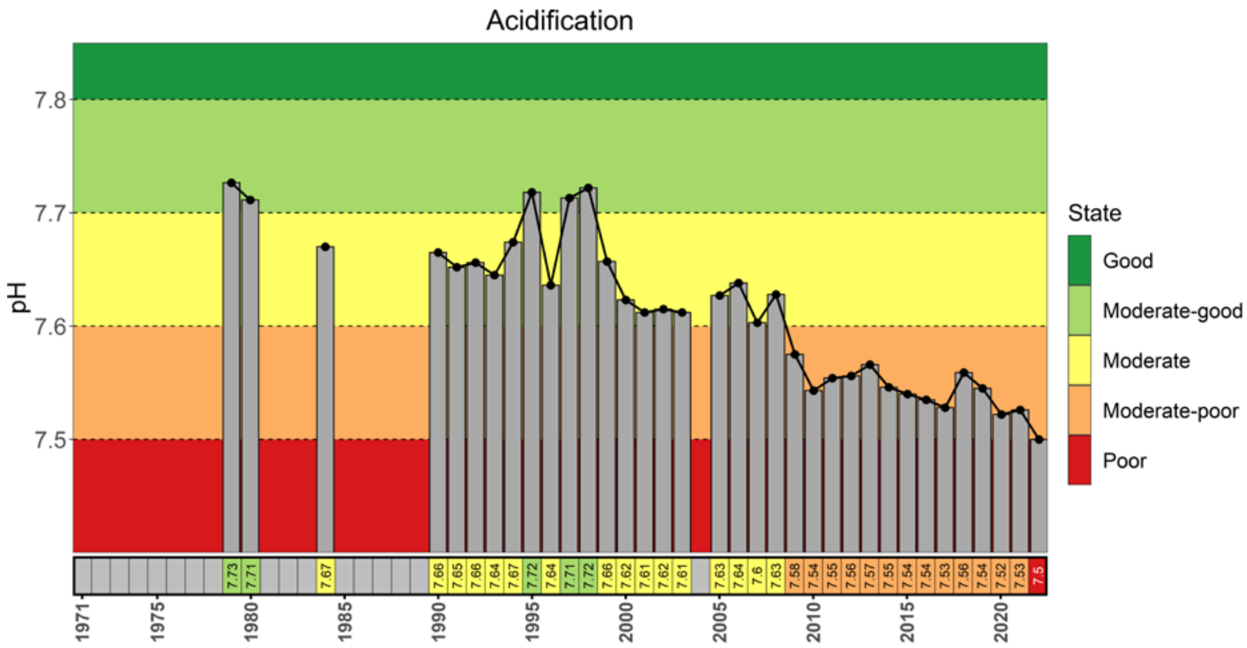


Figure 2.12 pH levels measured in the deep waters of the estuary from 1971 to 2022

Long-term deterioration in both pH and dissolved oxygen

In the early 1930s, dissolved oxygen saturation in the deep waters of the estuary was nearly 40%, with pH values ranging from 7.8 to 7.9, a level considered normal in this type of aquatic ecosystem. Since 2020, mean oxygen saturation values have been below 15%, creating a low-oxygen environment in which the survival of many commercially important species is virtually impossible. In 2022, the pH was close to 7.5, which represents a decrease of 0.3 to 0.4 pH units from the 1930s. This means that the deep waters of the estuary are now 100% to 150% more acidic. A change in acidity of this magnitude over a relatively short period of time can have detrimental effects on many organisms.

What is the impact of climate change on oceanographic processes?

Climate change has a direct impact on ocean currents, which in turn influence various oceanographic processes. The deep waters that enter the Gulf and flow up the Laurentian Channel to the estuary are composed of warm water from the Gulf Stream and cold water from the Labrador Current. As a result of climate change and the associated changes in ocean currents, warm Gulf Stream water now makes up a greater proportion of the deeper waters. Because of the warmer water temperatures, dissolved oxygen levels have decreased. The warmer water also increases marine organisms' respiration rates and hence their demand for dissolved oxygen.

During the process of respiration, marine organisms not only consume oxygen, but also produce CO_2, which amplifies acidification. As a result of the increased acidity, less calcium carbonate is available for the many aquatic organisms that use this mineral to build their shells and skeletons. Along with the change in the relative proportions of the water masses that make up the deep waters of the Gulf, the decomposition of organic matter at those depths is also thought to be a contributing factor in the phenomena of hypoxia and acidification observed in the St. Lawrence River. Lastly, the increased atmospheric CO_2 accompanying climate change is continuously absorbed by, and accumulates in, the ocean, also playing a role in acidification.

For more information

BLAIS, M., P. S. GALBRAITH, S. PLOURDE, E. DEVRED, S. CLAY, C. LEHOUX, and L. DEVINE, 2021. Chemical and Biological Oceanographic Conditions in the Estuary and Gulf of St. Lawrence During 2020. DFO Can. Sci. Advis. Sec. Res. Doc. 2021/060. iv + 67 pp.

BRENNAN, Catherine E., Hannah BLANCHARD, and Katja FENNEL, 2016. "Putting Temperature and Oxygen Thresholds of Marine Animals in Context of Environmental Change: A Regional Perspective for the Scotian Shelf and Gulf of St. Lawrence," *PLoS One*, Vol. 11, no. 12, pp. 1–27.

DUPONT-PRINET, Aurélie, Marion PILLET, Denis CHABOT, Tanya HANSEN, Réjean TREMBLAY, and Céline AUDET, 2013. "Northern shrimp (*Pandalus borealis*) oxygen consumption and metabolic enzyme activities are severely constrained by hypoxia in the Estuary and Gulf of St. Lawrence," *Journal of Experimental Marine Biology and Ecology*, Vol. 448, pp. 298–307.

MUCCI, Alfonso, Michel STARR, Denis GILBERT, and Bjorn SUNDBY, 2011. "Acidification of lower St. Lawrence Estuary bottom waters," *Atmosphere-Ocean*, Vol. 49, no. 3, pp. 206–218, doi:10.1080/07055900.2011.599265.

WALDBUSSER, George G., Burke HALES, Chris J. LANGDON, Brian A. HALEY, Paul SCHRADER, Elizabeth L. BRUNNER, Mathhew W. GRAY, Cale A. MILLER, and Iria GIMENEZ, 2015. "Saturation-state sensitivity of marine bivalve larvae to ocean acidification," *Nature Climate Change*, Vol. 5, nº. 3, pp. 273–280.

Oceanographic processes: water temperature and sea ice

Lead organization: Fisheries and Oceans Canada (DFO)
Study area: lower estuary and Gulf of St. Lawrence

Status: poor in 2018–2022
Trend: deterioration since 2017

In summer, the waters of the estuary and the Gulf of St. Lawrence consist of three distinct layers:

- the surface layer, which shows a clear seasonal cycle defined by its interactions with the atmosphere;
- the summer cold intermediate layer (CIL), which consists of cold water remaining from the previous winter;
- and the deep layer (below 150 m), which is cut off from exchanges with the atmosphere.

The overall status of this indicator is deemed "poor," mainly because of the high temperatures of the deep waters.

Surface and cold intermediate layer temperatures and sea ice rated "moderate"

In 2022, average surface water temperatures in August and from May to November were the warmest since record-keeping began in 1981. In addition, the summer of 2021 was the longest on record, with summer-like temperatures persisting very late into the season.

The temperature of the cold intermediate layer and the extent of sea ice are highly variable, since they are influenced by winter atmospheric conditions. Owing to mild winter conditions in 2021, the Gulf remained almost ice-free and cold intermediate layer temperatures were the warmest on record since 1980.

While surface water temperatures have remained stable relative to the 2013–2017 period, temperatures in the cold intermediate layer and the deep layer have increased.

In September 2020, the bottom area on the Magdalen Shallows covered by waters colder than 1 °C was at a record low (since 1964). At the same time, the average temperature at bottom depths of more than 30 m on the Magdalen Shallows reached a record 2.25 °C.

Deepest waters warming

Since 2015, temperatures in the deepest portion (300 m and below) of the lower estuary and Gulf have reached record high levels since record-keeping began in 1915. In 2022, the average temperature at a depth of 300 m exceeded the threshold of 7 °C for the first time.

Since 2009, continued warming has been observed at these depths. These waters consist of a mixture of warm water from the Gulf Stream and cold water from the eastern part of the Labrador Current. The altered composition of this mixture is the main cause of the changes observed in deep-water temperatures, which have increased universally relative to historical levels (1981–2010).

What does this indicator tell us about the environmental issues affecting the St. Lawrence River?

The warming of the deepest waters and the associated increase in hypoxia is attributable to two phenomena: the warmer waters entering the Gulf of St. Lawrence contain less dissolved oxygen, and the warmer water temperatures stimulate bacterial oxygen consumption. With warm Gulf Stream water making up a greater proportion of the inflows to the St. Lawrence system and this water containing lower levels of dissolved oxygen than Labrador Current water, the hypoxia situation is likely to worsen.

How is this indicator affected by climate change?

Surface water temperatures are directly affected by atmospheric warming, while cold intermediate layer temperatures and the extent of the sea ice cover are tied, at least in part, to winter air temperatures. Deep-water temperatures (300 m and below) in the Gulf of St. Lawrence have followed an upward trend since 2009, due to a change in the composition of the inflows to the region, specifically the increase in warm Gulf Stream water, which is less oxygenated than Labrador Current water and therefore can only make the hypoxia situation worse. The change in the mixture of water inflows may be related in turn to changes in ocean circulation caused by global warming (Claret et al. 2018).

For more information

GALBRAITH, P.S., J. CHASSÉ, J. DUMAS, J.-L. SHAW, C. CAVERHILL, D. LEFAIVRE, and C. LAFLEUR, 2022. Physical Oceanographic Conditions in the Gulf of St. Lawrence During 2021. DFO Can. Sci. Advis. Sec. Res. Doc. 2022/034. iv + 83 pp.

GOVERNMENT OF CANADA – Atlantic Zone Monitoring Program (AZMP).

References

CLARET, Mariona, Eric D. GALBRAITH, Jaime B. PALTER, Daniele BIANCHI, Katja FENNEL, Denis GILBERT, and John P. DUNNE, 2018. "Rapid coastal deoxygenation due to ocean circulation shift in the northwest Atlantic," *Nature Climate Change*, Vol. 8, pp. 868–872. https://doi.org/10.1038/s41558-018-0263-1.

Shellfish water quality

Lead organization: Environment and Climate Change Canada (ECCC)
Study area: lower estuary and Gulf

Status: moderate-good in 2022 Trend: unchanged since 2018

Coastal waters are very vulnerable to the impacts of human activities, which continue to cause the loss of uses such as recreational clam and mussel harvesting. Fecal coliforms in contaminated waters accumulate in shellfish tissues and can make them unfit for consumption. The primary role of ECCC's Shellfish Water Classification Program (SWCP) is to assess sanitary conditions in bivalve mollusc harvesting and growing areas.

To this end, ECCC conducts sanitary surveys in shoreline areas and measures fecal coliform concentrations in shellfish growing waters to support the Canadian Shellfish Sanitation Program (CSSP). In order to provide an overview of the situation, a rating (A, B or C) is assigned to 250 shellfish areas based on the results of the last assessment. This rating indicates whether water quality is suitable for shellfish harvesting:

- A: Meets the criteria for an approved area;
- B: Meets the criteria for a conditionally approved area;
- C: Does not meet the criteria for an approved area (restricted or prohibited).

Figure 2.13 Shellfish harvesting regions assessed between 2018 and 2022

Shellfish water quality variable by region

The overall status of shellfish harvest areas in the St. Lawrence based on water quality (which determines whether harvesting can take place) was assessed as "moderate-good" between 2018 and 2022. Of the 250 shellfish areas identified, 52% received a C rating (harvesting not permitted), 40% met the criteria for an approved area (A rating), and 8% had a B rating. Water quality and the proportion of areas assessed as A or B varied greatly from region to region.

Magdalen Islands

The bacteriological quality of the shellfish waters in the Magdalen Islands is excellent. A total of 44 areas were assessed, with the majority (84%) meeting the criteria for an approved or conditionally approved area (A or B rating). Only 16% were considered unacceptable for shellfish harvesting. Compared with the results of the previous period (2014–2018), the status of the Magdalen Islands' shellfish harvest areas remains stable.

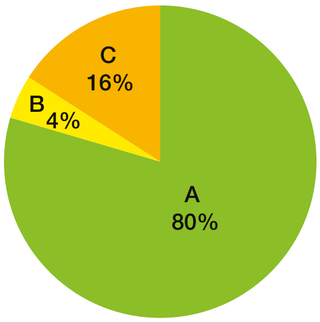


Figure 2.14a Percentage of sectors in Magdalen Islands by bacteriological quality rating

Lower North Shore

In this region, 53% of the 19 shellfish areas assessed met the criteria for an approved sector, and the trend is stable. This region includes a large proportion of coastal zones that have not been subdivided into shellfish areas, and where the water quality is believed to be excellent, because of the absence or limited presence of nearby sources of contamination.

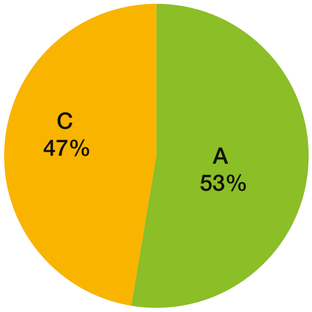


Figure 2.14b Percentage of sectors in Lower North Shore by bacteriological quality rating

Middle North Shore

The quality of shellfish waters in this region is divided almost equally between the A and C categories, with only a small proportion given a B rating. The same finding was obtained for the 2014–2018 period, and the trend is stable.

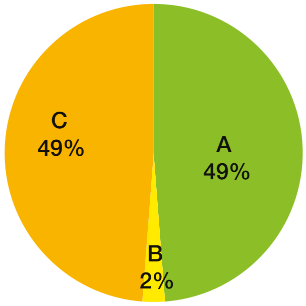


Figure 2.14c Percentage of sectors in Middle North Shore by bacteriological quality rating

Upper North Shore / Charlevoix

Over half of the areas assessed in the Upper North Shore / Charlevoix region (52%) met the criteria for an approved or conditionally approved area (A or B rating). A stable trend in shellfish water quality in the Upper North Shore / Charlevoix region has been noted since 2014–2018, similar to the previous regions.

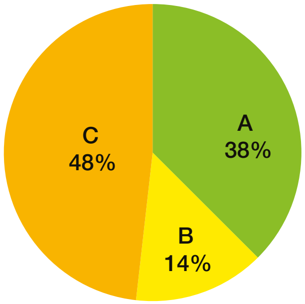


Figure 2.14d Percentage of sectors in Upper North Shore / Charlevoix by bacteriological quality rating

Gaspé region

In the Gaspé region, only 29% of the 63 areas assessed met the criteria for an approved or conditionally approved area (A or B rating), compared with 71% that did not meet the criteria (C rating). The trend has been stable since 2014–2018.

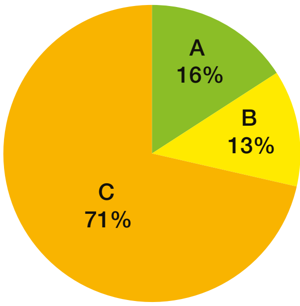


Figure 2.14e Percentage of sectors in Gaspé region by bacteriological quality rating

Lower St. Lawrence

Of the 27 areas assessed, 81% received a C rating, which means that shellfish harvesting was prohibited (or restricted). The trend has been stable since 2014–2018.

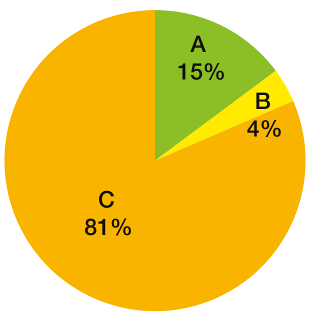


Figure 2.14f Percentage of sectors in Lower St. Lawrence by bacteriological quality rating

Improvement expected in the long term

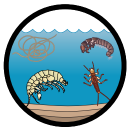
The overall trend for bacteriological water quality in shellfish harvest areas was stable in 2022 relative to 2018. Agricultural activities and wastewater from municipalities and isolated dwellings are the main sources of bacteriological contamination in the Gaspé, Lower St. Lawrence, Magdalen Islands and North Shore regions. However, water quality is expected to improve in the long term, following the implementation of the amendments to the *Wastewater Systems Effluent Regulations* under the *Fisheries Act* through the Equivalency Agreement with Quebec. The amended regulations are intended to promote the construction and upgrading of wastewater treatment plants, and some municipalities have begun taking steps in this regard.

For more information

DOUVILLE, Mélanie, 2021. Shellfish water quality in the estuary and Gulf of St. Lawrence. Fact sheet. State of the St. Lawrence Monitoring Program. Environment and Climate Change Canada.

