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NUTRIENTS IN THE ST. LAWRENCE RIVER

CANADIAN ENVIRONMENTAL SUSTAINABILITY INDICATORS

Canada

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CANADIAN ENVIRONMENTAL SUSTAINABILITY INDICATORS

NUTRIENTS IN THE ST. LAWRENCE RIVER

January 2021

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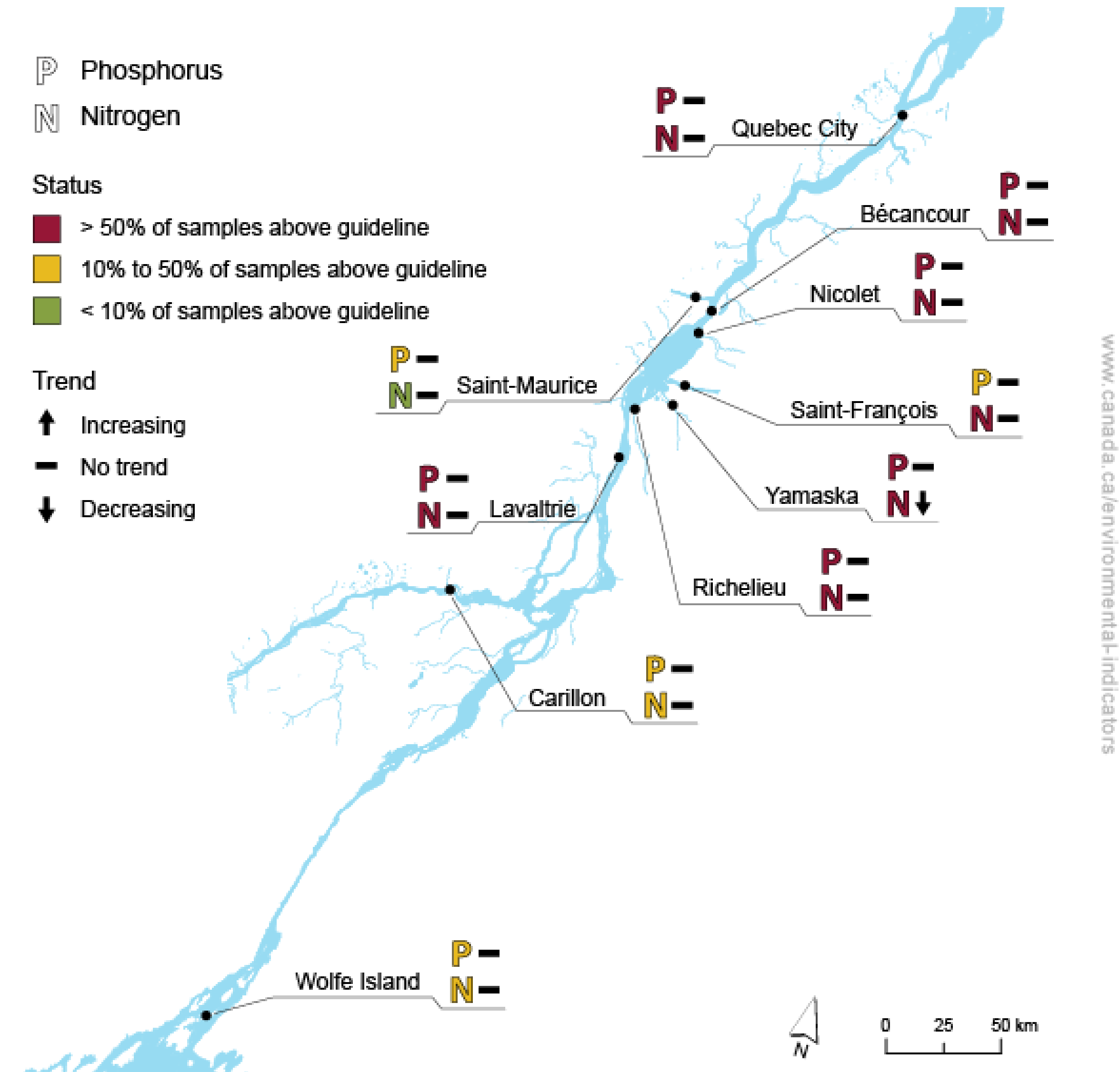
Nutrients in the St. Lawrence River

Phosphorus and nitrogen are essential plant nutrients. However, when phosphorus or nitrogen levels are too high or too low, they can have harmful effects on the food web of a river. They are an important measure of the health of the river and its surrounding watersheds. These indicators provide the status of phosphorus and nitrogen levels along the St. Lawrence River.

Key results

- For the 2017 to 2019 period,
    - phosphorus and nitrogen levels exceeded water quality guidelines at most monitoring stations
    - only at Saint-Maurice did nitrogen level exceedances occur in less than 10% of samples
- From 2010 to 2019, Yamaska had decreasing nitrogen levels

Figure 1. Status of total phosphorus and total nitrogen levels for the 2017 to 2019 period and total phosphorus and total nitrogen level trends in the St. Lawrence River, Canada, 2010 to 2019



[Data for Figure 1]

Note: The nutrient status at a monitoring station is considered Good when nutrient levels (phosphorus or nitrogen) exceed the guideline in less than 10% of samples. A Fair status is applied when the guideline is exceeded in 10% to 50% of samples. A Poor status is applied when exceedances occur in over 50% of samples. The status of total phosphorus and total nitrogen at water quality monitoring stations was determined by comparing water quality monitoring data to Ontario and Quebec's total phosphorus water quality guideline of 0.03 milligrams of phosphorus per litre (mg P/L)[1] and a derived total nitrogen water quality guideline of 0.63 milligrams of nitrogen per litre (mg N/L). For more details about the water quality guidelines, please refer to the Data sources and methods. Samples from the mouths of the Yamaska, Saint-François and Nicolet rivers are collected from May to September only.
Source: Environment and Climate Change Canada (2020) Saint Lawrence River basin long-term water quality monitoring data and Great Lakes connecting channels monitoring and surveillance data.

The St. Lawrence River links the Great Lakes with the Atlantic Ocean and is among the world's most important commercial waterways. It is a complex ecosystem that includes freshwater lakes and river reaches, a long estuary, and a salt-water gulf. Its many different habitats are home to a diverse range of plants, fish and other animals.

Phosphorus and nitrogen levels in the St. Lawrence River are affected by a variety of human activities along the river. Just downstream of Montreal, at Lavaltrie, phosphorus and nitrogen levels exceeded the water quality guidelines because of the release of municipal wastewater into the river. Farther downstream, tributary rivers draining agricultural regions transport higher concentrations of phosphorus and nitrogen which result from the chemical fertilizers and manure used to grow crops. Upstream of Quebec City, water from tributary rivers, such as the Saint-Maurice, which drain the north shore have lower phosphorus and nitrogen levels because they run through an area with more forest cover than that found on the south shore of the river. Beyond Quebec City, the St. Lawrence River flows into the Gulf of St. Lawrence, where the nitrogen and phosphorus levels contribute to harmful algal blooms.

For the St. Lawrence River, nutrient status at a monitoring station is considered Good when fewer than 10% of samples exceed the water quality guidelines for total phosphorus or total nitrogen. The 10% cut-off limit allows for 1 sample per year to exceed the guideline. In rivers, total phosphorus and total nitrogen concentrations will often exceed the guidelines when water levels are high, a situation that is mainly observed when the snow melts in the spring. When 10% to 50% of the samples exceed the guidelines, the nutrient status is considered Fair. In contrast, nutrient status is Poor if more than 50% of the samples exceed the water quality guidelines.

During the 2017 to 2019 period, status of phosphorus and nitrogen levels at the majority of water quality monitoring stations along the St. Lawrence River was rated as Poor. Over the last 10 years, 2010 to 2019, the Yamaska station had a slight decreasing trend in nitrogen levels, while the remaining stations showed no detectable trends. There were no phosphorus level trends at any station.