Benthic macroinvertebrate communities

Lead organization: Environment and Climate Change Canada (ECCC)
Study area: Fluvial section (from Lake Saint-François to Lake Saint-Pierre)
Period: 2018–2023



Status: undetermined
Trend: undetermined

The most recent assessment of benthic macroinvertebrate communities in the St. Lawrence River (2013–2018), based on work by Environment and Climate Change Canada (ECCC) scientists, rated the status of these communities as "moderate." An upstream-downstream gradient of increasing contamination was found between Lake Saint-François and Lake Saint-Pierre, with all the shoreline benthic communities in Lake Saint-Pierre exposed to pesticide contamination in the water.

From 2004 to 2018, benthic macroinvertebrate samples were collected in aquatic grass beds and low marshes along the St. Lawrence using the protocol developed by the Canadian Aquatic Biomonitoring Network (CABIN), a collaborative biomonitoring program managed by ECCC. The results, published in 2020, focuses on four sectors: Lake Saint-François, Lake Saint-Louis, the portion of the fluvial section between Varennes and Contrecœur, and Lake Saint-Pierre (Figure 2.15).

From 2019 to 2023, some sampling stations in the river were revisited (Figure 2.16), although no sampling took place in 2020 due to COVID-19 restrictions. The data will be analyzed and presented in a fact sheet on the status of benthic communities in 2025.

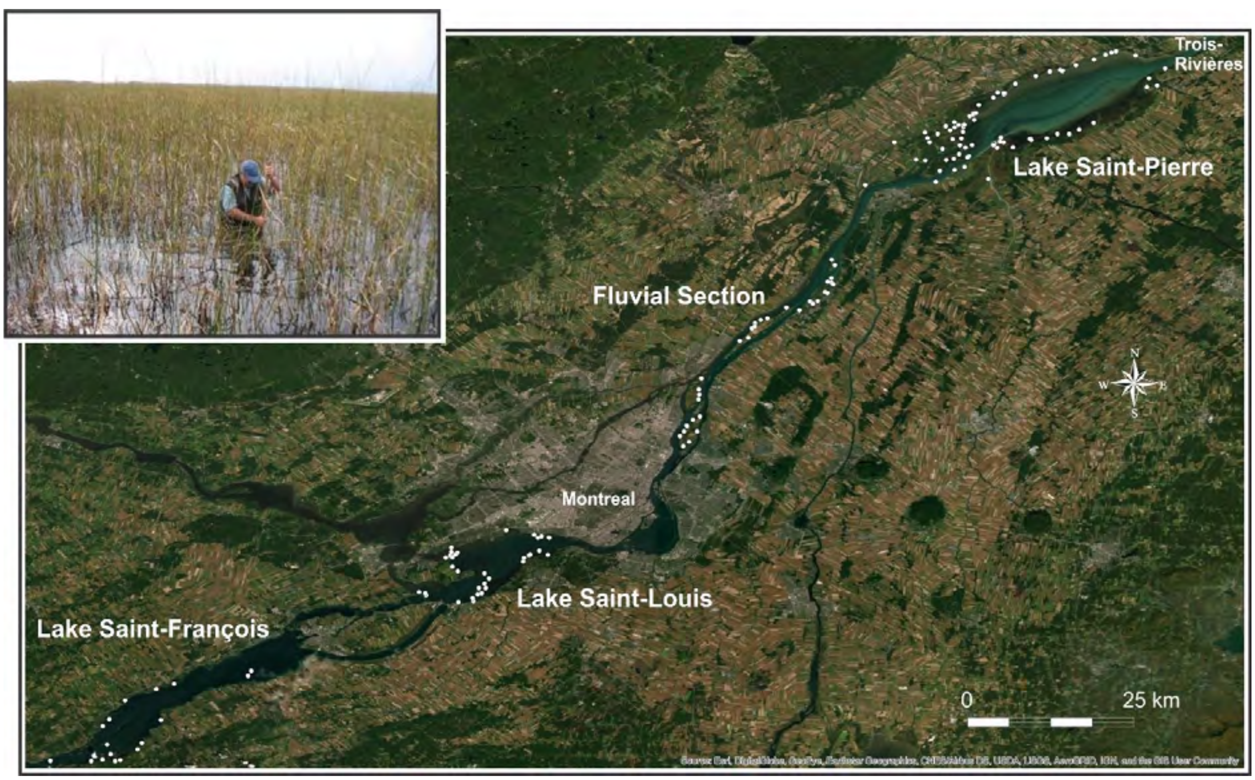


Figure 2.15 Benthic macroinvertebrate sampling sites in the St. Lawrence River (2004–2018)

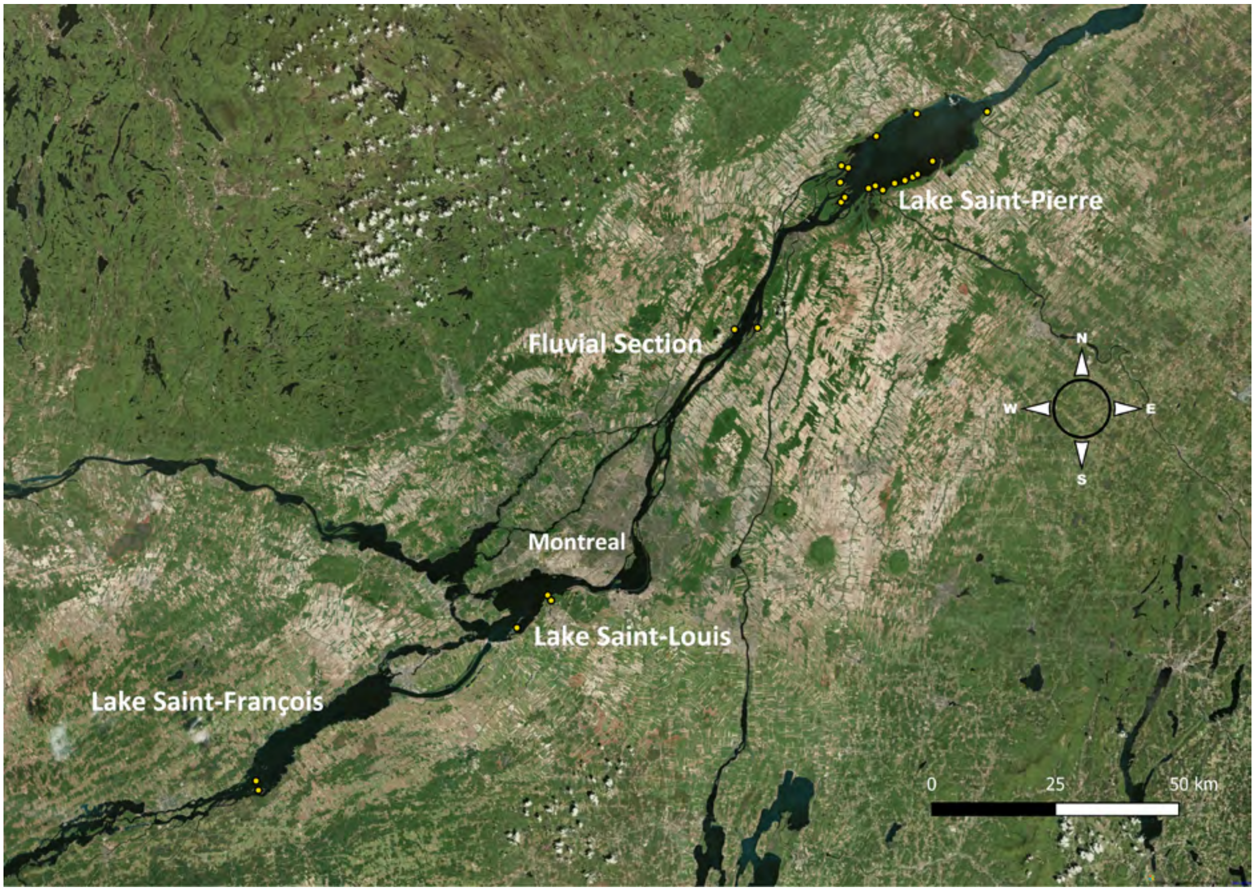


Figure 2.16 Benthic macroinvertebrate sampling sites in the St. Lawrence River (2019–2023)

In addition, as part of the Living Lab – Quebec initiative by Agriculture and Agri-Food Canada (AAFC), benthos samples were taken in 2021 and 2022 in a few small agricultural streams in the watersheds around Lake Saint-Pierre. The soft-bottomed streams in question were located in the Rivière du Bois-Blanc and Rivière du Pot-au-Beurre watersheds, as well as what is referred to as the South Shore of Lake Saint-Pierre watershed, which consists of small watersheds on the south shore emptying directly into Lake Saint-Pierre.

For more information

ARMELLIN, A., 2020. What is the status of benthic communities in the St. Lawrence River? Fact sheet. State of the St. Lawrence Monitoring Program. Environment and Climate Change Canada.

Phytoplankton communities

Lead organization: Fisheries and Oceans Canada (DFO)
Study area: Lower estuary and Gulf of St. Lawrence

Status: moderate-good in 2018–2021
Trend: slight deterioration since 2010

Phytoplankton form the base of the marine food chain. Like their plant counterparts in terrestrial environments, phytoplankton can convert inorganic carbon (CO2) to organic carbon through photosynthesis. However, to do this, they require various nutrients, including nitrates (NO3). The organic carbon that phytoplankton produce can then be used as an energy source by organisms at higher trophic levels.

More phytoplankton biomass despite variable nitrate availability

The results from 2018 to 2022 show above-normal phytoplankton biomass levels compared to the 1999 to 2010 reference period, despite the lower than normal abundance of diatoms, which are among the largest single-celled phytoplankton. In 2018 and 2022, the phytoplankton bloom occurred particularly early in the season, accompanied by below-normal nitrate availability. By contrast, in 2020 and 2021, significantly higher than normal nitrate levels were observed in the cold intermediate layer.

Since phytoplankton have a very short life cycle and, depending on the indicator, are only sampled three or four times a year across the estuary and Gulf, interannual variability is usually high. This variability can make it difficult to detect changes in the status of phytoplankton communities.

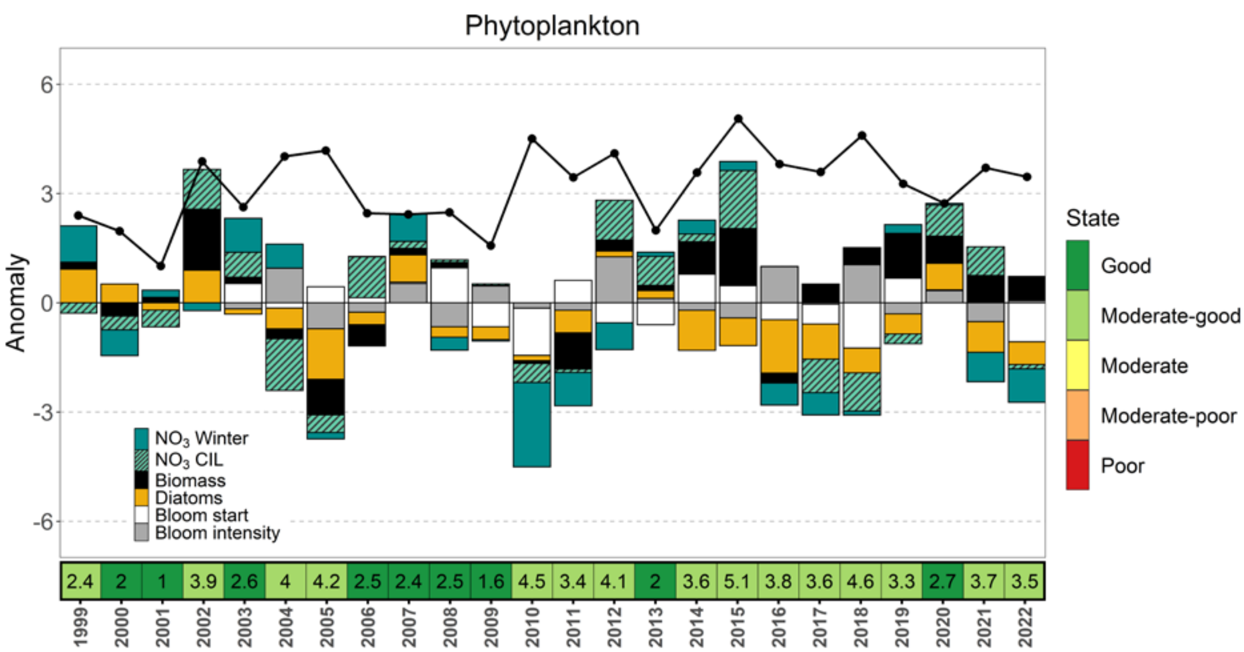


Figure 2.17 Anomalies observed in measurements of the different parameters associated with phytoplankton communities in the estuary and Gulf from 1999 to 2022

Some essential spring bloom nutrients scarcer since 2010

Although few significant changes have occurred since the previous study period (2013–2017), certain trends can be observed over a longer period. Starting in 2010, the average values of several parameters began to diverge more markedly from normal values (i.e. those in the 1999–2010 reference period). For instance, the nitrate content of the winter surface mixed layer regularly registered below-normal values, which are typical of warmer winter conditions. Indeed, warmer conditions (less ice cover and higher water temperatures) are typically associated with weak winter mixing and lower nutrient availability, while colder conditions are associated with intense winter mixing, which transports nutrients to the surface layer (0–50 m). Nitrates are required for the spring phytoplankton bloom, with their availability partially influencing bloom timing and duration.

Blooms earlier in spring since 2010

Warmer environmental conditions are also associated with early phytoplankton blooms in spring. Warm conditions can cause unseasonably early ice-out and early water-column stratification, a combination conducive to early blooms. Early phytoplankton blooms have been observed regularly since 2010, along with above-normal phytoplankton biomass (except in 2011 and 2016). Furthermore, in the estuary and some parts of the Gulf, very high phytoplankton concentrations are being seen more and more in late summer or in fall after storms. Furthermore, since 2010, blooms have been characterized by a below-normal proportion of diatoms relative to all phytoplankton groups. Phytoplankton communities dominated by larger single-celled organisms such as diatoms are generally recognized to promote efficient transfer of energy to higher trophic levels. Therefore, changes in diatom abundance may alter energy flow through the food chain.

What impact does climate change have on phytoplankton communities?

Phytoplankton and nutrients are good indicators of climate change because they respond directly and almost instantaneously to changes in environmental conditions, including temperature, ice retreat, and water-column mixing. In general, a warmer climate may lead to an earlier onset of the phytoplankton bloom in spring, as well as reduced spring and annual phytoplankton production. Higher temperatures generally increase water column stratification, thus reducing water mixing and the upwelling of nutrients required by phytoplankton. Since phytoplankton make up the first trophic level, all the changes they experience are likely to have repercussions on the higher trophic levels.

For more information

BLAIS, Marjolaine, 2021. Phytoplankton, toxic algae and zooplankton in the estuary and Gulf of St. Lawrence. Fact sheet. State of the St. Lawrence Monitoring Program. Fisheries and Oceans Canada.

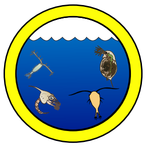
BLAIS, M., P. S. GALBRAITH, S. PLOURDE, E. DEVRED, S. CLAY, C. LEHOUX, and L. DEVINE, 2021. *Chemical and Biological Oceanographic Conditions in the Estuary and Gulf of St. Lawrence during 2020*. DFO Can. Sci. Advis. Sec. Res. Doc. 2021/060. iv + 67 pp.

LEVASSEUR, Maurice, Jean-Claude THERRIAULT, and Louis LEGENDRE, 1984. “Hierarchical control of phytoplankton succession by physical factors,” *Marine Ecology Progress Series*, Vol. 19, pp. 211–222.

SOMMER, Ulrich, and Kathrin LENGFELLNER, 2008. “Climate change and the timing, magnitude, and composition of the phytoplankton spring bloom,” *Global Change Biology*, Vol. 14, pp. 1199–1208.

Zooplankton communities

Lead organization: Fisheries and Oceans Canada (DFO)
Study area: Lower estuary and Gulf of St. Lawrence



Status: moderate in 2018–2021
Trend: deterioration since 2010

Zooplankton are microscopic animals that live suspended in the water and are moved about primarily by marine currents. These communities—which, in the estuary and Gulf of St. Lawrence, are dominated by copepods—make up the second level of the pelagic marine food web, which is responsible for the transfer of energy between phytoplankton and higher trophic levels (e.g. fish, whales). The abundance of the different taxonomic groups of zooplankton provides valuable information on this community's size structure and, in combination with biomass, gives an indication of the potential quantity of energy transferred to higher trophic levels.

- **Low zooplankton biomass and decreased copepod size**

During the 2018–2022 period, some changes were observed in the biomass and size structure of zooplankton communities in the estuary and Gulf relative to the 1999–2010 reference period (normal values). These changes included generally below-normal zooplankton biomass values, particularly in 2021 and 2022, and a below-normal abundance of large calanoid copepods. Conversely, the abundance of small calanoid copepods, non-copepods and warm-water copepods was above normal throughout the 2018–2022 period. Although most of these changes have been apparent since 2006, they have been more marked since 2010.