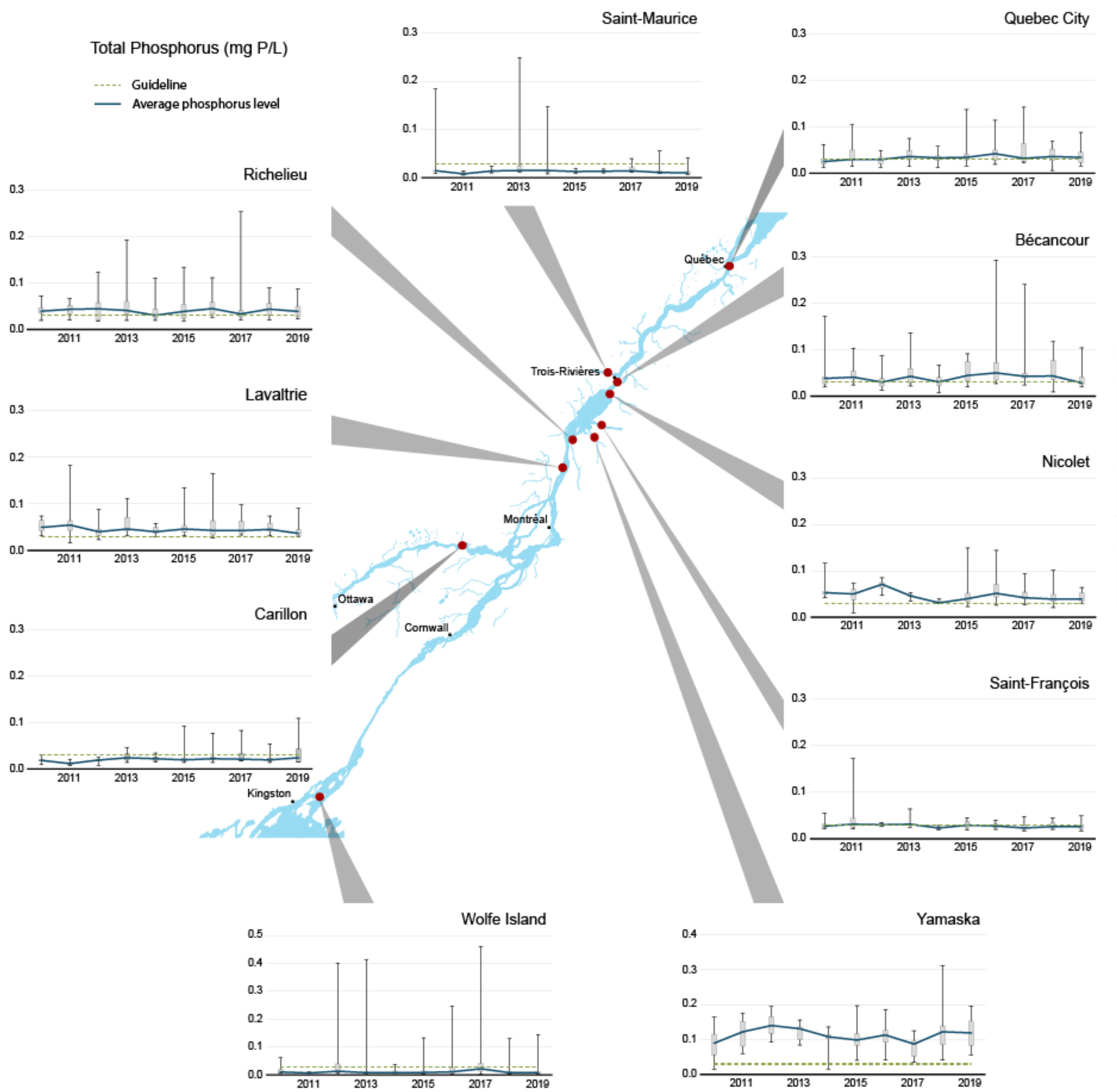
[1] Ontario Ministry of the Environment and Energy (1994) Water Management Policies, Guidelines, Provincial Water Quality Objectives. Government of Canada (2008) Technical Guidance Document for Water Quality Index Practitioners Reporting Under the Canadian Environmental Sustainability Indicators (CESI) Initiative 2008. Environment and Climate Change Canada and Statistics Canada. Ministère du Développement durable, Environnement et Lutte contre les changements climatiques (2009) Critères de qualité de l'eau de surface : phosphore total (en P) (in French only). Retrieved on January 8, 2021.

Phosphorus levels by water quality monitoring station

Key results

- A trends analysis from 2010 to 2019 showed there were no detectable trends at any station

Figure 2. Annual total phosphorus levels for 10 water quality monitoring stations along the St. Lawrence River, 2010 to 2019



Data for Figure 2

Note: Each boxplot summarizes annual phosphorus levels at a monitoring station and shows the range of values measured. The dotted line shows Ontario and Quebec's total phosphorus water quality guideline value of 0.03 milligrams of phosphorus per litre (mg P/L). The solid line is drawn through the median to give a sense of the changes in concentrations over time. A Seasonal Kendall trend analysis for phosphorus was calculated for each station from 2010 to 2019. Samples from the mouths of the Yamaska, Saint-François and Nicolet rivers are collected from May to September only.
Source: Environment and Climate Change Canada (2020) Saint Lawrence River basin long-term water quality monitoring data and Great Lakes connecting channels monitoring and surveillance data.

Plotting phosphorus data for each station by year provides a general view of how phosphorus levels are changing along the St. Lawrence River. From 2010 to 2019, median phosphorus levels were below the guideline at Saint-

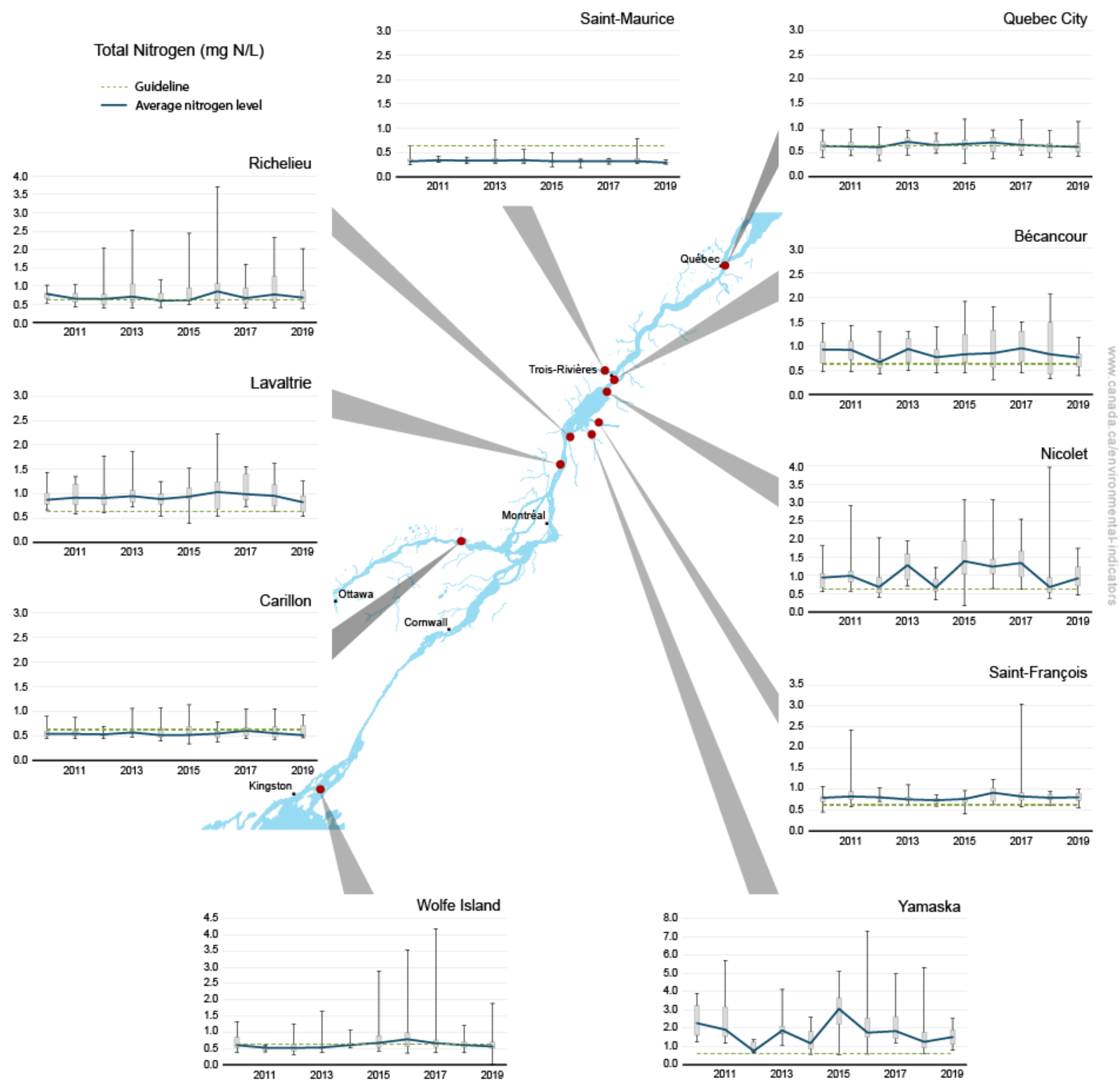
Maurice, Wolfe Island and Carillon. Over the same time period, median phosphorus levels were above the guideline at Yamaska, Nicolet and Lavaltrie. At Saint-François, Bécancour, Quebec City and Richelieu, median phosphorus levels fluctuated above and below the guideline.

Nitrogen levels by water quality monitoring station

Key results

- A trends analysis from 2010 to 2019 showed:
  - Yamaska had a slight decrease in nitrogen levels
  - there were no detectable trends at the other 9 stations

Figure 3. Annual total nitrogen levels for 10 water quality monitoring stations along the St. Lawrence River, 2010 to 2019



Data for Figure 3

Note: Each boxplot summarizes annual nitrogen levels for a monitoring station and shows the range of values measured. The dotted line shows the guideline value of 0.63 milligrams of nitrogen per litre (mg N/L). The solid line is drawn through the median to give a sense of trends in concentration. A Seasonal Kendall trend analysis for nitrogen was calculated for each station from 2010 to 2019. Samples from the mouths

of the Yamaska, Saint-François and Nicolet rivers are collected from May to September only.
Source: Environment and Climate Change Canada (2020) Saint Lawrence River basin long-term water quality monitoring data and Great Lakes connecting channels monitoring and surveillance data.

Plotting nitrogen data for each station by year provides a general view of how nitrogen levels are changing over time along the St. Lawrence River. Nitrogen levels tend to be lower at stations situated near forested areas with smaller urban populations, such as Carillon and Saint-Maurice. From 2010 to 2019, median nitrogen levels were below the guideline at Saint-Maurice and Carillon. Over the same time period, median nitrogen levels were above the guideline at Lavaltrie, Yamaska, Nicolet, Bécancour and Saint-François. At Wolfe Island, Quebec City and Richelieu, median nitrogen levels fluctuated above and below the guideline.

About the indicators

What the indicators measure

The indicators report on the status of total phosphorus and total nitrogen levels along the St. Lawrence River. It ranks the status based on how often total phosphorus and total nitrogen levels exceed their respective water quality guidelines.

These indicators assume that water in the St. Lawrence River would rarely exceed water quality guidelines for phosphorus and nitrogen in the absence of human development. They provide information about how human activity contributes to phosphorus and nitrogen levels in the river. The more often the water quality guidelines are exceeded, the greater the risk to the health of the St. Lawrence River. The phosphorus and nitrogen trend analysis provides information about how concentrations are changing over time.

Why these indicators are important

Clean freshwater is an essential resource. It protects aquatic plant and animal biodiversity. We use it for manufacturing, energy production, irrigation, swimming, boating, fishing and for domestic use (for example, drinking, washing). Degraded water quality damages the health of all freshwater ecosystems, such as rivers, lakes, reservoirs and wetlands. It can also disrupt fisheries, tourism and agriculture, and make it more expensive to treat to drinking water standards. When phosphorus and nitrogen levels in water become too high, aquatic plant growth can become excessive and harmful. The decay of excess plant material can reduce the amount of oxygen available for fish and other aquatic animals. High nutrient levels can also lead to harmful algal blooms, which can kill animals that use the water and affect human health. Conversely, too little phosphorus or nitrogen can result in not enough plant growth to support a river's food web, which could reduce fish populations and harm local fisheries.

Phosphorus and nitrogen used in chemical fertilizers reach the river through erosion, leaching from urban areas, farmland runoff, municipal and industrial wastewater discharges, and air pollution. Over time, excess phosphorus and nitrogen levels in the river can alter its food web.

These indicators are used to provide information about the state of the St. Lawrence River. Ongoing tracking of phosphorus and nitrogen levels allows governments and citizens to remain aware of an important aspect of the environmental condition of the river.

Pristine lakes and rivers

These indicators support the measurement of progress towards the following 2019 to 2022 Federal Sustainable Development Strategy long-term goal: Clean and healthy lakes and rivers support economic prosperity and the well-being of Canadians.

In addition, the indicators contribute to the Sustainable Development Goals of the 2030 Agenda for Sustainable Development. They are linked to Goal 6, Clean water and sanitation and Target 6.3, "By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally."

The indicators also contribute towards reporting on Target 10 of the 2020 Biodiversity goals and targets for Canada: "By 2020, pollution levels in Canadian waters, including pollution from excess nutrients, are reduced or maintained at levels that support healthy aquatic ecosystems."

Related indicators

The Water quality in Canadian rivers indicators provide a measure of the ability of river water across Canada to support plants and animals.

The Phosphorus levels in the offshore waters of the Canadian Great Lakes and the Nutrients in Lake Winnipeg indicators report on the status of total phosphorus and total nitrogen levels in these 2 ecosystems.

The Phosphorus loading to Lake Erie indicators report on the total phosphorus loadings flowing directly into Lake Erie or from its tributary rivers.

The Household use of chemical pesticides and fertilizers indicator reports on how many people in Canada use pesticides and fertilizers on their lawns and gardens.

The Municipal wastewater treatment indicators measure the level of wastewater treatment provided to the Canadian population.

Data sources and methods

Data sources

Total phosphorus and total nitrogen data were provided by Environment and Climate Change Canada's Fresh Water Quality Monitoring and Surveillance program. The data can be found on the Saint Lawrence River basin long-term water quality monitoring data and the Great Lakes connecting channels monitoring and surveillance data Open Data web pages.

More information

Sampling

The status of total phosphorus and total nitrogen levels are based on measurements recorded between January 2017 and December 2019. The trend analysis uses data from 2010 to 2019.

The sampling frequency at the water quality monitoring stations included in these indicators is not uniform. Sampling at the Carillon, Lavaltrie, Richelieu, Saint-Maurice, Bécancour and Quebec City stations is conducted on a monthly basis. At monitoring stations at the mouths of the Yamaska, Saint-François and Nicolet rivers, samples are typically collected on a weekly basis from May to September. Sampling at the Wolfe Island station is typically conducted on a weekly basis year round. Gaps exist in the data due to program changes, field laboratory updates, weather and mechanical issues with the equipment used to collect the data.

Water quality monitoring station locations

Data were obtained from 10 monitoring stations along the St. Lawrence River from the outlet of Lake Ontario at Wolfe Island near Kingston in the west to Quebec City in the east (Table 1). The stations are sited so as to monitor the principal water sources entering the St. Lawrence River and are sometimes installed at the mouths of tributary rivers.