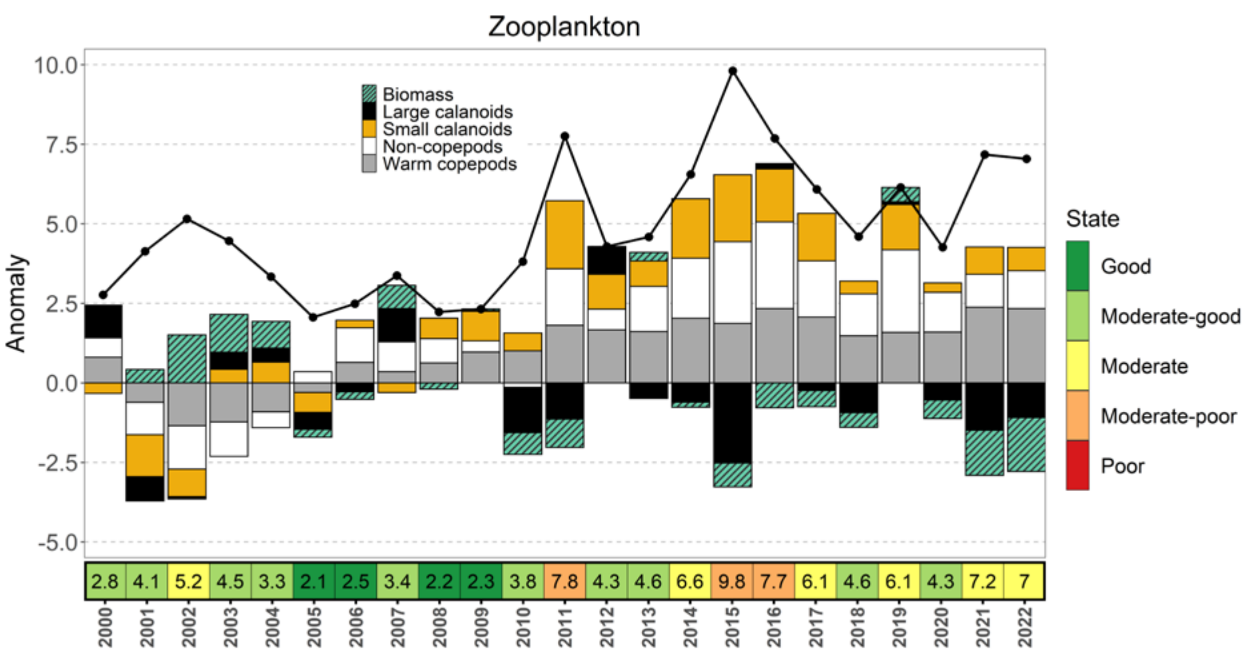


Figure 2.18 Anomalies measured in zooplankton communities from 2000 to 2022

Major changes in the status of communities since 2010

Although few significant changes have occurred since the previous study period (2013–2017), some are apparent over a longer period. Starting in 2010, the average values of the different indices began to diverge more markedly from normal values (i.e. 1999–2010 reference period), particularly in 2011, 2014–2017, 2019, 2021 and 2022. For example, zooplankton biomass, which is primarily associated with large copepod abundance, has generally been below normal since 2010. This result suggests a decline in the potential transfer of energy to higher trophic levels.

Altered community size structure affects the food chain

Since 2010, the abundance of large calanoid copepods (e.g. *Calanus finmarchicus and Calanus hyperboreus*) has been below average overall. Environmental conditions in the estuary and Gulf appear to be less conducive to these species' growth and retention than they were prior to 2010. Conversely, the abundance of small calanoid copepods is increasing. This means that the size structure of the zooplankton community is changing, which will have an impact on the food chain. In particular, generalist feeders will be forced to rely on smaller prey of potentially lower nutritional quality, meaning that they will have to catch more prey to obtain the equivalent of a large calanoid copepod.

The average abundance of non-copepods has also increased relative to the 1999–2010 reference period. This category includes different groups, notably gelatinous organisms and the planktonic larval stages of benthic organisms. Members of this group generally have lower nutritional value than copepods.

A crucial role in the marine food web and the carbon cycle

Zooplankton are an essential food resource for many pelagic animals. Therefore, changes in their growth, survival, and retention in the waters of the estuary and Gulf can have repercussions on recruitment processes and productivity at higher trophic levels, affecting commercially valuable species. Variations in plankton production dynamics are just one of several environmental stressors—which also include hypoxia and ocean acidification—that affect the marine food web.

What impact does climate change have on zooplankton communities?

The abundance, composition and distribution of zooplankton communities are influenced by environmental conditions, including:

- The temperature of the cold intermediate layer and deep layer;
- Extent of the ice cover and timing of ice retreat;
- Timing of the spring bloom, and the quantity and type of food available (phytoplankton);
- Timing and extent of the freshwater discharge from the St. Lawrence River in the spring;
- Composition of the deep water mass that enters the Gulf at Cabot Strait.

In general, a warmer climate (early ice retreat and phytoplankton bloom) could promote the earlier growth of zooplankton and, in combination with changes in the circulation of water masses in the estuary and Gulf and the influx of warmer deep waters into the Gulf through Cabot Strait, modify the composition of the zooplankton assemblage.

For more information

BLAIS, Marjolaine, 2021. Phytoplankton, toxic algae and zooplankton in the estuary and Gulf of St. Lawrence. Fact sheet. State of the St. Lawrence Monitoring Program. Fisheries and Oceans Canada.

BLAIS, M., P. S. GALBRAITH, S. PLOURDE, E. DEVRED, S. CLAY, C. LEHOUX, and L. DEVINE, 2021. Chemical and Biological Oceanographic Conditions in the Estuary and Gulf of St. Lawrence during 2020. DFO Can. Sci. Advis. Sec. Res. Doc. 2021/060, iv + 67 pp.

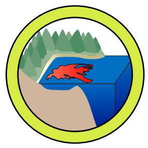
BRENNAN, Catherine, Frédéric MAPS, Wendy C. GENTLEMAN, Diane LAVOIE, Joël CHASSÉ, Stéphane PLOURDE, and Catherine L. JOHNSON, 2021. "Ocean circulation changes drive shifts in Calanus abundance in North Atlantic right whale foraging habitat: A model comparison of cool and warm year scenarios," *Progress in Oceanography*, Vol. 197, pp. 102629

PLOURDE, Stéphane, Pierre JOLY, Jeffrey A. RUNGE, Julian DODSON, and Bruno ZAKARDJIAN, 2003. "Life cycle of Calanus hyperboreus in the lower St. Lawrence Estuary and its relationship to local environmental conditions," *Marine Ecology Progress Series*, Vol. 255, pp. 219–233.

WINDER, Monika, and Alan D. JASSBY, 2011. "Shifts in zooplankton community structure: Implications for food web processes in the upper San Francisco estuary," *Estuaries and Coasts*, Vol. 34, pp. 675–690.

Toxic algae

Lead organization: Fisheries and Oceans Canada (DFO)
Study area: lower estuary and Gulf of St. Lawrence



Status: moderate-good in 2018–2022
Trend: slight deterioration since 2010

Toxic algae are monitored at six sites in the lower estuary and Gulf of St. Lawrence. The overall status of this indicator is rated "moderate-good," based on an analysis of the frequency and intensity of blooms of species in the genera *Alexandrium* and *Pseudo-nitzschia*. The status of the indicator remains unchanged from the 2013–2018 period.

Figure 2.19 Monitoring sites of toxic algae in the lower estuary and Gulf of St. Lawrence

Pseudo-nitzschia blooms more frequent than *Alexandrium* blooms

Between 2018 and 2022, the frequency and intensity of *Alexandrium* blooms decreased on average relative to the reference period (1994–2017). The opposite is true for the genus *Pseudo-nitzschia*, with above-average bloom frequency and intensity observed, notably in 2021. *Pseudo-nitzschia* blooms were particularly abundant in the lower estuary of the St. Lawrence and in Chaleur Bay.

Relative to the 2011–2013 period, an improving trend in toxic algae is observed with respect to the frequency and intensity of *Alexandrium* blooms compared with a deteriorating trend with respect to *Pseudo-nitzschia* blooms. Bloom intensity nonetheless remained stable for the latter species, despite a record high bloom intensity in 2021. In addition, an increase in the interannual variability of toxic algal blooms in the estuary and Gulf of St. Lawrence has been noted since 1994.

Dry summer conditions hinder *Alexandrium* blooms

The genus *Alexandrium* is largely dominated by the dinoflagellate species *Alexandrium catenella*, which is well represented in the lower estuary of the St. Lawrence. Blooms of this dinoflagellate often occur in the summer following heavy precipitation, combined with increased discharge from tributaries of the St. Lawrence River (see Starr et al. 2017).

Red tide of 2008 - M. Starr, Fisheries and Oceans Canada

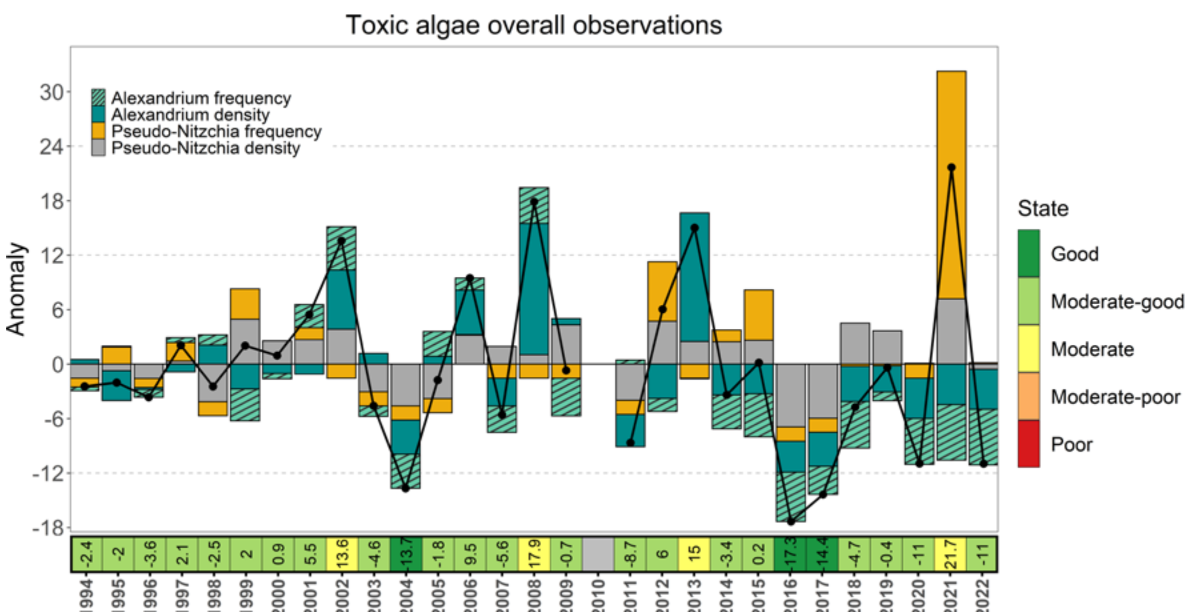


Figure 2.20 Anomalies measured in algae communities from 1994 to 2022

Freshwater inflows from tributaries reduce salinity and increase water temperature in the receiving environment, creating conditions favourable for *A. catenella* cell growth. Riverine inputs of dissolved organic matter and nutrients also enhance the species' growth. However, the drier summer conditions over the past decade may have hindered *Alexandrium* bloom development, thus contributing to an improvement in the toxic algae indicator with respect to *Alexandrium* blooms.

In contrast, diatoms of the genus *Pseudo-nitzschia* prefer environmental conditions characterized by higher salinity and weaker stratification (Boivin-Rioux et al. 2021, 2022). These conditions were present in the lower estuary in 2021 (Galbraith et al. 2022), a year when exceptional blooms of *Pseudo-nitzschia* were observed. However, this phenomenon (and its occurrence) is poorly understood, and more in-depth analysis is required to determine the causes. These large bloom events (the most recent event of comparable magnitude dates back to 1994) underscore the need to continue monitoring toxic algae in the estuary and Gulf of St. Lawrence.

What environmental issue is associated with toxic algae?

Toxic algae are naturally present in bodies of salt water and are an integral part of the St. Lawrence ecosystem. However, mass blooms of these algae produce high concentrations of neurotoxins, which are released into the surrounding water. These neurotoxins build up in the food chain through the processes of bioaccumulation and biomagnification, and can cause mortalities in many marine and aquatic species. Blooms of these algae are a frequent occurrence in the St. Lawrence River and can trigger the closure of shellfish harvest areas (Bates et al. 2020; McKenzie 2021), in addition to causing unusually high mortality of aquatic organisms, including species at risk such as the Beluga (Starr et al. 2017). Eutrophication of coastal waters is one of the factors implicated in the increased prevalence of toxic algal species observed in many regions of the world (Glibert et al. 2017).

What impact does climate change have on toxic algae?

Toxic algae are sensitive to environmental conditions and may respond to climatic variations. Recent studies on the potential effects of climate change on the occurrence of several toxic algae species on Canada's East Coast (including the estuary and Gulf of St. Lawrence) have predicted increases in the frequency and spatial extent of Alexandrium catenella blooms, along with a change in seasonality patterns. Researchers also predict an increase in interannual variability. By contrast, simulations of climatic conditions point to a stabilization, or decrease, in blooms of Pseudo-nitzschia seriata. The anticipated changes in bloom occurrence are based on projections of warming surface water temperatures and increased freshwater inputs over the coming decades.

For more information

BLAIS, Marjolaine, 2021. Phytoplankton, toxic algae and zooplankton in the estuary and Gulf of St. Lawrence. Fact sheet. State of the St. Lawrence Monitoring Program. Fisheries and Oceans Canada.

BOIVIN-RIOUX, Aude, Michel STARR, Joël CHASSÉ, Michael SCARRATT, William PERRIE, and Zhenxia LONG, 2021. "Predicting the Effects of Climate Change on the Occurrence of the Toxic Dinoflagellate Alexandrium catenella Along Canada's East Coast," *Frontiers in Marine Science*, Vol. 7, p.

St. Lawrence Global Observatory. Harmful algae monitoring.

References

BATES, Stephen S., Daniel G. BEACH, Luc A. COMEAU, Nicola HAIGH, Nancy I. LEWIS, Andrea LOCKE, Jennifer L. MARTIN, Pearse MCCARRON, Cynthia H. MCKENZIE, Christine MICHEL, Christopher O. MILES, Michel POULIN, Michael A. QUILLIAM, Wade A. ROURKE, Michael G. SCARRATT, Michel STARR, and Terri WELLS, 2020. *Marine harmful algal blooms and phycotoxins of concern to Canada*. Can. Tech. Rep. Fish. Aquat. Sci., No. 3384, x + 322 pp.

BOIVIN-RIOUX, Aude, Michel STARR, Joël CHASSÉ, Michael SCARRATT, William PERRIE, Zhenxia LONG, and Diane LAVOIE, 2022. "Harmful algae and climate change on the Canadian East Coast: Exploring occurrence predictions of *Dinophysis acuminata*, *D. norvegica*, and *Pseudo-nitzschia seriata*," *Harmful Algae*, Vol. 112, p. 102183. https://doi.org/10.1016/j.hal.2022.102183.

GALBRAITH, P.S., J. CHASSÉ, J. DUMAS, J.-L. SHAW, C. CAVERHILL, D. LEFAIVRE, and C. LAFLEUR, 2022. *Physical Oceanographic Conditions in the Gulf of St. Lawrence during 2021*. DFO Can. Sci. Advis. Sec. Res. Doc. 2022/034. iv + 83 pp.

GLIBERT, Patricia M., 2017. “Eutrophication, harmful algae and biodiversity — Challenging paradigms in a world of complex nutrient changes,” *Marine Pollution Bulletin*, Vol. 124, pp. 591–606.

MCKENZIE, Cynthia H., Stephen S. BATES, Jennifer L. MARTIN, Nicola HAIGH, Kimberly L. HOWLAND, Nancy I. LEWIS, Andrea LOCKE, Angelica PEÑA, Michel POULIN, André ROCHON, Wade A. ROURKE, Michael G. SCARRATT, Michel STARR, and Terri WELLS, 2021. “Three decades of Canadian marine harmful algal events: phytoplankton and phycotoxins of concern to human and ecosystem health,” *Harmful Algae*, Vol. 102, p. 101852. https://doi.org/10.1016/j.hal.2020.101852.

STARR, M., S. LAIR, S. MICHAUD, M. SCARRATT, M. QUILLIAM, D. LEFAIVRE, M. ROBERT, A. WOTHERSPOON, R. MICHAUD, N. MÉNARD, G. SAUVÉ, S. LESSARD, P. BÉLAND, and L. MEASURES, 2017. “Multispecies mass mortality of marine fauna linked to a toxic dinoflagellate bloom,” *PLoS ONE*, Vol. 12, No. 5, p. e0176299. https://doi.org/10.1371/journal.pone.0176299.

Striped Bass population

Lead organization: Ministère de l’Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MELCCFP)
Study area: fluvial section, fluvial estuary and upper estuary

Status: moderate-good between 2013 and 2022
Trend: improvement since 2013

Twenty years after the reintroduction program for the St. Lawrence River population of the Striped Bass was implemented, the species is showing signs of recovery. Information obtained from abundance monitoring (Figure 2.20), along with other research activities carried out by MELCCFP, is used to track the recovery of the Striped Bass over time.

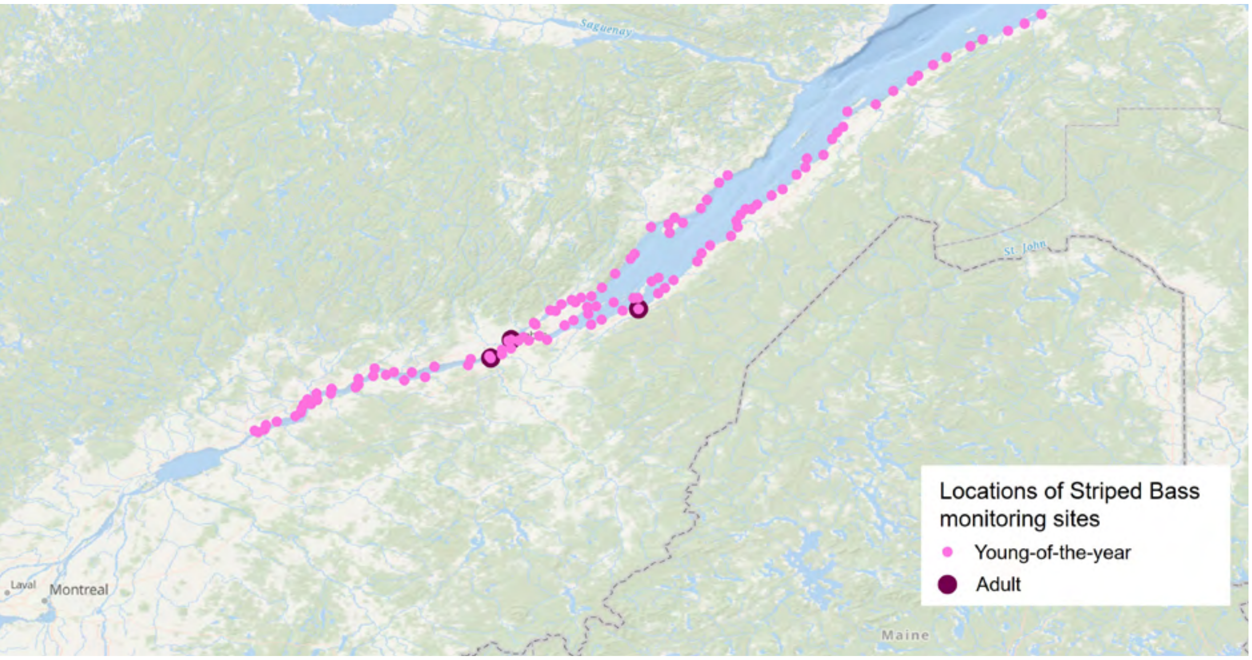


Figure 2.21 Locations of monitoring sites for young-of-the-year (fuchsia) and adult Striped Bass (dark red) of the St. Lawrence River population

Monitoring young-of-the-year

Individuals have been captured in every campaign to monitor young-of-the-year Striped Bass since this monitoring began, indicating that spawning has taken place every year. This is a positive finding, since it indicates that, every year, a certain number of young are surviving beyond the larval stage, an especially vulnerable period in the species' life cycle.

Between 2013 and 2022, mean annual abundance of young-of-the-year Striped Bass was variable, ranging from 0.3 to 8.0 individuals per station (Figure 2.21), which nevertheless indicates an increasing trend according to the most recent statistical analyses (generalized linear mixed effect models). At present, it is impossible to determine whether the abundance of young Striped Bass is stabilizing or whether it will continue to increase gradually.

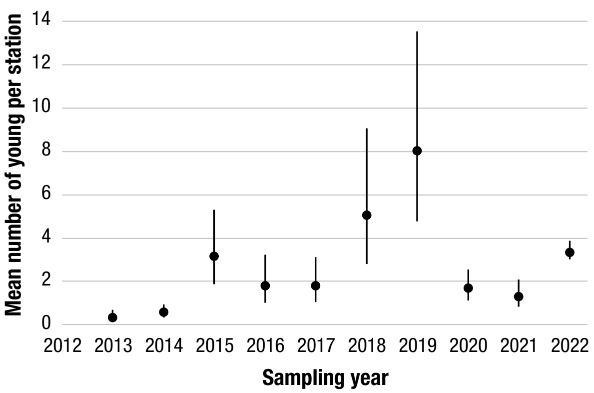


Figure 2.22 Mean number of young-of-the-year Striped Bass caught per station from 2013 to 2022. The vertical bars represent the 95% confidence interval.

Just as abundance has varied, the proportion of stations with captures of young-of-the-year Striped Bass has varied from year to year, ranging from 14% to 46%. In addition, a station east of L'Isle-Verte was added to the monitoring program because of the ever-increasing number of young-of-the-year reported in that area, which points to an expansion in the distribution of this life stage.

Monitoring adults

Surveys conducted at spawning sites from 2015 to 2018, together with data collected by the Réseau d'inventaire des poissons de l'estuaire (Estuary Fish Inventory Network, or EFIN) since 2020, indicate that St. Lawrence River Striped Bass are reproducing successfully. Some individuals from each cohort born in the wild since 2008 have reached the adult stage (Figure 2.22). Based on an analysis of fish scale chemical composition, it was determined that over 99% of the adults sampled in 2017 and 2018 at spawning sites were hatched in the wild.

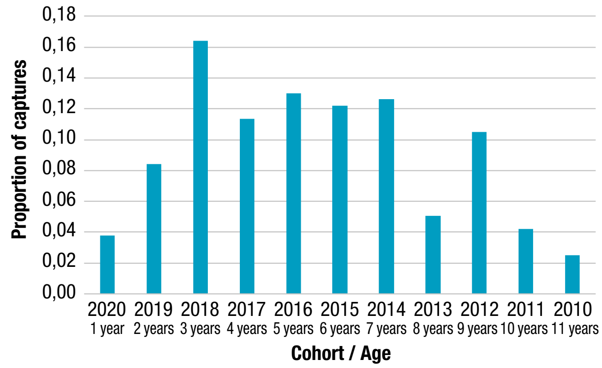


Figure 2.23 Age structure of Striped Bass caught in 2021 during weir fishing conducted by EFIN.

The proportion of captures for each cohort (individuals 1–11 years) hatched in the St. Lawrence River between 2010 and 2020 is presented.

An improving trend

As was the case in the 2019 Overview, the overall status of the indicator for the St. Lawrence River Striped Bass population is "moderate-good." Natural spawning is occurring. The young are surviving and growing, and some are being recruited to the spawning component of the population. These results are positive because they indicate that the population is now able to sustain itself in the St. Lawrence River without supplementation through stocking, a major milestone in the species' recovery. The stocking program, initiated in 2002, was suspended in 2018 on the basis of the above findings.

While the abundance of young-of-the-year has shown a gradually improving trend, it will be a few years before the relative abundance of adults can be assessed. At present, additional inventory techniques, such as acoustic telemetry tracking of adults, are being used to evaluate some key elements of population dynamics, including survival rates.

On the whole, the results of the past few years are encouraging. However, given the high interannual variability that characterizes the Striped Bass population, particularly in terms of recruitment, a cautious approach should be taken in assessing its situation. Maintaining monitoring efforts over the long term is therefore essential for refining the reference points and assessing the population's recovery.

What does this indicator tell us about the environmental issues affecting the St. Lawrence River?

The Striped Bass is the only fish species that has been extirpated from the St. Lawrence River. Its disappearance has been attributed to habitat alteration and overfishing. The species' successful reintroduction and the improvement in its status indicate that these pressures have been reined in to some extent.

How is this indicator affected by climate change?

This indicator is not directly affected by climate change. Nonetheless, climatic variations could have an indirect effect on the growth and survival of Striped Bass as well as on their spawning success, which could be reflected in the monitoring results. For example, water temperature and salinity are abiotic factors that can partly explain the observed fluctuations in the abundance of young Striped Bass. A change in these parameters could also affect the trends observed.

How is the Striped Bass population monitored?

Beach seine sampling conducted to monitor young-of-the-year Striped Bass. Photo: Denis Fournier

MELCCFP has been monitoring **the abundance of young-of-the-year** using a standardized approach since 2013.

Monitoring is conducted annually in mid-September; it initially included 100 stations, but was increased to 110 in 2020 to take in an area farther east between L'Isle-Verte and Bic (Figure 2.20). The monitoring stations are distributed along the St. Lawrence from Trois-Rivières to La Malbaie on the north shore, and from Bécancour to Rimouski on the south shore. The main islands are also represented.

MELCCFP also monitors **juvenile and adult Striped Bass abundance** through the Estuary Fish Inventory Network, which uses four weir fishing sites in the fluvial estuary and the upper estuary. This activity was implemented in 2020 to replace the gillnet-based adult monitoring program conducted on the species' spawning grounds, which began in 2015 and was suspended in 2019 because certain analyses could not be performed as planned (capture-mark-recapture analyses). This change will not affect the network's ability to assess recruitment to the population. However, changes in population abundance or structure that have occurred since the 2019 Overview cannot be assessed.

For more information

MINISTÈRE DE L'ENVIRONNEMENT ET DE LA LUTTE CONTRE LES CHANGEMENTS CLIMATIQUES, 2020. Rapport sur l'état des ressources en eau et des écosystèmes aquatiques du Québec, *2020*, 480 pp.

FISHERIES AND OCEANS CANADA, 2021. Recovery Strategy and Action Plan for the Striped Bass (Morone saxatilis), St. Lawrence River population, in Canada. Species at Risk Act Recovery Strategy Series and Action Plan Series, vi + 65 pp.

L'ITALIEN, L., J. MAINGUY, and E. VALIQUETTE, 2020. Dynamique et habitats de reproduction de la population réintroduite de bars rayés (Morone saxatilis) dans le fleuve Saint-Laurent, Ministère des Forêts, de la Faune et des Parcs, Quebec, xvi + 123 pp.

Fish communities in fresh and brackish waters

Lead organization: Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MELCCFP)
Study area: fluvial section, fluvial estuary and upper estuary

Status: moderate between 2019 and 2021*
Trend: unchanged since the 2019 Overview but deterioration since 1995*

(*Note that the findings vary by species and location)

According to the various monitoring results, the overall state of health of fish communities in the fresh and brackish water portions of the St. Lawrence is rated "moderate" (Figure 2.23). This must be interpreted as representing the average situation for each area monitored. In actual fact, the status of some areas or some species falls in the "moderate-poor" category, particularly downstream of Lake Saint-Louis.

Over the years, a number of fish stocks in the St. Lawrence have experienced periods of decline associated with overfishing. Fortunately, appropriate management measures have made it possible, in some cases, to restore the populations to a sustainable harvesting level (e.g. Lake Sturgeon). However, some stocks have been slow to recover and are still showing signs of collapse or low abundance despite the various measures implemented to support their recovery (e.g. Yellow Perch in Lake Saint-Pierre and the Bécancour-Batiscan area). Some factors unrelated to fishing have also limited the recovery of certain species such as the American Eel. The degradation of aquatic habitats, poor water quality, loss of connectivity between key habitats and turbine-induced mortalities have had a major impact on the production of spawners in this species. In addition, the presence of invasive species has had a limiting effect on the productivity of all native species.

"Moderate-poor" status of Lake Saint-Pierre fish communities

The fish communities in Lake Saint-Pierre have shown particularly rapid signs of degradation. Species associated with aquatic grass beds and the floodplain, such as Yellow Perch and Northern Pike, have shown a steep decline,

Figure 2.24 Main areas of the St. Lawrence sampled by the Réseau de suivi ichtyologique (Fish Monitoring Network, or FMN) and the Réseau d'inventaire des poissons de l'estuaire (Estuary Fish Inventory Network, or EFIN)

allowing opportunistic and tolerant species like Channel Catfish to make inroads. In Lake Saint-Pierre and in the stretch of river between Laviolette Bridge and Saint-Pierre-les-Becquets, Yellow Perch has experienced a steep decline over the past two decades because of the deterioration in its spawning and rearing habitats. Sport fishing and commercial fishing have been prohibited there since 2012. Significant variability is observed in the status of some species between different sections of the St. Lawrence. For example, in Lakes Saint-François and Saint-Louis, Yellow Perch stocks are abundant and support a sustainable recreational fishery.

"Moderate" status of estuary communities

Although the information available on the status of fish communities in the St. Lawrence estuary is more fragmentary, no major community-wide impacts have been observed in recent years. However, some flagship species have experienced declines; for example, Atlantic Tomcod abundance has decreased by about 27% since 2009. With regard to Atlantic Sturgeon, an increase in abundance has been observed since 2006, but the size structure of the population has changed over the past few years, with an increase in small individuals and a decrease in large ones. Nonetheless, the species' high recruitment has so far offset the decrease in the abundance of large Atlantic Sturgeon and prevented a decline in the total population. The long-term implications of this aspect of the species' population dynamics are not known, hence a cautious approach to managing fishing is in order.

Status of the American Eel stock worrisome

Formerly one of the most common species in the region, the American Eel has experienced a decrease in its distribution and its abundance. Despite the recovery efforts made over the past 20 years, recruitment has continued to decline, and the stock has shown no signs of recovery. A 77% decrease in fishing mortality was recorded between 1996 and 2022 after several licence buyback programs were implemented in the commercial fishery in an effort to stem the decline in spawners. Various conservation measures were also put in place during this period, helping to stabilize the situation (Figure 2.24). The status of the American Eel stock is nonetheless considered of great concern in Quebec and throughout its range.

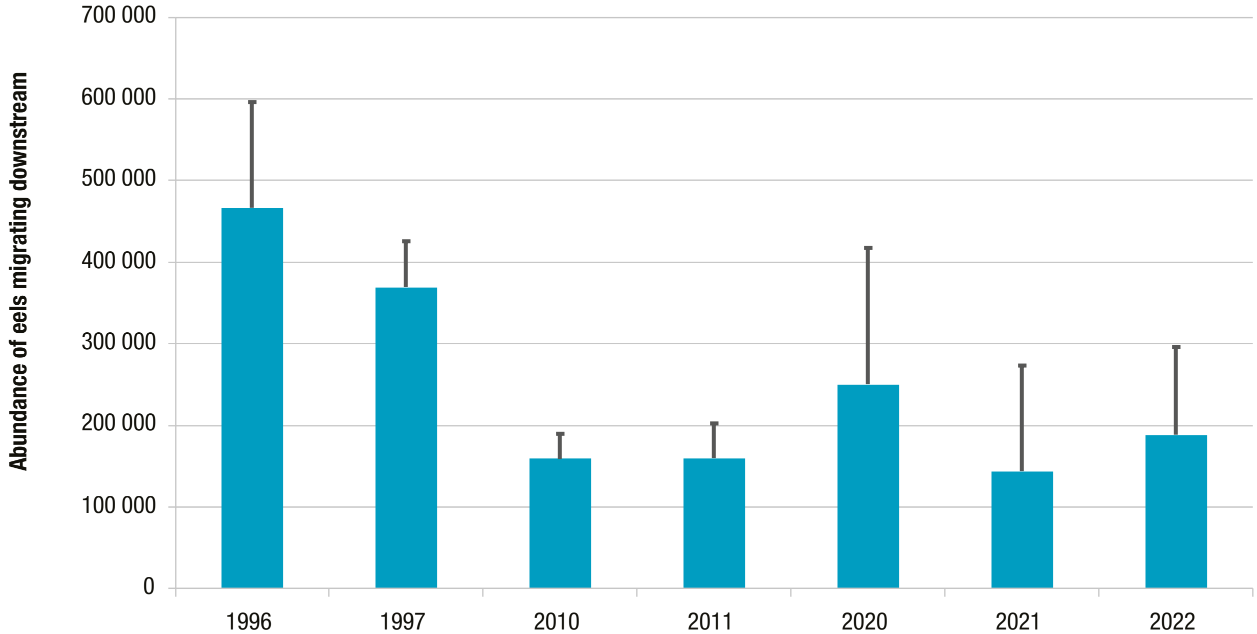


Figure 2.25 Temporal change in the abundance of eels migrating downstream in the St. Lawrence

The spawning stock generated annually by the St. Lawrence system is periodically estimated on the basis of captures and tagging in the Quebec City area and recaptures in the Lower St. Lawrence and Charlevoix regions.

Status unchanged since the 2019 Overview*

Over the last two decades, many rapid changes have been observed in the characteristics of aquatic habitats and in the structure of fish communities, attesting to the evolution of the river ecosystem and the degradation that has affected some areas. The most noticeable and best documented degradation has taken place in Lake Saint-Pierre.