Table 1. Water quality monitoring stations used for the indicators

Monitoring station	Station code	Station name	Latitude	Longitude
Wolfe Island	ON02MA0030	St. Lawrence River (South Channel)	44.2078	-76.2368
Carillon	QU02LB9001	Ottawa River at Carillon	45.5676	-74.3799
Lavaltrie	QU02OB9004	St. Lawrence River, water intake at Lavaltrie water treatment plant	45.8744	-73.2806

Monitoring station	Station code	Station name	Latitude	Longitude
Richelieu	QU02OJ0052	Richelieu River, water intake of Sorel's filtration plant	46.0340	-73.1176
Yamaska	QU02OG3007	Yamaska River, Route 132 bridge	46.0051	-72.9101
Saint-François	QU02OF3004	Saint-François River at Pierreville	46.0664	-72.8122
Nicolet	QU02OD3004	Nicolet River at Nicolet	46.2454	-72.6512
Saint-Maurice	QU02NG3013	Saint-Maurice River, water intake at Trois-Rivières water treatment plant	46.3820	-72.6105
Bécancour	QU02OD9009	St. Lawrence River, water intake of Bécancour's filtration plant	46.3116	-72.5460
Quebec City	QU02PH9024	St. Lawrence River at Lévis	46.8071	-71.1900

Methods

The status of phosphorus and nitrogen levels at each monitoring station was calculated on the basis of how often levels were above their water quality guidelines.

A Seasonal Kendall test with Seasonal Kendall slope was used to test for the presence of a statistically significant increasing or decreasing trend in total phosphorus and total nitrogen over the last 10 years.[2]

More information

Water quality guidelines

Total phosphorus

Ontario and Quebec's total phosphorus water quality guideline for the protection of aquatic life, specifically 0.03 milligrams of phosphorus per litre (mg P/L) was used.[3]

Total nitrogen

Neither Ontario, Quebec nor the Canadian Council of Ministers of the Environment (CCME) has a water quality guideline for total nitrogen. Accordingly, a total nitrogen guideline for the St. Lawrence River was derived in keeping with the CCME's lines-of-evidence approach (PDF; 1.95 MB). A total nitrogen guideline of 0.63 milligrams of nitrogen per litre (mg N/L) was selected for calculation of the indicators. This coincides with the ideal performance standard[4] of 0.63 mg N/L for large rivers in the Mixedwood Plains Ecozone as recommended during Environment and Climate Change Canada's National Agri-Environmental Standards Initiative.[5]

See Annex B for more detail on how the total nitrogen guideline was derived.

[2] Helsel DR and Hirsch RM (2002) Statistical Methods in Water Resources. Chapter 12 Trend Analysis. Statistical Methods in Water Resources Techniques of Water Resources Investigations Book 4, Chapter A3. US Geological Survey. 522 p. Retrieved on January 8, 2021.

[3] Ontario Ministry of the Environment and Energy (1994) Water Management Policies, Guidelines, Provincial Water Quality Objectives. Government of Canada (2008) Technical Guidance Document for Water Quality Index Practitioners Reporting Under the Canadian Environmental Sustainability Indicators (CESI) Initiative 2008. Environment and Climate Change Canada and Statistics Canada. Ministère du Développement durable, Environnement et Lutte contre les changements climatiques (2009) Critères de qualité de l'eau de surface : phosphore total (en P) (in French only). Retrieved on January 8, 2021.

[4] An ideal performance standard is a long-term goal describing the desired level of environmental quality, which makes it comparable to a water quality guideline. It contrasts with an achievable performance standard, which describes environmental quality attainable using current technology.

[5] Chambers PA et al. (2009) Nitrogen and Phosphorus Standards to Protect the Ecological Condition of Canadian Streams, Rivers and Coastal Waters. National Agri-Environmental Standards Initiative Synthesis Report No. 11. Environment Canada. Gatineau, Quebec. 79 p.

Calculation of phosphorus and nitrogen status for the St. Lawrence River

The phosphorus status at each of the 10 water quality monitoring stations was computed by comparing total phosphorus concentrations at each station with the total phosphorus water quality guideline for the protection of aquatic life of 0.03 mg P/L.[6] Similarly, the nitrogen status at each water quality monitoring station was determined by comparing the total nitrogen concentrations at each station to the St. Lawrence-specific total nitrogen water quality guideline for the protection of aquatic life of 0.63 mg N/L (see Annex B).

The number of times total phosphorus and total nitrogen concentrations exceeded the guidelines were summed from 2017 to 2019, and the results were divided by the total number of samples collected over the same time period. The status of each station was determined by calculating the percentage of samples exceeding the guidelines.

- Good nutrient status = fewer than 10% of samples exceed the guidelines
- Fair nutrient status = 10% to 50% of samples exceed the guidelines
- Poor nutrient status = more than 50% of samples exceed the guidelines

Trend analysis

Data requirements

With environmental trend analysis, the more data available, the more statistical power the test has. For a station to be included in trend analysis reporting, at least 10 years of data were required. These data requirements were met by all stations for total phosphorus and total nitrogen. Total phosphorus concentrations are strongly correlated with the river's flows because high flows transport more suspended sediment with bound phosphorus. For example, phospohorus and nitrogen loads at Quebec City and the Ottawa River at Carillon were higher due to the inflow from tributary rivers at these stations, compared to the outflow from Lake Ontario into the St. Lawrence River at Wolfe Island.[7]

Stations sampled throughout the year

With the exception of Wolfe Island, which was sampled weekly, stations were typically sampled monthly throughout the entire year. Within the dataset for each station, data were sorted by sampling date from oldest to most current. Duplicate (replicate) values were removed and each sample was assigned to a month based on the sampling date. To correct sampling frequency variation in the data, and to minimize analytical issues associated with serial correlation in the data, one sample per month (approximate 30-day interval) was selected for the analysis. An Excel function was run to count the number of days between sampling dates. If there were more than one sample in the same month, the extra samples were removed from the dataset based on the desired 30-day interval between samples. The analysis was run using the Kendall package within the R software environment.

Stations sampled seasonally

The samples from the mouths of the Yamaska, Saint-François and Nicolet rivers were typically collected on a weekly basis from May to September. Within the dataset for each station, duplicate (replicate) values were removed and each sample was assigned to 1 of 22 weeks from May 1 to October 1. To correct sampling frequency variation in the data, and to minimize analytical issues associated with serial correlation in the data, a single sample taken approximately every 7 days was selected for the analysis. Only weeks 9 through 17 (June 26 to August 27) had enough samples over the 10-year period to be used for the trend analysis. The analysis was run using the Kendall package within the R software environment.

[6] United States Environmental Protection Agency (2000b) Ecoregional Nutrient Criteria Documents for Rivers and Streams: Nutrient Ecoregion VII: Mostly Glaciated Dairy Region (PDF; 331 kB). Report No. EPA-822-B-00-018. Retrieved on January 8, 2021.

[7] Hudon C et al. (2017) Hydrological and biological processes modulate carbon, nitrogen and phosphorus flux from the St. Lawrence River to its estuary (Quebec, Canada). Biogeochemistry 135:251 to 276. Retrieved on January 8, 2021.

Table 2. Seasonal Kendall analysis output from R for total phosphorus, 2010 to 2019

Monitoring station	Parameter	Tau	2-sided p-value	Seasonal Kendall slope
Wolfe Island	Total phosphorus	0.029	0.721	0.000
Carillon	Total phosphorus	0.228	0.001	0.001
Lavaltrie	Total phosphorus	-0.117	0.109	0.001
Richelieu	Total phosphorus	0.028	0.716	0.000
Yamaska	Total phosphorus	0.098	0.260	0.002
Saint-François	Total phosphorus	-0.077	0.378	0.000
Nicolet	Total phosphorus	-0.108	0.210	-0.001
Saint-Maurice	Total phosphorus	-0.093	0.202	0.000
Bécancour	Total phosphorus	0.070	0.337	0.000
Quebec City	Total phosphorus	0.177	0.016	0.001

Table 3. Seasonal Kendall analysis output from R for total nitrogen, 2010 to 2019

Monitoring station	Parameter	Tau	2-sided p-value	Seasonal Kendall slope
Wolfe Island	Total nitrogen	0.134	0.085	0.006
Carillon	Total nitrogen	0.004	0.979	0.000
Lavaltrie	Total nitrogen	0.041	0.582	0.003
Richelieu	Total nitrogen	-0.008	0.936	0.000
Yamaska	Total nitrogen	-0.222	0.009	-0.054
Saint-François	Total nitrogen	0.151	0.079	0.007
Nicolet	Total nitrogen	0.059	0.498	0.010
Saint-Maurice	Total nitrogen	-0.128	0.076	-0.002
Bécancour	Total nitrogen	-0.037	0.622	-0.005
Quebec City	Total nitrogen	-0.012	0.892	0.000

Interpretation of the trends

The analysis was run using the Kendall package (version 2.2, 2011) of the statistical software R (version 3.4.4, 2018) to detect the presence of statistically significant trends in total phosphorus and total nitrogen levels from 2010 to 2019. The Seasonal Kendall analysis statistical outputs from R are shown in Table 2 for total phosphorus and Table 3 for total nitrogen.

Kendall's tau was used to measure the strength of the relationship between total phosphorus or total nitrogen and the sampling date. The tau values in tables 2 and 3 are all close to 0, which indicates there is negligible correlation between the nutrient samples and the sampling date.

The observed significance level or 2-sided p-value statistic was used to determine whether a statistically significant trend through time was present in the data. A p-value statistic of 0.05 or less indicates there is sufficient evidence in the data to signal the presence of a trend. Further, a p-value statistic of less than 0.01 indicates strong evidence of a trend in the data. A p-value statistic greater than 0.05 indicates the absence of a trend.

Where the p-value indicated a trend, the Seasonal Kendall slope was used to determine whether the trend was increasing or decreasing. A positive slope value indicates an upward trend or increasing phosphorus or nitrogen levels. A negative slope value indicates a downward trend or decreasing phosphorus or nitrogen levels. Trends were only reported if the slope was greater than 0. In the case of the total phosphorus trends for these indicators, the significant slope at Carillon and Quebec City was 0.001 and thus too small and close to 0 to give a direction.

The boxplot charts within figures 2 and 3 can also give a sense of trends in total phosphorus or total nitrogen levels over time. The changes in concentrations from one year to the next can be viewed using the solid line drawn through the median.

Recent changes

A 10th station was added to the indicators. This station is located at the outflow of Lake Ontario into the St. Lawrence River at Wolfe Island near Kingston, Ontario.

In the previous version of the indicators, only 7 of 9 stations met the minimum data requirements for a phosphorus trends analysis and none of the stations met the data requirements for a nitrogen trends analysis. In the current version, enough data was available for all monitoring stations (10) for both the phosphorus and nitrogen trends analyses. Refer to the Methods section for more information on the trend analysis.

Caveats and limitations

The indicators reflect the state of water quality in the St. Lawrence River based on total phosphorus and total nitrogen concentrations. These concentrations do not reflect the effect of spills or other transient events unless they are frequent or long-lasting.

Caution must be exercised when comparing these indicators with similar indicators for lakes. In rivers, total phosphorus concentrations are influenced by suspended particles in the water that increase during high-flow events. Elevated total nitrogen concentrations result from high runoff associated with precipitation, which washes nitrogen out of soils. This situation differs in lake ecosystems, as suspended particles generally settle out. However, it is still reasonable to compare lake and river systems as long as the methods used to determine the water quality classifications are clear.

Resources

References

Canadian Council of Ministers of the Environment (2016) Guidance manual for developing nutrient guidelines for rivers and streams (PDF; 1.95 MB). Retrieved on January 8, 2021.

Chambers PA, Guy M, Dixit SS, Benoy GA, Brua RB, Culp JM, McGoldrick D, Upsdell BL and Vis C (2009) Nitrogen and Phosphorus Standards to Protect the Ecological Condition of Canadian Streams, Rivers and Coastal Waters. National Agri-Environmental Standards Initiative Synthesis Report No. 11. Environment Canada. Gatineau, Quebec. 79 p.

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Related information

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Environment and Climate Change Canada (2017) St. Lawrence River: phosphorus at the mouths of Lake Saint-Pierre tributaries. Retrieved on January 8, 2021.

Annexes

Annex A. Data tables for the figures presented in this document

Table A.1. Data for Figure 1. Status of total phosphorus and total nitrogen levels for the 2017 to 2019 period and total phosphorus and total nitrogen level trends in the St. Lawrence River, Canada, 2010 to 2019

Monitoring station	2017 to 2019 total phosphorus guideline exceedance (percentage)	Total phosphorus status	2010 to 2019 total phosphorus trend	2017 to 2019 total nitrogen guideline exceedance (percentage)	Total nitrogen status	2010 to 2019 total nitrogen trend
Wolfe Island	19	Fair	Phosphorus levels show no trend	48	Fair	Nitrogen levels show no trend
Carillon	31	Fair	Phosphorus levels show no trend	38	Fair	Nitrogen levels show no trend
Lavaltrie	97	Poor	Phosphorus levels show no trend	92	Poor	Nitrogen levels show no trend
Richelieu	69	Poor	Phosphorus levels show no trend	64	Poor	Nitrogen levels show no trend
Yamaska	100	Poor	Phosphorus levels show no trend	98	Poor	Nitrogen levels are decreasing
Saint-François	29	Fair	Phosphorus levels show no trend	94	Poor	Nitrogen levels show no trend
Nicolet	90	Poor	Phosphorus levels show no trend	76	Poor	Nitrogen levels show no trend
Saint-Maurice	14	Fair	Phosphorus levels show no trend	3	Good	Nitrogen levels show no trend
Bécancour	69	Poor	Phosphorus levels show no trend	69	Poor	Nitrogen levels show no trend
Quebec City	61	Poor	Phosphorus levels show no trend	53	Poor	Nitrogen levels show no trend

Note: The nutrient status at a monitoring station is considered Good when nutrient levels (phosphorus or nitrogen) exceed the guideline in less than 10% of thesamples. A Fair status is applied when the guideline is exceeded in 10% to 50% of the samples. A Poor status is applied when exceedances occur in over 50% of samples. The status of total phosphorus and total nitrogen at water quality monitoring stations was determined by comparing water quality monitoring data to Ontario and Quebec's total phosphorus water quality guideline of 0.03 milligrams of phosphorus per litre and a derived total nitrogen water quality guideline of 0.63 milligrams of nitrogen per litre. For more details about the water quality guidelines, please refer to the Data sources and methods. Samples from the mouths of the Yamaska, Saint-François and Nicolet rivers are collected from May to September only.
Source: Environment and Climate Change Canada (2020) Saint Lawrence River basin long-term water quality monitoring data and Great Lakes connecting channels monitoring and surveillance data.

Table A.2. Data for Figure 2. Annual total phosphorus levels for 10 water quality monitoring stations along the St. Lawrence River, 2010 to 2019Figure 2. Annual total phosphorus levels for 10 water quality monitoring stations along the St. Lawrence River, 2010 to 2019

Monitoring station	Year	Median phosphorus level (milligrams of phosphorus per litre)	Minimum phosphorus level (milligrams of phosphorus per litre)	Maximum phosphorus level (milligrams of phosphorus per litre)	Number of samples
Wolfe Island	2010	0.010	0.005	0.061	26

Monitoring station	Year	Median phosphorus level (milligrams of phosphorus per litre)	Minimum phosphorus level (milligrams of phosphorus per litre)	Maximum phosphorus level (milligrams of phosphorus per litre)	Number of samples
Wolfe Island	2011	0.007	0.005	0.010	13
Wolfe Island	2012	0.013	0.005	0.401	52
Wolfe Island	2013	0.008	0.005	0.412	65
Wolfe Island	2014	0.008	0.005	0.038	28
Wolfe Island	2015	0.009	0.003	0.133	33
Wolfe Island	2016	0.011	0.003	0.246	63
Wolfe Island	2017	0.022	0.002	0.461	55
Wolfe Island	2018	0.008	0.002	0.130	48
Wolfe Island	2019	0.008	0.004	0.145	51
Carillon	2010	0.019	0.009	0.030	14
Carillon	2011	0.012	0.008	0.021	14
Carillon	2012	0.019	0.008	0.025	14
Carillon	2013	0.024	0.014	0.046	13
Carillon	2014	0.022	0.015	0.034	14
Carillon	2015	0.020	0.014	0.092	14
Carillon	2016	0.022	0.014	0.077	14
Carillon	2017	0.021	0.017	0.083	14
Carillon	2018	0.020	0.014	0.054	14
Carillon	2019	0.024	0.015	0.109	14
Lavaltrie	2010	0.050	0.032	0.074	12
Lavaltrie	2011	0.055	0.016	0.183	12
Lavaltrie	2012	0.040	0.023	0.088	12
Lavaltrie	2013	0.046	0.032	0.112	13
Lavaltrie	2014	0.040	0.030	0.058	12
Lavaltrie	2015	0.046	0.031	0.135	12
Lavaltrie	2016	0.043	0.027	0.165	12
Lavaltrie	2017	0.043	0.033	0.098	12
Lavaltrie	2018	0.045	0.031	0.074	12
Lavaltrie	2019	0.037	0.029	0.090	12
Richelieu	2010	0.039	0.019	0.072	12
Richelieu	2011	0.043	0.020	0.066	12
Richelieu	2012	0.044	0.017	0.123	12
Richelieu	2013	0.041	0.019	0.192	12
Richelieu	2014	0.030	0.019	0.110	12
Richelieu	2015	0.039	0.018	0.133	12
Richelieu	2016	0.045	0.026	0.111	12
Richelieu	2017	0.033	0.020	0.253	12