In Lake Saint-Pierre, human activities have had significant impacts on aquatic habitats and therefore on fish communities (Figure 2.25). Over the last 30 years, changes in cropping practices, including the shift from perennial to annual crops, have profoundly modified the Lake Saint-Pierre floodplain, resulting in the loss of Yellow Perch spawning habitats equivalent in size to more than 9,000 football fields. Recruitment (the addition of new individuals to the population) has decreased significantly since the early 2000s, and the aquatic grass beds that serve as rearing habitat for young perch have continued to shrink in size (Figure 2.26). Habitat degradation in Lake Saint-Pierre has not only affected Yellow Perch, but the entire fish community in this area has been altered over the past 20 or so years through the negative effects of human activities on aquatic habitats (Figure 2.25). Most of the fish community that was present in the early 2000s was dependent on aquatic grass beds and the floodplain. The community is now dominated by opportunistic species that feed on the lake bottom or in the water column.

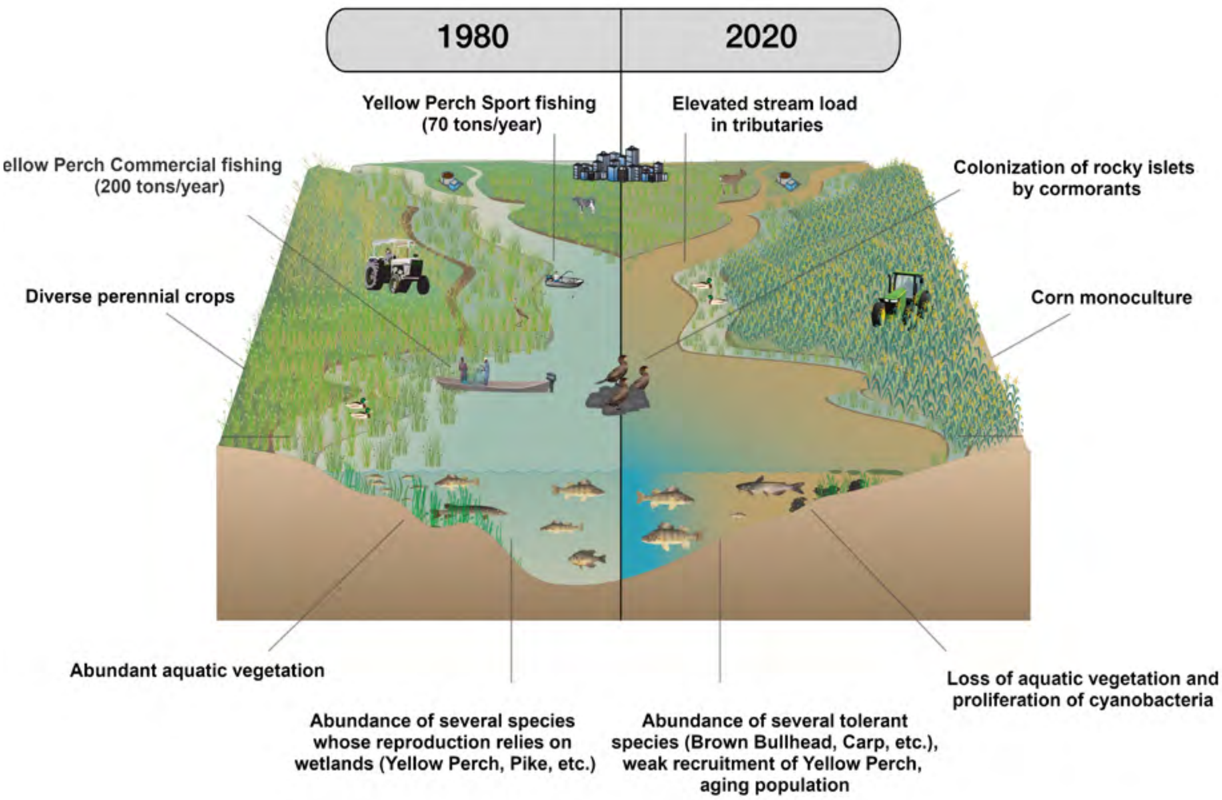


Figure 2.26 Changes in Lake Saint-Pierre since the 1980s and impacts on habitat and fish communities

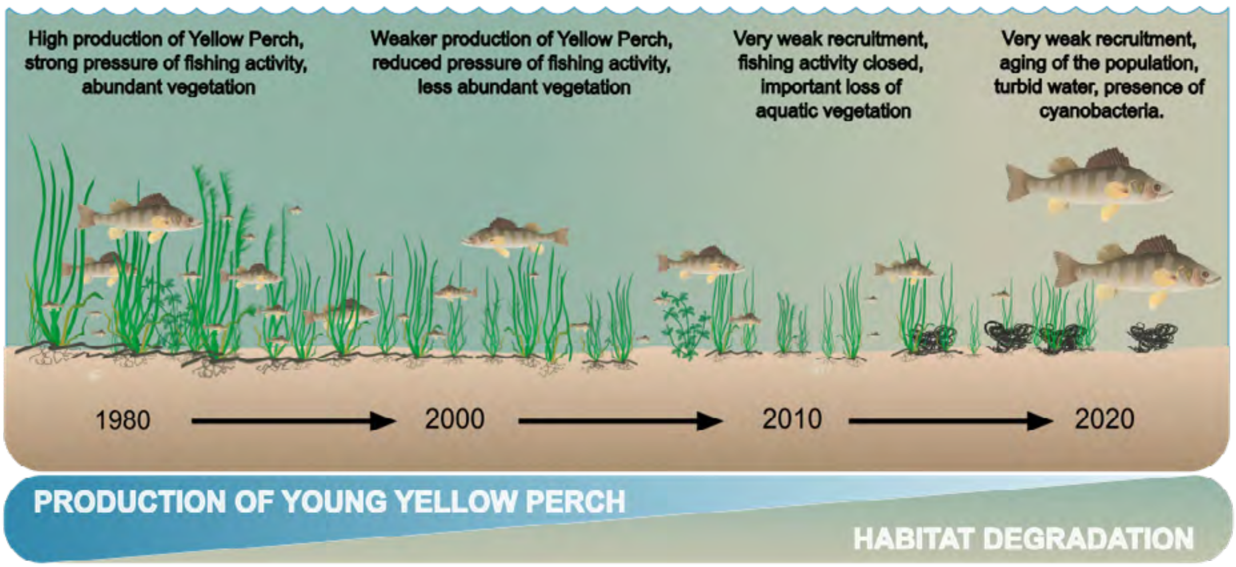


Figure 2.27 Transformation of Yellow Perch habitat and changes in the species' abundance in Lake Saint-Pierre

Recruitment has decreased significantly since the early 2000s. Individuals aged 1–3 are 75% less abundant (modified from Brodeur et al. 2022)

Fortunately, the degradation of aquatic habitats does not appear to be as pronounced in the other stretches of the fluvial section or in the estuary. In addition, some species have been observed using habitats that were presumed to have been lost. For example, Lake Sturgeon have been observed at certain spawning grounds that were not documented in the past (or were not well documented) or were thought to have been abandoned (e.g. the Chaudière, Montmorency and Richelieu Rivers, the Rivière des Mille-Îles, and the Rivière du Sud). This is indicative of an improvement in this species' situation in the St. Lawrence River after three decades of decline.

In conclusion, profound and rapid changes in the state of aquatic habitats have been observed in some areas, resulting in significant modifications in the structure of fish communities in the St. Lawrence.

- **What does this indicator tell us about the environmental issues affecting the St. Lawrence River?**

Fish are excellent bioindicators of the state of health of aquatic ecosystems, and also have considerable heritage and socio-economic value. The state of fish communities is influenced by a range of environmental issues that are addressed by other indicators (e.g. changes in Lake Saint-Pierre).

- **How is this indicator affected by climate change?**

It is difficult to isolate the role that climate has played in relation to changes in the status of fish communities in the St. Lawrence River. Nonetheless, climate change can have an indirect effect on aspects such as species growth and reproduction, as well as on the condition of aquatic grass beds, and this may be reflected in the monitoring results.

How is the status of fish communities assessed?



Photos of sampling activities (from left to right, gillnet sampling, beach seine sampling and tagging of eels). Photo: MELCCFP

The status of the fish communities in the St. Lawrence River is assessed by examining relative abundance, population structure, community composition, species diversity and the characteristics of aquatic habitats. In the fluvial corridor of the St. Lawrence, the Réseau de suivi ichtyologique (Fish Monitoring Network, or FMN) has been tracking the status of fish populations since 1995. Complementary data are provided by the Réseau d'inventaire des poissons de l'estuaire (Estuary Fish Inventory Network, or EFIN), which was established in 2009 to monitor the health of fish species in the upper estuary.

For more information

PARADIS, Y., M. MINGELBIER, P. BRODEUR, N. VACHON, C. CÔTÉ, D. HATIN, M.A. COUILLARD, G. VERREAULT, L. L'ITALIEN, R. POULIOT, A. FOUBERT, F. LECOMTE, E. VALIQUETTE, and D. CÔTÉ-VAILLANCOURT, 2020. Status of Fish Communities of the Freshwater and Brackish Water of the St. Lawrence. Plan St. Laurent, 3rd edition, Ministère des Forêts, de la Faune et des Parcs, Québec, 14 pp.

LAPORTE, M., M.-J. GAGNON, P.N. BÉGIN, P. BRODEUR, É. PAQUIN, J. MAINGUY, M. MINGELBIER, C. CÔTÉ, F. LECOMTE, C. BEAUVAIS, Z.E. TARANU, Y. PARADIS, and R. POULIOT, 2023. "Déclin de la végétation aquatique submergée au lac Saint-Pierre entre 2002 et 2021," *Le Naturaliste canadien*, 147 (2). pp. 69-81. DOI: 10.7202/1105486ar.

BRODEUR, P., P. DUMONT, P. MAGNAN, É. PAQUIN, Y. PARADIS, N. VACHON, and Y. MAILHOT, 2022. *Évaluation par simulation de la capacité du stock de perchaudes du lac Saint-Pierre à soutenir une pêcherie durable*. Ministère des Forêts, de la Faune et des Parcs. iii + 19 pp. and appendices.

References

BRODEUR, P., É. PAQUIN, Y. PARADIS, N. VACHON, and S. LACHANCE, 2022. "La perchaude du lac Saint-Pierre : bien plus qu'une histoire de pêche," *Sentier Chasse et Pêche*, October, pp. 44–49.

Beluga population

Lead organization: Fisheries and Oceans Canada (DFO)
Study area: upper estuary and lower estuary

Status: moderate-poor
Trend: slight improvement since 2013–2017

The St. Lawrence Beluga is isolated from other Beluga populations distributed throughout the circumpolar region of the Arctic. Owing to their year-round presence in the estuary, Beluga are regularly exposed to the pressures that human activities can exert on marine mammals in general. Collision risks and disturbances from pleasure craft, chronic noise generated by marine traffic, and the presence of chemical and bacteriological contaminants are a few examples. The viability of the St. Lawrence Beluga population has been threatened by these stressors since the last century. The overall status of this indicator has been rated as “moderate-poor” for the 2018–2023 period.

The decline in the Beluga population that began in the early 2000s appears to have slowed in recent years and the population may have stabilized, since Beluga numbers were recently estimated to be between 1,530 and 2,180 individuals. The abundance and mortality indices for young individuals (ages 0–1) nonetheless raise concerns in relation to the status of the St. Lawrence Beluga population. The apparent stabilization of the population can be explained in part by a significant decrease in the incidence of cancers; however, this improvement is likely offset by the continuing high rate of female and newborn mortality during the calving period. The same findings were observed during the period prior to 2018, as reported in the *Overview of the State of the St. Lawrence 2019*.

Between 2010 and 2022, 4 to 17 times more carcasses of newborns were recovered relative to the median for the period from 1983 to 2007. Though these increases remain unexplained, they may indicate that the survival of newborns is threatened. However, since none of the calves examined showed pathological signs (e.g. injury, infection or tumours) that could explain their deaths, it seems likely that disruption in the mother-calf relationship is the main cause of mortality in newborns.

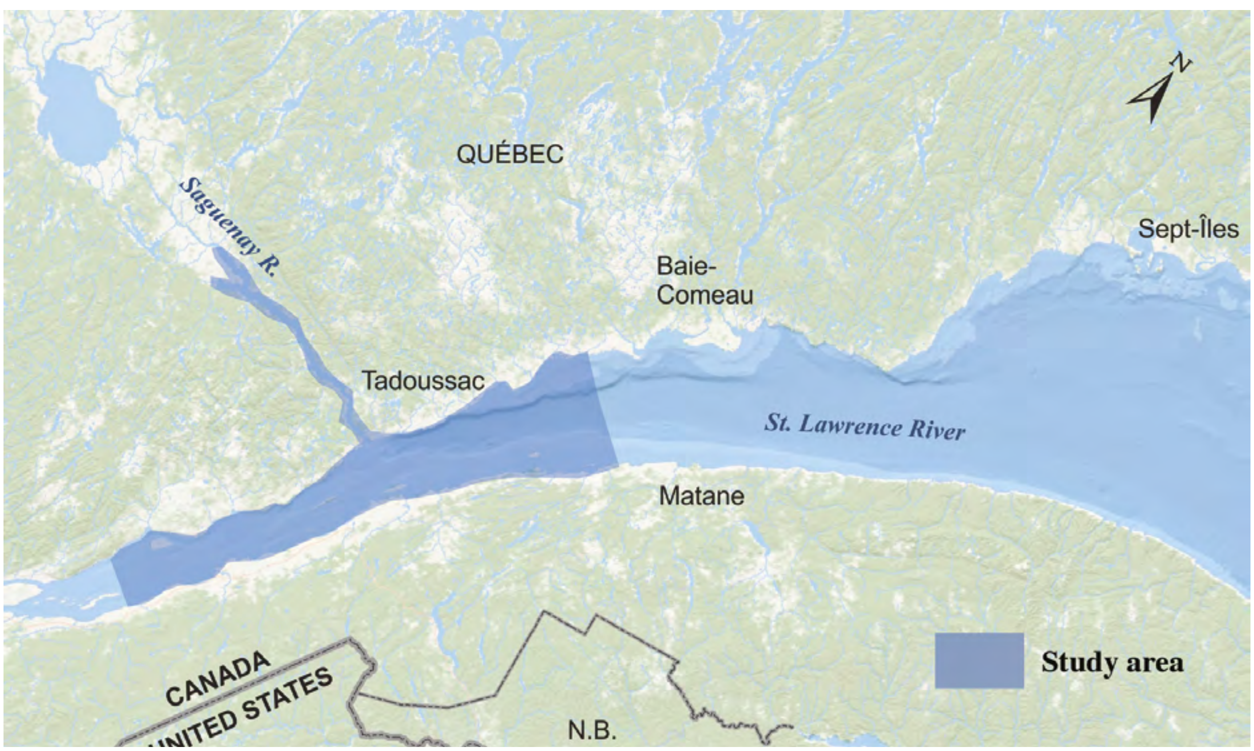


Figure 2.28 Summer distribution of the Beluga

Photo: DFO

The high level of female and calf mortality may be attributable to factors affecting females' health and their physical condition or to factors that interfere with the calving process. These may include contamination by chemicals, disturbance from pleasure boats and chronic noise generated by commercial ships. Low food availability due to climate variability and changes in fisheries, or reduced access to food sources due to disturbance or habitat degradation, may also play a role.

A return to stability

In the mid-1800s, the St. Lawrence Beluga population numbered over 13,000 individuals. By the end of the 1970s, however, commercial whaling and sport hunting had reduced the population to a few hundred individuals. The population was stable or grew at a slow rate until the early 2000s, when it experienced another period of decline which lasted several years.

In recent years, the population has shown a certain degree of stability (Fisheries and Oceans Canada 2023). According to the most recent estimate, the population numbered approximately 1,850 individuals in 2022. Although this estimate is double the size of the 2012 one, it does not mean that Beluga numbers are increasing. Instead, it reflects an improvement in the techniques used to derive population estimates, which can correct for animals that are not visible at the surface and are therefore not included in aerial survey counts (Lesage et al. 2023). Furthermore, it is predicted that the population could start declining again in the coming years, taking into account the high level of female and calf mortalities during calving observed since 2010 (Tinker et al. 2023). The high rate of mortality in adult females translates into a decrease of 15 years in average life expectancy, considerably shortening females' reproductive lifespan and the potential number of calves that they can produce.

During the 1990s, young Belugas (ages 0–1) made up between 15% and 18% of the population. Since 2000, there has been a two- or three-fold decrease in this proportion, which has ranged from 3% to 9% (St-Pierre et al. 2023). The state of this indicator is considered "poor," because young individuals should make up close to 20% of the total population in order for it to be considered healthy. Low recruitment can have an adverse effect on a population's ability to recover when these small cohorts reach sexual maturity.

- **The St. Lawrence Beluga: one of the most contaminated marine mammals**

In recent years, the levels of some pollutants in these whales have decreased, including PAHs and PCBs, which are suspected to have caused the high incidence of cancers observed in the St. Lawrence Belugua population. The regulations governing the use of these chemicals appear to have borne fruit, since no new cases of cancer have been recorded since 2011. During the 1990s, however, the concentrations of some emerging pollutants, including PBDEs, increased exponentially. The rate of increase in concentrations in adult males began to slow in the early 2000s, and appears to have levelled off according to the most recent observations, which date back to 2013 (Simond et al. 2017).