Monitoring station	Year	Median phosphorus level (milligrams of phosphorus per litre)	Minimum phosphorus level (milligrams of phosphorus per litre)	Maximum phosphorus level (milligrams of phosphorus per litre)	Number of samples
Richelieu	2018	0.044	0.020	0.089	12
Richelieu	2019	0.039	0.022	0.087	12
Yamaska	2010	0.090	0.015	0.164	18
Yamaska	2011	0.122	0.060	0.175	14
Yamaska	2012	0.140	0.093	0.195	7
Yamaska	2013	0.131	0.084	0.156	9
Yamaska	2014	0.108	0.015	0.136	9
Yamaska	2015	0.099	0.040	0.197	12
Yamaska	2016	0.113	0.041	0.186	16
Yamaska	2017	0.087	0.035	0.125	17
Yamaska	2018	0.122	0.041	0.312	17
Yamaska	2019	0.119	0.056	0.196	17
Saint-François	2010	0.027	0.021	0.055	15
Saint-François	2011	0.031	0.021	0.172	14
Saint-François	2012	0.030	0.027	0.035	7
Saint-François	2013	0.031	0.025	0.064	9
Saint-François	2014	0.023	0.019	0.028	9
Saint-François	2015	0.029	0.018	0.045	12
Saint-François	2016	0.028	0.020	0.040	16
Saint-François	2017	0.023	0.017	0.048	17
Saint-François	2018	0.026	0.020	0.045	17
Saint-François	2019	0.026	0.017	0.049	17
Nicolet	2010	0.053	0.042	0.116	15
Nicolet	2011	0.050	0.010	0.073	14
Nicolet	2012	0.071	0.047	0.085	7
Nicolet	2013	0.046	0.035	0.053	9
Nicolet	2014	0.031	0.029	0.039	9
Nicolet	2015	0.040	0.023	0.149	12
Nicolet	2016	0.052	0.026	0.144	16
Nicolet	2017	0.042	0.027	0.094	17
Nicolet	2018	0.039	0.021	0.101	17
Nicolet	2019	0.039	0.029	0.064	17
Saint-Maurice	2010	0.015	0.009	0.184	12
Saint-Maurice	2011	0.008	0.005	0.015	13
Saint-Maurice	2012	0.014	0.010	0.024	12
Saint-Maurice	2013	0.015	0.012	0.250	13
Saint-Maurice	2014	0.015	0.008	0.147	12

Monitoring station	Year	Median phosphorus level (milligrams of phosphorus per litre)	Minimum phosphorus level (milligrams of phosphorus per litre)	Maximum phosphorus level (milligrams of phosphorus per litre)	Number of samples
Saint-Maurice	2015	0.013	0.009	0.019	12
Saint-Maurice	2016	0.014	0.010	0.018	12
Saint-Maurice	2017	0.015	0.011	0.040	12
Saint-Maurice	2018	0.011	0.009	0.056	12
Saint-Maurice	2019	0.010	0.007	0.041	12
Bécancour	2010	0.038	0.020	0.172	12
Bécancour	2011	0.041	0.024	0.103	12
Bécancour	2012	0.030	0.013	0.087	12
Bécancour	2013	0.043	0.022	0.136	12
Bécancour	2014	0.031	0.007	0.067	12
Bécancour	2015	0.045	0.020	0.091	12
Bécancour	2016	0.050	0.027	0.293	12
Bécancour	2017	0.043	0.024	0.240	12
Bécancour	2018	0.044	0.009	0.117	12
Bécancour	2019	0.029	0.021	0.104	12
Quebec City	2010	0.025	0.013	0.062	17
Quebec City	2011	0.030	0.015	0.104	17
Quebec City	2012	0.030	0.013	0.049	20
Quebec City	2013	0.036	0.015	0.075	15
Quebec City	2014	0.033	0.013	0.058	15
Quebec City	2015	0.034	0.016	0.137	17
Quebec City	2016	0.042	0.019	0.114	17
Quebec City	2017	0.032	0.022	0.142	17
Quebec City	2018	0.036	0.006	0.069	17
Quebec City	2019	0.034	0.016	0.088	17

Note: Samples from the mouths of the Yamaska, Saint-François and Nicolet rivers are collected from May to September only.
Source: Environment and Climate Change Canada (2020) Saint Lawrence River basin long-term water quality monitoring data and Great Lakes connecting channels monitoring and surveillance data.

Table A.3. Data for Figure 3. Annual total nitrogen levels for 10 water quality monitoring stations along the St. Lawrence River, 2010 to 2019Figure 3. Annual total nitrogen levels for 10 water quality monitoring stations along the St. Lawrence River

Monitoring station	Year	Median nitrogen level (milligrams of nitrogen per litre)	Minimum nitrogen level (milligrams of nitrogen per litre)	Maximum nitrogen level (milligrams of nitrogen per litre)	Number of samples
Wolfe Island	2010	0.605	0.387	1.326	24
Wolfe Island	2011	0.523	0.398	0.606	13
Wolfe Island	2012	0.520	0.315	1.252	52

Monitoring station	Year	Median nitrogen level (milligrams of nitrogen per litre)	Minimum nitrogen level (milligrams of nitrogen per litre)	Maximum nitrogen level (milligrams of nitrogen per litre)	Number of samples
Wolfe Island	2013	0.535	0.377	1.646	65
Wolfe Island	2014	0.608	0.526	1.056	28
Wolfe Island	2015	0.674	0.423	2.885	31
Wolfe Island	2016	0.785	0.360	3.538	63
Wolfe Island	2017	0.663	0.375	4.192	55
Wolfe Island	2018	0.608	0.374	1.207	48
Wolfe Island	2019	0.562	0.021	1.887	51
Carillon	2010	0.543	0.450	0.897	14
Carillon	2011	0.540	0.440	0.870	14
Carillon	2012	0.530	0.440	0.690	13
Carillon	2013	0.570	0.480	1.060	13
Carillon	2014	0.515	0.400	1.070	14
Carillon	2015	0.520	0.340	1.130	14
Carillon	2016	0.545	0.380	0.780	14
Carillon	2017	0.605	0.440	1.050	14
Carillon	2018	0.555	0.430	1.050	14
Carillon	2019	0.515	0.460	0.920	14
Lavaltrie	2010	0.875	0.670	1.440	12
Lavaltrie	2011	0.920	0.580	1.350	12
Lavaltrie	2012	0.910	0.610	1.770	12
Lavaltrie	2013	0.950	0.730	1.860	12
Lavaltrie	2014	0.890	0.540	1.250	12
Lavaltrie	2015	0.940	0.390	1.520	11
Lavaltrie	2016	1.035	0.540	2.220	12
Lavaltrie	2017	0.990	0.740	1.560	12
Lavaltrie	2018	0.955	0.640	1.620	12
Lavaltrie	2019	0.825	0.530	1.260	12
Richelieu	2010	0.780	0.520	1.020	9
Richelieu	2011	0.650	0.430	1.030	12
Richelieu	2012	0.645	0.400	2.030	12
Richelieu	2013	0.705	0.400	2.520	12
Richelieu	2014	0.600	0.410	1.160	12
Richelieu	2015	0.610	0.500	2.440	12
Richelieu	2016	0.850	0.390	3.720	12
Richelieu	2017	0.665	0.390	1.590	12
Richelieu	2018	0.765	0.400	2.320	12

Monitoring station	Year	Median nitrogen level (milligrams of nitrogen per litre)	Minimum nitrogen level (milligrams of nitrogen per litre)	Maximum nitrogen level (milligrams of nitrogen per litre)	Number of samples
Richelieu	2019	0.680	0.380	2.020	12
Yamaska	2010	2.270	1.250	3.910	15
Yamaska	2011	1.920	1.170	5.700	14
Yamaska	2012	0.750	0.660	1.370	7
Yamaska	2013	1.870	1.070	4.120	9
Yamaska	2014	1.170	0.570	2.600	9
Yamaska	2015	3.055	0.560	5.094	12
Yamaska	2016	1.750	0.580	7.300	16
Yamaska	2017	1.840	1.200	4.970	17
Yamaska	2018	1.250	0.620	5.320	17
Yamaska	2019	1.510	0.780	2.520	17
Saint-François	2010	0.800	0.460	1.070	15
Saint-François	2011	0.830	0.590	2.420	14
Saint-François	2012	0.810	0.710	1.040	7
Saint-François	2013	0.760	0.610	1.110	9
Saint-François	2014	0.740	0.600	0.870	9
Saint-François	2015	0.770	0.410	0.969	12
Saint-François	2016	0.920	0.650	1.240	16
Saint-François	2017	0.830	0.580	3.040	17
Saint-François	2018	0.800	0.620	0.950	17
Saint-François	2019	0.810	0.560	1.000	17
Nicolet	2010	0.940	0.550	1.810	15
Nicolet	2011	0.990	0.570	2.900	14
Nicolet	2012	0.680	0.400	2.030	16
Nicolet	2013	1.280	0.710	1.940	9
Nicolet	2014	0.670	0.340	1.220	9
Nicolet	2015	1.390	0.170	3.070	12
Nicolet	2016	1.240	0.640	3.070	15
Nicolet	2017	1.340	0.620	2.540	17
Nicolet	2018	0.680	0.380	3.960	17
Nicolet	2019	0.920	0.460	1.740	17
Saint-Maurice	2010	0.315	0.243	0.630	12
Saint-Maurice	2011	0.340	0.290	0.417	13
Saint-Maurice	2012	0.330	0.270	0.400	12
Saint-Maurice	2013	0.330	0.270	0.760	13
Saint-Maurice	2014	0.340	0.280	0.560	12

Monitoring station	Year	Median nitrogen level (milligrams of nitrogen per litre)	Minimum nitrogen level (milligrams of nitrogen per litre)	Maximum nitrogen level (milligrams of nitrogen per litre)	Number of samples
Saint-Maurice	2015	0.320	0.210	0.490	12
Saint-Maurice	2016	0.320	0.190	0.360	12
Saint-Maurice	2017	0.320	0.260	0.380	12
Saint-Maurice	2018	0.320	0.270	0.780	12
Saint-Maurice	2019	0.290	0.260	0.350	12
Bécancour	2010	0.925	0.470	1.470	12
Bécancour	2011	0.915	0.470	1.420	12
Bécancour	2012	0.665	0.420	1.290	12
Bécancour	2013	0.935	0.490	1.290	12
Bécancour	2014	0.765	0.440	1.390	12
Bécancour	2015	0.825	0.440	1.910	12
Bécancour	2016	0.850	0.310	1.800	12
Bécancour	2017	0.950	0.440	1.490	12
Bécancour	2018	0.825	0.320	2.060	12
Bécancour	2019	0.760	0.390	1.170	12
Quebec City	2010	0.630	0.400	0.960	17
Quebec City	2011	0.620	0.430	0.970	17
Quebec City	2012	0.605	0.330	1.020	20
Quebec City	2013	0.715	0.450	0.940	14
Quebec City	2014	0.645	0.480	0.890	14
Quebec City	2015	0.670	0.270	1.180	17
Quebec City	2016	0.700	0.370	0.960	17
Quebec City	2017	0.650	0.440	1.170	17
Quebec City	2018	0.630	0.400	0.940	17
Quebec City	2019	0.610	0.420	1.130	17

Note: Samples from the mouths of the Yamaska, Saint-François and Nicolet rivers are collected from May to September only.
Source: Environment and Climate Change Canada (2020) Saint Lawrence River basin long-term water quality monitoring data and Great Lakes connecting channels monitoring and surveillance data.

Annex B. A total nitrogen guideline to protect the ecological condition of the St. Lawrence

Neither the governments of Ontario and Quebec nor the Canadian Council of Ministers of the Environment (CCME) has a water quality guideline for total nitrogen. In order to develop a guideline for the indicator, research and analysis was performed following the lines-of-evidence approach outlined in the CCME's Guidance manual for developing nutrient guidelines for rivers and streams (PDF; 1.95 MB). This approach recommends a number of consecutive steps to formulate a final guideline. A summary of the key steps followed to develop the guideline of 0.63 mg N/L for the calculation of the Nutrients in the St. Lawrence River indicators are set-out below.

It is important to note that this guideline has been designed for use in this indicator and may not include all possible data. Should an official total nitrogen guideline be developed for the St. Lawrence River, it will replace the guideline derived here.

Step 1. Definition of the area of interest

For the purpose of the indicators and the analysis performed, the St. Lawrence River is defined as extending from the outflow of Lake Ontario at Wolfe Island in the west to Quebec City in the east.

Site Description

The St. Lawrence River is a very large river with a catchment area of 1 610 000 km^2. It is situated in the St. Lawrence Lowlands ecoregion of the Mixedwood Plains Ecozone. About 60% of the region is intensively cultivated farmland, with dairy and mixed farming systems prevailing. Urban development is extensive. Intensive land use is increasing, with a trend toward rising nutrient loads to streams and rivers. The St. Lawrence Lowlands ecoregion has a humid, continental climate with very cold winters and very hot summers. Rivers in humid regions tend to have more water throughout the year.

The river was formed around the end of the last ice age when faulting led to the sinking of the area around the river (a rift valley), which was then flooded with water from the Atlantic Ocean. It forms much of the southwestern outline of the Canadian Shield in Quebec.

Step 2. Establishment of the desired outcomes and selection of the guideline variables

The desired outcome of this nitrogen guideline is to prevent eutrophication in the St. Lawrence River and the Gulf of St. Lawrence caused by total nitrogen.

Step 3. Classification of streams

The St. Lawrence River is a very large river ecosystem. In such systems, the relationships between aquatic communities and nutrients may be confounded by physical factors that exert their influence temporally and spatially at the local scale, as well as along a continuum of river size from small streams to large rivers. Water quality in streams is more subject to sudden changes in hydrology than is the case for rivers, and plant and animal community abundance and composition varies with river size. For these reasons, separate standards to protect the ecological condition of different rivers are necessary.

The river was not subdivided into separate subregions for this guideline derivation because of the need for a single value that would apply along the whole river to allow comparability among stations.