For more information

LESAGE, Véronique, 2021. St. Lawrence Estuary Beluga Whale. Fact sheet. State of the St. Lawrence Monitoring Program. Fisheries and Oceans Canada (DFO).

References

FISHERIES AND OCEANS CANADA, 2023. *Abundance and population trajectory of St. Lawrence beluga*. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2023/024.

LESAGE, V., S. WING, A.F. ZUUR, J.-F. GOSSELIN, A. MOSNIER, A.P. ST-PIERRE, R. MICHAUD, and D. BERTEAUX, D., 2023. *Environmental factors and behaviour of St. Lawrence Estuary beluga generate heterogeneity in availability bias for photographic and visual aerial surveys*. DFO Can. Sci. Advis. Sec. Res. Doc. 2023/046.

SIMOND, A., M. HOUDE, V. LESAGE and J. VERREAULT, 2017. "Temporal trends of PBDEs and emerging flame retardants in belugas from the St. Lawrence Estuary (Canada) and comparisons with minke whales and Canadian Arctic belugas," *Environmental Research*, Vol. 156, pp. 494–504.

ST-PIERRE, A.P., V. LESAGE, A. MOSNIER, M.T. TINKER, and J.-F. GOSSELIN, 2023. *Summer abundance estimates for St. Lawrence Estuary beluga (Delphinapterus leucas) from 52 visual line transect surveys and 11 photographic surveys conducted from 1990 to 2022*. DFO Can. Sci. Advis. Sec. Res. Doc. 2023/048.

TINKER, M.T., A. MOSNIER, A.P. ST-PIERRE, J.-F. GOSSELIN, S. LAIR, R. MICHAUD, and V. LESAGE, 2023. *An Integrated Population Model for St. Lawrence Estuary Belugas (Delphinapterus leucas)*. DFO Can. Sci. Advis. Sec. Res. Doc. 2023/047.

Seabird populations

Lead organization: Environment and Climate Change Canada (ECCC)
Study area: Lower estuary and Gulf of St. Lawrence

Status: moderate in 2018–2022
Trend: unchanged since 2010

The overall status of this indicator is “moderate,” based on an assessment of the populations of five species characteristic of the Gulf of St. Lawrence—Razorbill, Common Murre, Atlantic Puffin, Herring Gull and Caspian Tern. The data were collected in surveys conducted in the North Shore migratory bird sanctuaries in 2022 to evaluate numbers of breeding individuals.

Numbers of Herring Gulls still declining

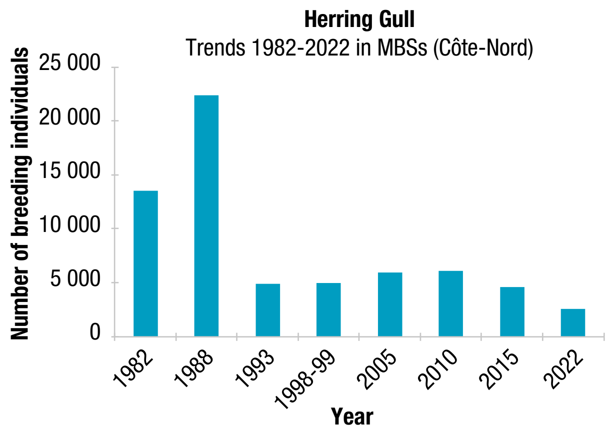


Figure 2.30 Number of Herring Gull breeding individuals in the North Shore migratory bird sanctuaries from 1982 to 2022

In 2022, the North Shore migratory bird sanctuaries were estimated to host roughly 2,500 nesting Herring Gulls. Significant population declines in the species have been

Figure 2.29 North Shore migratory bird sanctuaries

observed over the long and short term. Between 1988 and 1993, the population plummeted by 78%, from over 20,000 breeding individuals to fewer than 5,000. Numbers subsequently remained stable until 2010, which marked the start of an additional decline of 57% (over half the population) between 2010 and 2022.

The population declines that occurred in the late 1980s on the North Shore coincide with the collapse of cod stocks in the Gulf of St. Lawrence. Herring Gulls are omnipresent in ports, where they feed on discarded fish waste—particularly cod—from the fisheries. The drastic decline in the cod fishery had impacts on the species' population. The more recent decline (2010–2022) probably has multiple causes, however. Among others, the presence of mammalian predators should be considered. For example, in recent years, the vast majority of individuals on Île du Corossol apparently failed to nest, due to the presence of red foxes. A 90% decline in breeding individuals was noted in this location in 2022.

Caspian Tern making a comeback

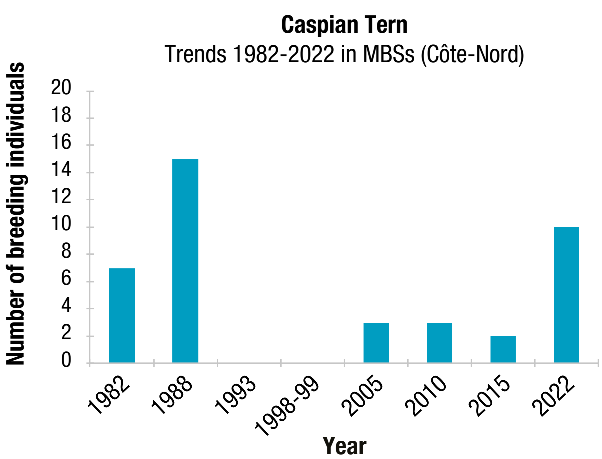


Figure 2.31 Number of Caspian Tern breeding individuals in the North Shore migratory bird sanctuaries from 1982 to 2022

In the past, the Caspian Tern population has struggled to survive, with only two or three individuals found in the previous surveys of the North Shore sanctuaries. However, in 2022, scientists counted five nests and 10 individuals; this includes one pair in the Saint-Augustin sanctuary, a location with only a single nesting record dating back to 1976. This points to a stable rather than declining population trend for the species relative to 1982. In the shorter term, a significant upward trend has been observed since 2010. This finding is encouraging, but it should be noted that the population is small and extremely vulnerable, particularly to human disturbance.

Common Murre and Razorbill doing well

The outlook is good for both the Common Murre and Razorbill, which seem to be benefiting from favourable environmental conditions, particularly an abundance of food in the form of small pelagic fish such as capelin and sand lance. Razorbill and murre numbers in the North Shore sanctuaries continue to increase strongly over both the long and short term, with upwards of 60,000 breeding individuals of each species counted in 2022. However, the presence of foxes on Île du Corossol has probably had a negative effect on both species' reproductive success and, if this situation continues, could have a major impact over the longer term.

Improvement for the Atlantic Puffin

Between 2010 and 2022, the Atlantic Puffin population increased by 60% to slightly above the level recorded in 1982. Despite the presence of arctic fox and even black bear in two nesting colonies on the Lower North Shore, the Atlantic Puffin population was estimated at nearly 35,000 individuals in 2022. Although this species has a diet similar to that of the Common Murre and Razorbill, the population has experienced fluctuations that are difficult to explain. Current numbers are just over half of historical levels (between 1925 and 1955).

What does this indicator tell us about the environmental issues affecting the St. Lawrence River?

Among the five seabird species included in this indicator, some are surface feeders, while others dive to considerable depths to obtain their food. Some feed near the coast, while others forage further offshore (pelagic feeders). Lastly, some are more vulnerable to human disturbance than others. Given the range of foraging styles, habitat use and sensitivity to disturbance in the species studied, the status of and trends in their populations can be considered indicative of the health of the ecosystem.

Environmental conditions—including the abundance of forage fish and fish waste, human disturbance, quality of the breeding grounds, the presence of contaminants and predators such as foxes, and avian disease outbreaks—have an influence on the health of seabird populations. According to the results of surveys conducted in 2022, the avian influenza outbreak in the spring of the same year had a greater impact on some colonies in the estuary (e.g. Common Eider) and the Gulf of St. Lawrence (see Northern Gannet indicator) than others, where the effects were virtually non-existent.

- **What impact does climate change have on seabird populations?**

The status of, and trends in, seabird populations—which reflect these species' reproductive success, among other factors—are in turn indicative of the abundance and availability of their prey species, notably small forage fish such as sand lance and capelin. Changes in oceanographic conditions caused by climate change can affect the distribution and abundance of these fish, with repercussions up and down the food chain.

For more information

ST. LAWRENCE GLOBAL OBSERVATORY. Size of seabird colonies.

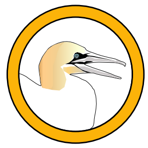
RAIL, J.-F., 2021. "Eighteenth census of seabirds breeding in the sanctuaries of the North Shore of the Gulf of St. Lawrence, 2015," *Canadian Field-Naturalist*, Vol. 135, No. 3, pp. 221–233.

RAIL, J.-F., 2020. Seabirds – Sentinel Species for the Gulf, 4th Edition. Fact sheet. State of the St. Lawrence Monitoring Program. Canadian Wildlife Service, Quebec Region, Environment and Climate Change Canada.

WILHELM, S.I., J.-F. RAIL, P.M. REGULAR, C. GJERDRUM and G.J. ROBERTSON, 2016. "Large-Scale Changes in Abundance of Breeding Herring Gulls (*Larus argentatus*) and Great Black-Backed Gulls (*Larus marinus*) Relative to Reduced Fishing Activities in Southeastern Canada," *Waterbirds*, Vol. 39, No. sp1, pp. 136–142.

Northern Gannet population

Lead organization: Environment and Climate Change Canada (ECCC)
Study area: Lower estuary and Gulf of St. Lawrence



Status: moderate-poor in 2018–2022
Trend: light deterioration since 2010

Overall, the status of the Northern Gannet population in the Gulf of St. Lawrence colonies is rated as "moderate-poor," based on an analysis of population size, reproductive success and contaminant levels measured in the species' eggs.

- **Fewer breeding pairs in 2022: avian influenza may be implicated**

In 2022, the number of Northern Gannet breeding pairs was estimated to be just under 57,000, which represents a 28% decline relative to average values between 2010 and 2020. However, in the Rocher aux Oiseaux colony, the decline was more dramatic, reaching 58%. This drastic decline is attributable to the avian influenza pandemic that raged in 2022, leaving thousands of carcasses visible in the colony and on numerous beaches throughout the Gulf of St. Lawrence. Surprisingly, the Bonaventure Island colony was much less affected, with a 13% drop in breeding pair numbers.

Overall, the Northern Gannet population remained stable between 2004 and 2021, at over 73,000 pairs. Therefore, in spite of the events of 2022, only a modest decline was observed over a 10-year period (since 2012). Consequently, the size of, and trends in, the population were assessed as "moderate." In 2022, the number of breeding pairs exceeded 40,000, which is also the threshold below which the population would be considered to be in poor condition. Nevertheless, the potential resurgence of the avian influenza pandemic raises concerns over further impacts on the Northern Gannet population, particularly during the nesting season.

Figure 2.32 Northern Gannet colonies in the Gulf of St. Lawrence

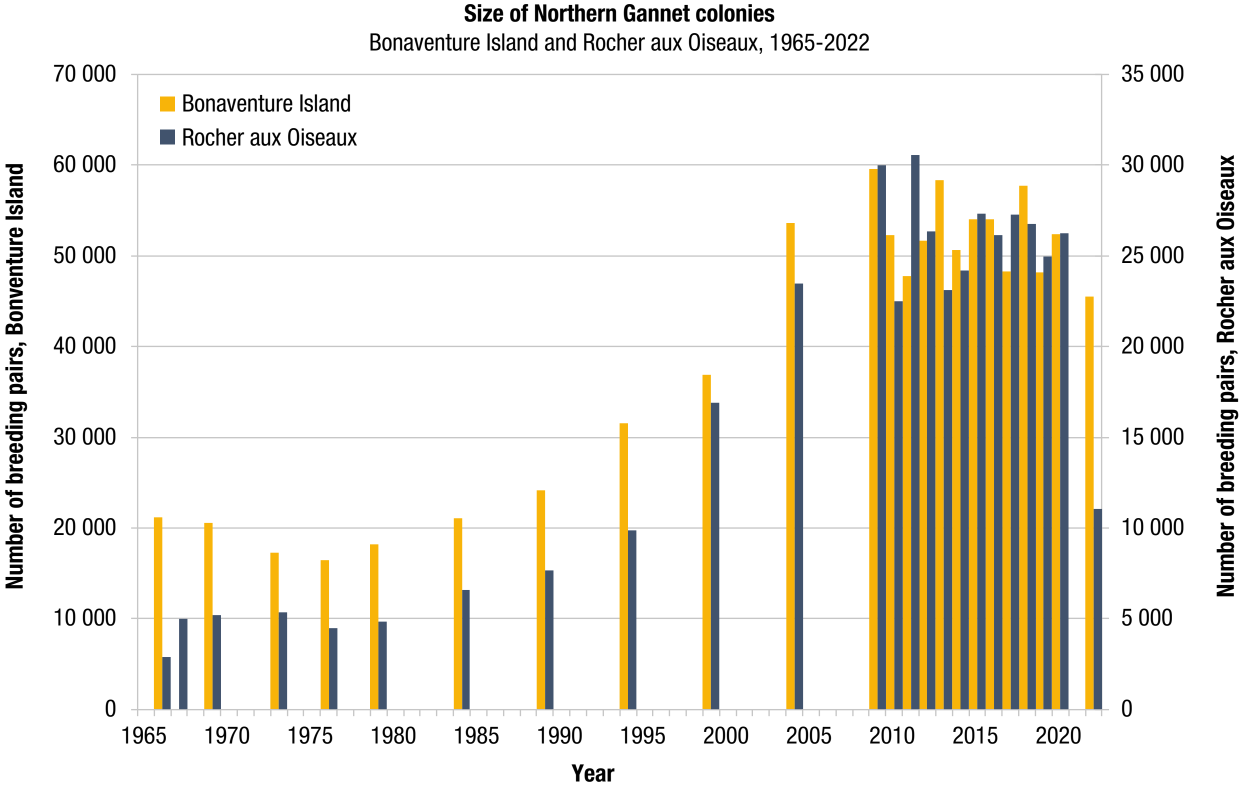


Figure 2.33 Number of Northern Gannet pairs on Bonaventure Island and Rocher aux Oiseaux from 1965 to 2022

Reproductive success still low and variable

In 2022, the species' reproductive success on Bonaventure Island was poor, with only 57% of pairs raising their chick to fledging. Although this percentage is the second highest recorded since 2005, reproductive success has been low on average in the last five years, with wide fluctuations and no significant improvement observed. Indeed, the 12.6% rate obtained in 2019 is one of the poorest on record. This low reproductive rate is attributable to the low abundance of the prey species consumed by the Northern Gannet, such as Atlantic herring and Atlantic mackerel.

No contaminants of concern detected in eggs

The results are encouraging with respect to the levels of contaminants (mercury, PCBs, DDE and PBDEs) measured in Northern Gannet eggs on Bonaventure Island in 2019. The concentrations found are not concerning and have decreased by over 70% on average relative to historical values. When the 2004–2009 period is used for the comparison, mercury, PCB and PBDE concentrations dipped slightly (decreases from 4% to 15%) or remained stable, while DDE concentrations showed a modest increase of 9%. Concentrations of all the contaminants measured were below toxicity thresholds. Although the levels of chemical substances measured in eggs in 2019 give little cause for concern, they will continue to be monitored in the coming years.

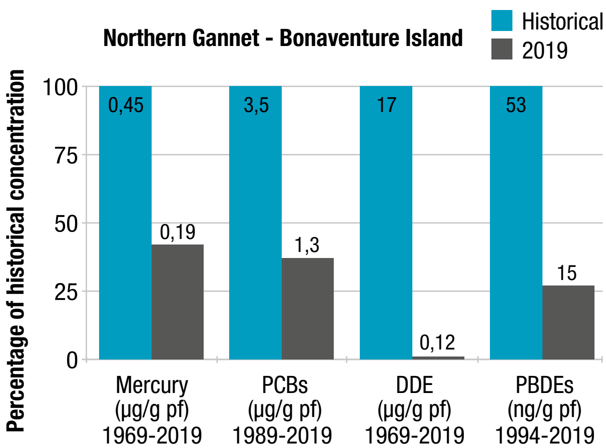


Figure 2.34 Concentrations of contaminants in the eggs of Northern Gannets on Bonaventure Island

What impact does climate change have on the Northern Gannet population?

Population size and reproductive success are strongly indicative of prey availability, particularly that of Atlantic mackerel. Changing climatic and oceanographic conditions can have an impact on the abundance of these fish, as well as on the entire food chain. Epidemics such as avian influenza are also concerning because of the potential for a resurgence.

Pour en savoir plus

RAIL, J.-F., 2021. Northern Gannet – A Sentinel Species for the Gulf, 4th edition. Fact sheet. State of the St. Lawrence Monitoring Program. Canadian Wildlife Service, Quebec Region, Environment and Climate Change Canada.

GOVERNMENT OF CANADA. Open Government Portal. Temporal Trends of Contaminants in the Eggs of Two Aquatic Bird Species Collected from the St. Lawrence (1969-ongoing).

GUILLEMETTE, M., F. GRÉGOIRE, D. BOUILLET, J.-F. RAIL, F. BOLDUC, A. CARON, and D. PELLETIER, 2018. "Breeding failure of seabirds in relation to fish depletion: is there one universal threshold of food abundance?" *Marine Ecology Progress Series*, Vol. 587, pp. 235–245.

MONTEVECCHI, W.A., P. REGULAR, J.-F. RAIL, K. POWER, C. MOONEY, K.J.N. D'ENTREMONT, S. GARTHE, L. GUZZWELL, and S.I. WILHELM, 2021. "Ocean heat wave induces breeding failure at southern breeding limit of the Northern Gannet *Morus Bassanus*," *Marine Ornithology*, Vol. 49, pp. 71–78.

ST. LAWRENCE GLOBAL OBSERVATORY. Data on the size of Northern Gannet colonies.

Contamination of the Great Blue Heron by toxic substances

Lead organization: Environment and Climate Change Canada (ECCC)
Study area: Fluvial section, lower estuary and Gulf of St. Lawrence

Status: good in 2018–2022
Trend: improvement since 1991–1992

The Great Blue Heron, Quebec's largest wading bird, is a fish-eating predator at the top of the aquatic food web. Its nesting sites during the breeding season are close to its foraging areas, making the species an ideal indicator for assessing pollution levels in the aquatic environment across time and space.

This indicator was studied by monitoring the four most prevalent or most worrisome groups of contaminants found in Great Blue Heron eggs (mercury, total PCBs, DDE, and total PBDEs) in four breeding colonies in the fluvial section, lower estuary and Gulf of St. Lawrence.

To assess the status of this indicator, contaminant concentrations recorded during the 2018–2022 period were compared to historical data and to toxicity criteria or thresholds taken from the scientific literature. Results showed that, overall, contamination in Great Blue Heron eggs can be considered "good." In all colonies, contaminant levels decreased relative to their historical levels. In addition, the values measured in 2022 were generally below the toxicity criteria.

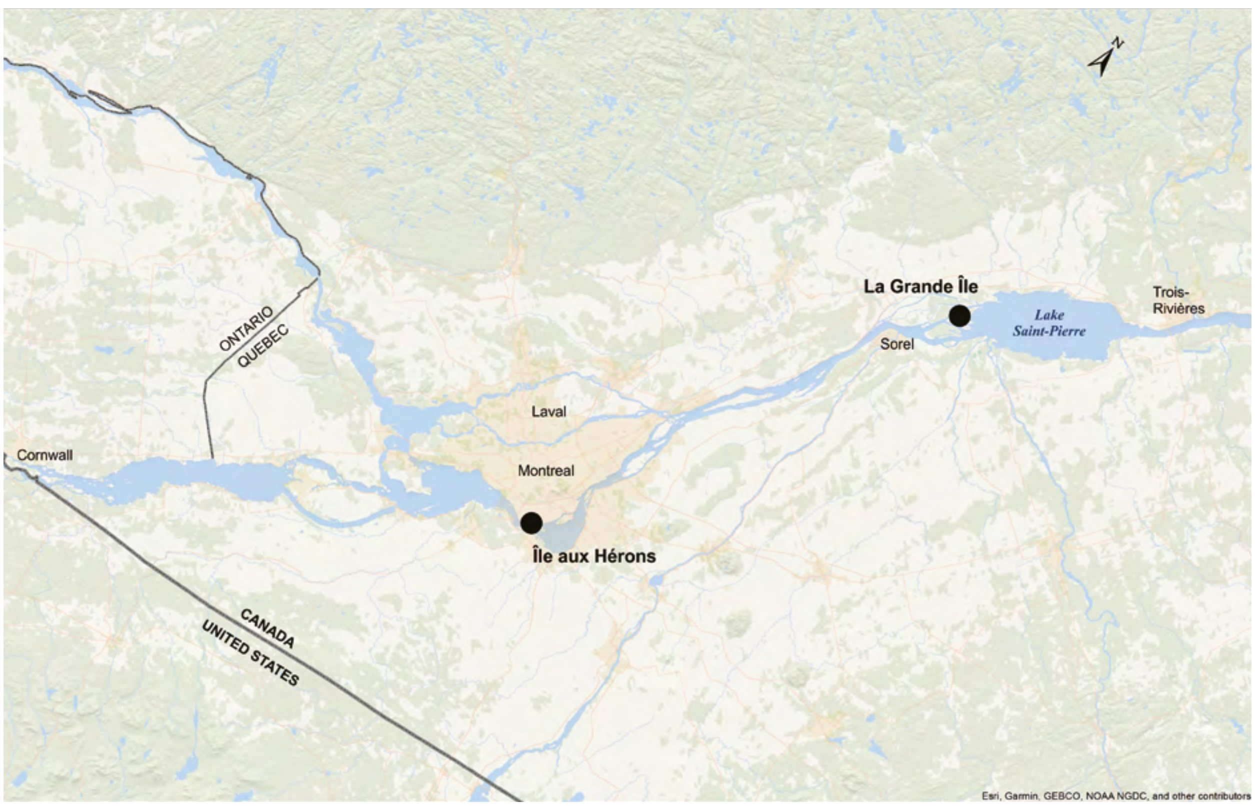


Figure 2.35 Great Blue Heron colonies in the fluvial section

Figure 2.36 Great Blue Heron colonies in the lower estuary and Gulf of St. Lawrence

"Moderate-good" status on Île aux Hérons

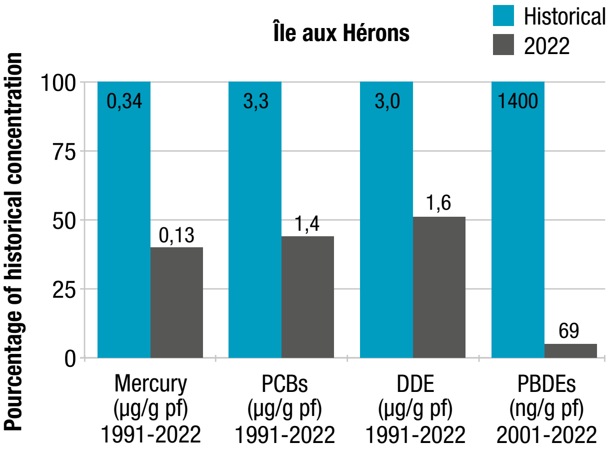


Figure 2.37 Comparison between historical and recent levels of contaminants in Great Blue Heron eggs on Île aux Hérons

An average decline of 65% in levels of all contaminants was found in Great Blue Heron eggs on Île aux Hérons, which is considered "moderate-good." Although the decline in total PBDEs was the steepest among all contaminants relative to historical values, total PBDEs were slightly over the toxicity threshold; nonetheless, this represents a marked improvement over the 2016 levels, which were nearly twice the threshold value.

"Good" status on La Grande Île

On average, contaminant levels measured in Great Blue Heron eggs on La Grande Île fell by 79%, which is considered "good." DDE and PBDEs had the strongest declines. PBDE levels in eggs on La Grande Île, unlike the levels on Île aux Hérons, did not exceed the toxicity criterion, which represents an improvement compared to 2016, when concentrations exceeded the criterion.

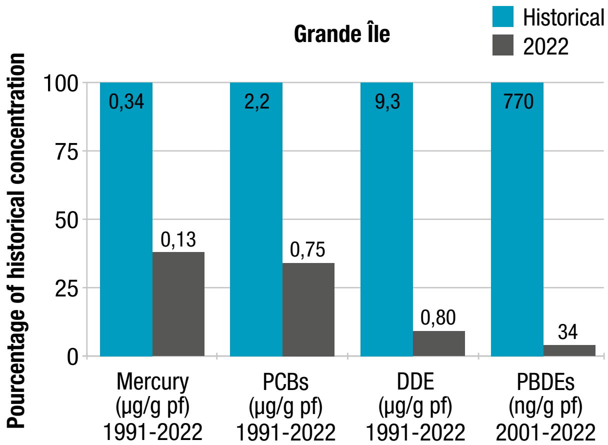


Figure 2.38 Comparison between historical and recent levels of contaminants in Great Blue Heron eggs on La Grande Île

"Moderate-good" status on Île aux Basques

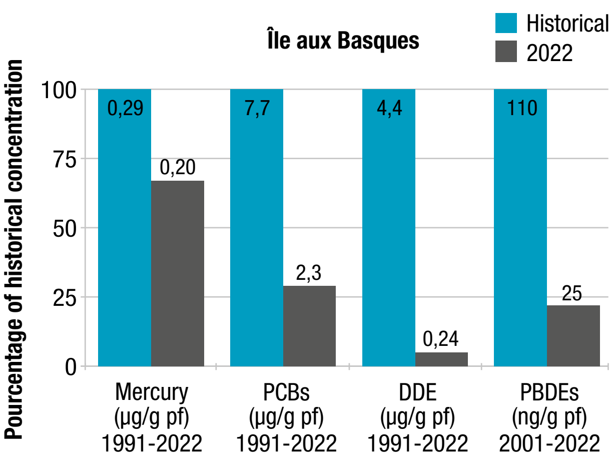


Figure 2.39 Comparison between historical and recent levels of contaminants in Great Blue Heron eggs on Île aux Basques

On Île aux Basques, levels of all contaminants fell by 69% on average, which is considered "moderate-good." Among the contaminants measured, the smallest decrease occurred in mercury. No criteria were exceeded.

"Good" status on Manowin Island and Île du Corossol

On Manowin Island and Île du Corossol, contaminant levels fell by 77% on average relative to historical values, which is considered "good." As was the case on Île aux Basques, mercury was the parameter with the smallest decline. PBDE concentrations at this site were six times lower than in the previous Overview in 2019 and, in 2022, were below the toxicity threshold. As was the case at most of the sites, the contaminant levels measured were below toxicity criteria.

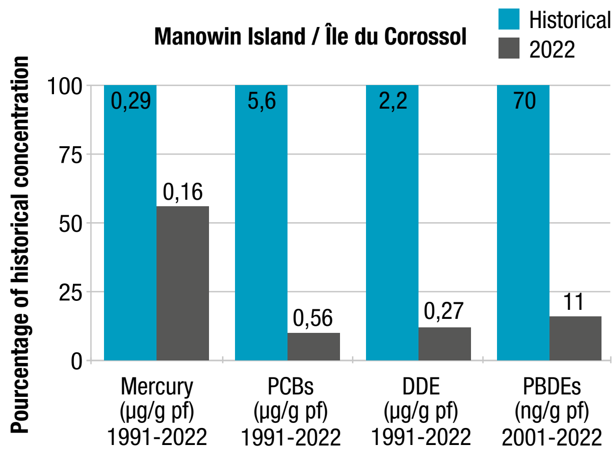


Figure 2.40 Comparison between historical values and recent values for contaminant levels in Great Blue Heron eggs on Manowin Island and Île du Corossol

Downward trend in contaminants

Overall, a downward trajectory can be seen in all temporal trends (i.e. 2022 data versus historical data), with an encouraging reduction in PCB, DDE, Hg and PBDE levels in all colonies. The decline in PCB and DDE levels has slowed somewhat, while the decrease in PBDE levels remains substantial. The decline in mercury levels has been more modest.

What impact does climate change have on contaminants in the Great Blue Heron?

This indicator can be affected by climate change, which causes changes in prey availability and therefore in the trophic transfer of contaminants.

For more information

CHAMPOUX, L. and P. BEAUPRÉ, 2015. Great Blue Heron: A Sentinel Species for the State of the St. Lawrence 2015. Fact sheet. State of the St. Lawrence Monitoring Program. Environment and Climate Change Canada and Ministère des Forêts, de la Faune et des Parcs du Québec

GOVERNMENT OF CANADA. Open Government Portal. Temporal Trends of Contaminants in the Eggs of Two Aquatic Bird Species Collected from the St. Lawrence (1969-ongoing).

BEYER, W.N., and J.P. MEADOR, editors, 2011. *Environmental contaminants in biota: interpreting tissue concentrations*, Second edition. CRC Press, Boca Raton, FL.

Wetland area

Lead organization: Environment and Climate Change Canada (ECCC)
Study area: fluvial section (Îles de Boucherville and Lake Saint-Pierre)

Status: moderate in 2018–2019
Trend: deterioration since 1990

Lake Saint-Pierre: status "moderate-poor"

- Habitats remarkably rich but vulnerable to human pressures

Direct anthropogenic pressures on the wetlands in Lake Saint-Pierre have increased. An analysis of changes in wetland area indicates losses of 90 ha since 2010, likely caused by the mowing of Reed Canarygrass (*Phalaris arundinacea*) in some high marshes. Only 28% of the perimeter of these wetlands is surrounded by a buffer zone, consisting primarily of forest. This meagre protective perimeter makes the wetlands vulnerable to anthropogenic pressures, notably agricultural activity, which is intense in the region.

Photo: Martin Jean, ECCC

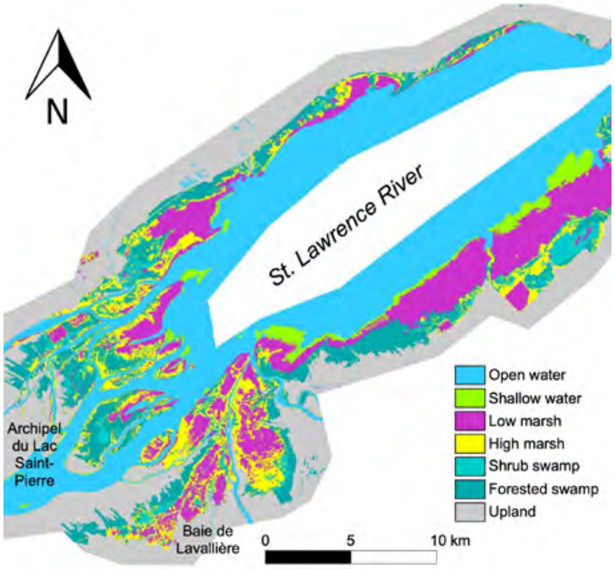


Figure 2.41 Wetland types in Lake Saint-Pierre

Due to low water levels in recent years, the drying of wetlands has been observed, with high marshes appearing since 1990. The internal dynamics of wetlands between 2010 and 2018 were rated "moderate." A "good" rating was received for habitat diversity, since low marshes, high marshes and treed swamps are all present in significant proportions. This characteristic of the Lake Saint-Pierre wetlands is one of the main reasons why Lake Saint-Pierre was designated a Biosphere Reserve by UNESCO.

Lake Saint-Pierre: deteriorating trend since 1990

- **Less wetland area than in 1990**

Despite some gains in wetland area in some locations (64 ha in total), net losses of 815 ha are estimated to have occurred in the lake's wetlands from 1990 to 2018. Internal wetland dynamics have also deteriorated, due mainly to the transformation of low marshes into high marshes. While some habitat conservation initiatives have been carried out for Lake Saint-Pierre, little change has occurred since 1990 in the protection of the lake's wetlands from anthropogenic pressures. However, the rich diversity of habitats in Lake Saint-Pierre seems to have remained unchanged and received a "good" rating.

Îles de Boucherville: moderate status

In 2019, a rise in water levels of nearly 80 cm was observed relative to 2010, resulting in the flooding of several marshes.

Direct anthropogenic pressures present in 2019 were rated "moderate." No significant changes in wetland area have been observed since 2010, except those caused by water-level fluctuations. These temporary changes are not considered in the analysis. Wetland dynamics in the Îles de Boucherville are also considered "moderate".

Photo: Martin Jean, ECCC

Habitat diversity also received a "moderate" rating, with high marshes accounting for 39% of wetland area, with no shrub swamps detected. Most of the high marshes in the sector are dominated by Common Reed (*Phragmites australis*), an invasive alien species.

The protection of the region's wetlands from external stressors received a "moderate" rating. Indeed, a buffer zone, dominated by meadows and woodlands, is present around 71% of the perimeter of these wetlands. However, roughly 17% of the wetland perimeter borders urban areas, primarily consisting of urbanized shoreline belonging to the municipality of Boucherville and the Montreal urban agglomeration.

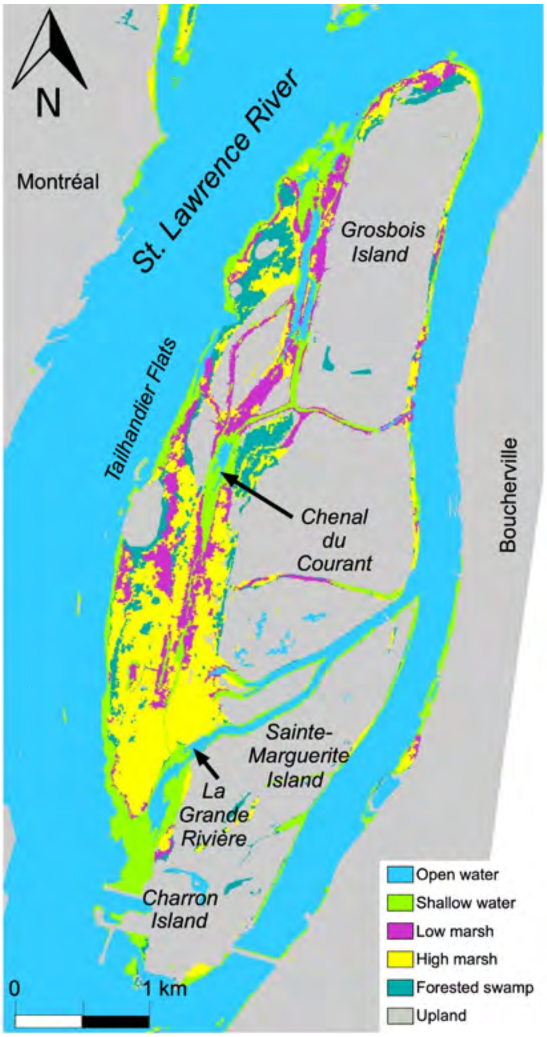


Figure 2.42 Wetland types on the Îles de Boucherville

Îles de Boucherville: no trend since 1990

Some positive changes observed in internal wetland dynamics

Few or no significant changes have been observed since 1990 in anthropogenic pressures, the protection of wetlands from external stressors, and diversity of habitats. The net balance of wetland area remains negative. According to observations in 2019, the 55 ha lost between 1990 and 2002 have not been offset by wetland gains. Since a significant proportion of wetlands in the sector benefit from legal protection (due in part to the presence of the Parc national des Îles-de-Boucherville, a provincial park), protection from external stressors has remained stable since 2002. Little improvement has been noted in habitat diversity; the main wetland classes are present, with the exception of shrub swamps. However, internal dynamics seem to be improving. The recent increase in water levels following the dry periods observed before 2010 is beneficial for wetland dynamics.

What does this indicator tell us about the environmental issues affecting the St. Lawrence River?

Wetlands are essential to the health of the St. Lawrence River. The presence of shallow water, marshes and swamps and their dynamics directly affect phenomena such as contamination by toxic substances, eutrophication, the diversity of flora and fauna, and the spread of invasive species. These ecosystems play a key role in water quality, and in mitigating erosion and the impacts of flooding.

How is this indicator affected by climate change?

Lower water levels in the St. Lawrence River due to climate change, combined with greater fluctuations in flow, could have a major impact on the distribution, composition and internal dynamics of wetlands. In addition, changes in the occupancy of waterfront land resulting from climate change could increase pressures on wetlands.

How is the status of St. Lawrence wetlands assessed?

Direct anthropogenic pressures are estimated on the basis of the net balance of losses and gains in wetland area. Changes over time are analyzed from an anthropogenic perspective, retaining only changes caused by human activity. The more prevalent the anthropogenic pressures, the less wetland areas are protected.

Internal wetland dynamics are estimated based on the total area that becomes drier (e.g. a low marsh is transformed to a high marsh) and the total area that becomes wetter (e.g. a high marsh is transformed to a low marsh). When dryer and wetter periods alternate, the wetlands are considered to have favourable internal dynamics.

Diversity of wetland habitats is estimated by calculating the relative proportions of the different wetland classes (shallow water, low marsh, high marsh, shrub swamp and treed swamp). The greater the diversity of habitats in a wetland, the healthier it is (and the better its status rating).

Protection of wetlands from external stressors is assessed on the basis of the presence of a buffer zone at least 50 m wide made up of natural terrestrial vegetation (forest or natural grassland) along the perimeter of the wetland. The longer the perimeter of a wetland protected by a buffer zone, the better the wetland will be protected from anthropogenic pressures.

For more information

ENVIRONMENT CANADA, 2013. *How much habitat is enough?* Third edition. Environment Canada, Toronto, Ontario.

LÉTOURNEAU, Guy, and Martin JEAN, 2005. Mapping the Wetlands of the St. Lawrence Using Remote Sensing (1990–1991). Scientific and Technical Report ST-232E. Environment Canada – Quebec Region, Environmental Conservation, St. Lawrence Centre. 98 pp.

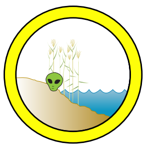
JEAN, Martin, and G. LÉTOURNEAU, 2022. Freshwater Wetlands – Fourth Edition. Fact sheet. State of the St. Lawrence Monitoring Program. Fresh Water Quality Monitoring and Surveillance, Environment and Climate Change Canada.

NORMAN, A.J., 1996. “The use of vegetative buffer strips to protect wetlands in southern Ontario,” in G. Mulamoottil, B.G. Warner and E.A. McBean, eds. *Wetlands: Environmental Gradients, Boundaries and Buffers*. CRC Press, New York, pp. 263–275.

TURNER, M.G., 1990. “Landscape changes in nine rural counties in Georgia,” *Photogrammetric Engineering and Remote Sensing*, Vol. 56, pp. 379–386.

Invasive alien plant species

Lead organization: Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MELCCFP)
Study area: fluvial section to the Gulf



Status: moderate in 2018–2020
Trend: unchanged between 2008 and 2020

- **Widespread presence of some invasive alien plant species**

According to the most recent data on invasive alien plant species (IAPS) obtained between 2008 and 2020, Reed Canarygrass and Common Reed are the species with the highest abundance indices in the St. Lawrence system. They are also among the most frequently observed IAPS, occurring at more than one third of the sites monitored (Figure 2.42). Reed Canarygrass was especially abundant in Baie de Lavallière and in the Contrecœur sector (Table 2.1), but was also fairly plentiful and frequent in Lake Saint-Pierre and in and around Montreal. Common Reed was observed most frequently at the Lake Saint Pierre stations, although it is generally found there in low abundance. This IAPS was especially abundant and frequently observed in the Haut-Saint-Laurent (Upper St. Lawrence) region and on the south shore of the upper and lower estuaries. It was also common and abundant in the Montreal and Contrecœur regions.

Purple Loosestrife was present at over half of the sites monitored, which makes it the IAPS most commonly observed in the St. Lawrence system, and was particularly frequent in the Lake Saint-Pierre and Contrecœur regions and on the south shore of the estuary. Flowering-Rush was also one of the most frequently observed IAPS, particularly in the Lake Saint-Pierre region, although it did not make up a significant proportion of the vegetation there. Reed Mannagrass was observed at a few stations in the Trois-Rivières region and on the south shore of the upper and lower estuaries.

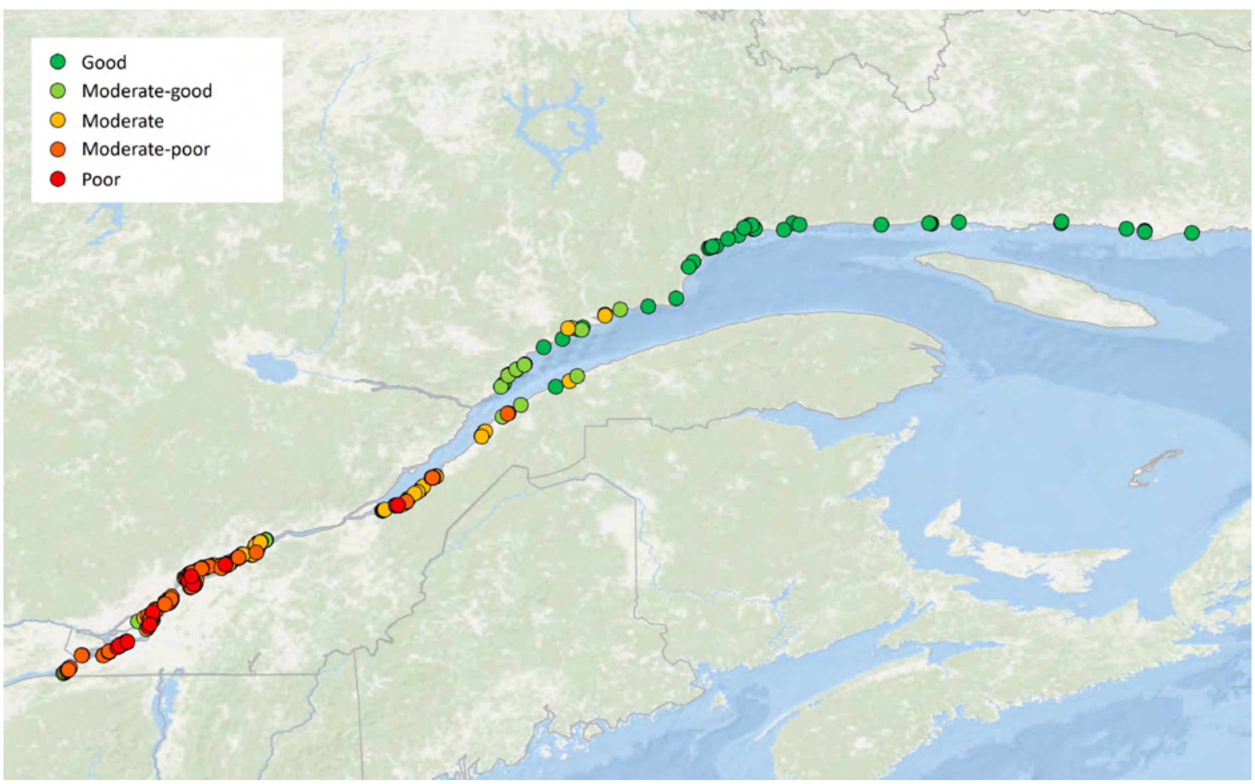


Figure 2.43 Map of sites monitored and the invasion rate of invasive alien plant species

Since the last Overview, two new sectors (north shore of lower estuary and north shore of Gulf) and four new plant species have been added to the monitoring activities.

European Frog-bit was common is a few sectors, particularly Lake Saint-Pierre, but typically its percent cover was low. Yellow Iris and Eurasian Water-milfoil were observed sporadically in some sectors, but also had a low percent cover. Glossy Buckthorn was only found in the two sectors furthest upstream (Haut-Saint-Laurent and Montreal), and was not abundant.

Japanese Knotweed was observed in a substantial proportion of the stations in the estuary, but its percent cover is not generally high. The abundance of Amphibious Yellowcress was significant in the Lake Saint-Pierre sector and, to a lesser extent, in Baie de Lavallière.

No IAPS were observed at the sites sampled along the north shore of the Gulf, and were also absent in a sizable proportion (42%) of the wetlands surveyed on the north shore of the lower estuary. However, Japanese Knotweed occurred at 42% of the stations, with Purple Loosestrife and European Frog-Bit the only other species detected in that sector.

Table 2.1 Status of species based on the value of the abundance index per species per sector

	HAUT-SAINT-LAURENT	MONTREAL	CONTRECŒUR	BAIE DE LAVALLIÈRE	LAKE SAINT-PIERRE	TROIS-RIVIÈRES	SOUTH SHORE OF ESTUARY	NORTH SHORE OF ESTUARY	NORTH SHORE OF GULF	ALL SECTORS
Reed Canarygrass	MG	M	MP	MP	M	MG	MG	G	G	M
Flowering-Rush	MG	MG	MG	M	M	MG	MG	G	G	MG
Reed Mannagrass	G	G	G	G	G	MG	MG	G	G	MG
European Frog bit	MG	MG	MG	MG	MG	MG	G	MG	G	MG
Yellow Iris	MG	MG	G	G	MG	MG	MG	G	G	MG
Eurasian Water-milfoil	MG	MG	MG	G	G	MG	G	G	G	MG
Glossy Buckthorn	MG	MG	G	G	G	G	G	G	G	MG
Japanese Knotweed	G	G	G	G	G	G	MG	MG	G	MG
Amphibious Yellowcress	G	G	MG	MG	M	MG	G	G	G	MG
Common Reed	MP	M	M	MG	MG	MG	MP	G	G	M
Purple Loosestrife	MG	MG	M	M	M	MG	MG	MG	G	MG

Good (G: zero abundance index), moderate-good (MG: low abundance index), moderate (M: moderate abundance index) and moderate-poor (MP: high abundance index)

Table 2.2 Invasion rate by sector

Haut-Saint-Laurent	**Moderate**
Montreal	**Moderate**
Contrecœur	**Moderate**
Baie de Lavallière	**Moderate**
Lake Saint-Pierre	**Moderate**
Trois-Rivières	**Moderate**
South shore of upper and lower estuaries	**Moderate**
North shore of lower estuary	**Moderate-Good**
North shore of Gulf	**Good**
All sectors	**Moderate**

Good (G: no invasion), moderate-good (MG: low invasion rate) and moderate (M: moderate invasion rate)

The most recent data, gathered between 2008 and 2020, indicate that the wetlands sampled (all sectors combined) have, on average, a "moderate" invasion rate (Table 2.2). In all, 87% of the sites visited contained at least one of the IAPS being monitored, with 3% having an invasion rate considered "poor"; 21%, "moderate-poor"; 42%, "moderate"; and 13%, "moderate-good." "Moderate" ratings were also obtained for the average invasion rate by sector (average of all sites in the sector), with the exception of the north shore of the lower estuary, which had a "moderate-good" rating, and the north shore of the Gulf, which had a "good" rating, with no IAPS present in the wetlands monitored. The Contrecœur sector had the highest average invasion rate, followed closely by the Baie de Lavallière, Lake Saint-Pierre and Montreal sectors.

Overall trend unchanged since 2008

Analyses of each species' presence (frequency of observation) were conducted, taking into account the effect of time (between the three years monitoring cycles from 2008 to 2020), sector, and the interaction between the two variables. Significant changes were observed in the presence of four species (Reed Canarygrass, Flowering-Rush, European Frog-bit and Purple Loosestrife). A significant downward trend was found for Reed Canarygrass in the Montreal, Trois-Rivières and Contrecœur sectors, while a slight declining trend was found for European Frog-Bit in the Contrecœur sector. Over the years of monitoring, the frequency of observation of Purple Loosestrife has declined in the Haut-Saint-Laurent, Montreal, Baie de Lavallière and Trois-Rivières sectors, but seems to have increased slightly in Lake Saint Pierre.

Similar analyses were conducted on the abundance (percent cover) of each species when present. The results showed that the percent cover values for Reed Canarygrass, Flowering Rush, Purple Loosestrife and Reed Mannagrass varied significantly by sector, but that time did not have a significant impact on this metric, except in the case of Reed Canarygrass. The percent cover of the latter tended to decline over time, particularly in the Montreal, Contrecœur and Trois-Rivières sectors. The trend in the percent cover of Yellow Iris and Glossy Buckthorn could not be analyzed due to an insufficient number of observations.

The overall IAPS invasion rate in St. Lawrence wetlands received a "moderate" rating in the 2019 Overview, based on data collected between 2008 and 2014. The analysis of all the data obtained from 2008 to 2020 shows that the trend varies significantly by sector. Overall, the invasion rate shows a stable trend, except in the Montreal region, where an improving trend was noted. Essentially, based on these new data, we believe that the invasion rate is still in the "moderate" category. However, the trends for the new IAPS monitored and the recently added stations cannot be assessed.

What does this indicator tell us about the environmental issues affecting the St. Lawrence River?

IAPS make up a significant portion of the vegetation cover in the wetlands in several sectors of the St. Lawrence. Their presence can lead to a decline in native plant species, particularly species at risk. They can also result in habitat alterations and changes in the animal species that inhabit these wetlands.

How is this indicator affected by climate change?

Since climate is one of the main limiting factors on plant invasions, climate change is expected to increase the risk posed by IAPS in Quebec. This increased risk is due to the fact that, over time, climate conditions will be favourable to IAPS over a larger area, which will enable new harmful species to survive and increase the fecundity rate of other species (de Blois et al. 2013). Moreover, changes in water levels may disturb riparian wetlands and favour the presence of IAPS, which are opportunistic species that are more tolerant of changing conditions.

How are invasive alien plant species in St. Lawrence wetlands assessed?

Data are collected at monitoring stations visited on a three-year cycle. The assessment of the status of **invasive alien plant species (IAPS)** in St. Lawrence wetlands is based on survey data from the most recent visit to each station between 2008 and 2020. However, the data used come primarily from the visit made during the most recent monitoring cycle (2018–2020).

- The **presence** of an IAPS refers to its frequency of observation in the wetlands visited.
- The **abundance** of an IAPS is measured by evaluating its percent cover, i.e. the proportion of the area of the sampling station occupied by that species.
- The **abundance index** per species per sector is the species' average percent cover at all the stations in a sector.
- The **invasion rate** is the percent cover of all the IAPS at the scale of an individual station, sector, or entire area covered in the monitoring network.

For more information

TOUSIGNANT, M.-E., 2018. Invasive Alien Plant Species of the St. Lawrence Wetlands. Fact sheet. State of the St. Lawrence Monitoring Program. Environment and Climate Change Canada and Ministère de l'Environnement et de la Lutte contre les changements climatiques.

References

DE BLOIS, S., L. BOISVERT-MARSH, R. SCHMUCKI, C.A. LOVAT, C. BYUN, P. GOMEZ-GARCIA, R. OTFINOWSKI, E. GROENEVELD and C. LAVOIE, 2013. *Outils pour évaluer les risques d'invasion biologique dans un contexte de changements climatiques*. McGill University. Montreal, Quebec. 80 pp. + appendices.

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