Step 4. Collection and analysis of data

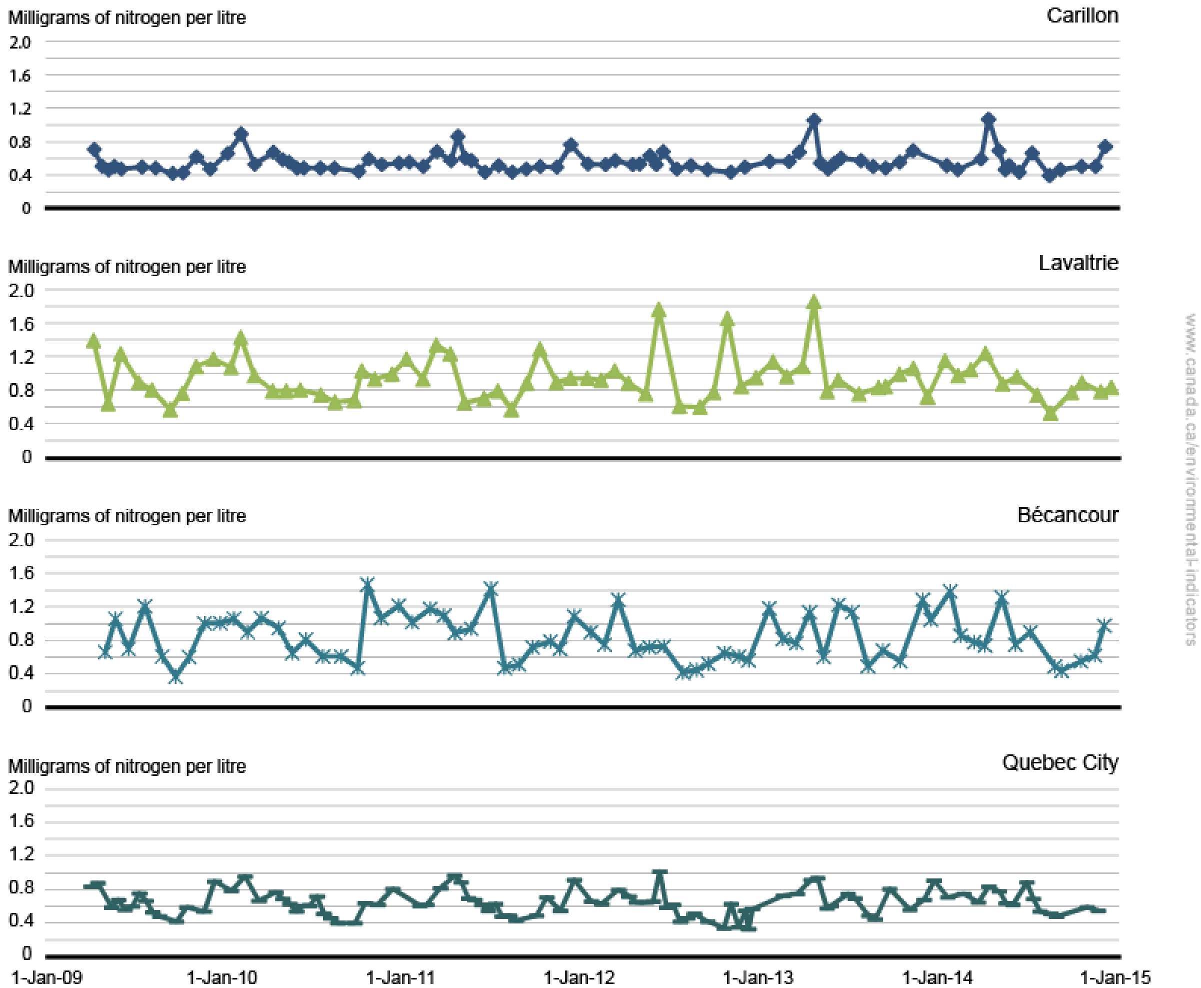
Total phosphorus and total nitrogen data were provided by Environment and Climate Change Canada's Freshwater Quality Monitoring and Surveillance program. The data can be found on the Freshwater quality monitoring: online data web page.

Observed spatial patterns in the data (Figure B.1; Table B.3):

- total nitrogen concentrations in the river tend to be lowest in summer and highest in winter
- total nitrogen concentrations increase from Carillon to Lavaltrie and then decrease to Bécancour and Quebec City
    - total nitrogen concentrations at Lavaltrie are influenced by the region of Montreal's sewage outfall

- at Bécancour, the influence of nitrogen inflow from tributaries draining the agricultural regions on the south shore of Lake Saint-Pierre can be seen

Figure B.1. Total nitrogen data for 4 water quality monitoring stations on the St. Lawrence River (stations are presented in order from Carillon in the west to Quebec City in the east)



Step 5. Literature review

Existing suggested guidelines for the St. Lawrence River were found in the primary and grey literature. The examples below were the most applicable.

Chambers et al. 2009

Ideal performance standards for medium and large rivers draining agricultural regions in Canada were developed following 2 lines of data analysis. The first method involved approximating background nutrient concentrations by calculating 25th percentiles for total phosphorus and total nitrogen following the United States Environmental Protection Agency's (U.S. EPA) nutrient criteria methodology (U.S. EPA 2000a). The second method involved exploring relationships between total nitrogen and total phosphorus and either benthic or sestonic algal biomass expressed as chlorophyll a using stepwise multiple linear regression on $\log_{10}$-transformed data.

The results of the analysis produced a suggested total nitrogen guideline of 0.63 mg N/L for large rivers in the Mixedwood Plains. Chambers et al. also recommended an ideal performance standard of 0.100 mg N/L for total nitrogen for Prince Edward Island coastal waters. This value is 6 times lower than the concentrations currently seen at Quebec City.

Caveats

Rivers with drainage basins larger than 10 000 km^2 were considered too large to be included in the analysis.

The methods deviated from the U.S. EPA approach by only using 25th percentiles for 2 reasons. First, given the amount of data in the freshwater database and the number of disparate sources of data, it was not possible to determine whether a site could be considered reference or low-impact. Second, the data came from rivers draining agricultural areas, signifying that they are impacted. The methods also deviated from the U.S. EPA method by analyzing data for large rivers collected for a 20-year period between 1985 and 2005 rather than the recommended 10-year period.

United States Environmental Protection Agency 2000b

The U.S. EPA's ecoregional nutrient criteria are intended to address cultural eutrophication. The criteria, or guidelines, are empirically derived to represent surface water conditions that are minimally impacted by human activities and protective of aquatic life and recreational uses.

This document sets out the U.S. EPA's recommended criteria for total nitrogen for rivers and streams in Nutrient Ecoregion VII (Mostly Glaciated Dairy Region) derived following procedures described in U.S. EPA 2000a. Reference condition criteria are based on the 25th percentiles of all nutrient data including a comparison of reference conditions for the aggregate ecoregion and the sub-ecoregions.

The analysis resulted in suggested total nitrogen guidelines for the whole ecoregion, as well as the sub-ecoregions closest to the St. Lawrence River (Table B.1).

Table B.1. Suggested total nitrogen guidelines for the United States Nutrient Ecoregion VII: Mostly Glaciated Dairy Region

Name	Suggested total nitrogen guideline (milligrams of nitrogen per litre)
Aggregate ecoregion VII	0.54 (reported)
Aggregate ecoregion VII	0.54 (calculated)
Sub-ecoregion 83 - Eastern Great Lakes and Hudson Lowlands	0.48 (reported)
Sub-ecoregion 83 - Eastern Great Lakes and Hudson Lowlands	0.50 (calculated)

Caveats

Nutrient criteria are derived for wadeable streams in the U.S. only, which generally have basins much smaller than 10 000 km^2.

United States Environmental Protection Agency 2001

The analysis in U.S. EPA 2001 is the same as that in U.S. EPA 2000b, except that it encompasses Nutrient Ecoregion VIII (Nutrient-Poor Largely Glaciated Upper Midwest and Northeast) (Table B.2).

Table B.2. Suggested total nitrogen guidelines for the United States Nutrient Ecoregion VIII (Nutrient-Poor Largely Glaciated Upper Midwest and Northeast)

Name	Suggested total nitrogen guideline (milligrams of nitrogen per litre)
Aggregate ecoregion VIII	0.38 (reported)
Sub-ecoregion 58 - Northeastern Highlands	0.42 (reported)
Sub-ecoregion 58 - Northeastern Highlands	0.26 (calculated)

Step 6. Collection and analysis of data

The following guideline calculation techniques were applied to the data for the 4 St. Lawrence River water quality monitoring stations. The U.S. EPA recommends the use of 10 years of data for its analysis; however, there were only 6 years of data available for the St. Lawrence River at the time of calculation.

United States Environmental Protection Agency 2000a

To derive nutrient criteria, the U.S. EPA recommends using the 75th percentile of 10 years of monitoring data from reference or low-impact sites. In the absence of adequate reference data, the 25th percentile of all monitoring sites can be used (Table B.3).

For the 25th percentile analysis for the St. Lawrence River, all total nitrogen data for each station were combined into a single median value for each season. The 25th percentile of all station medians was then calculated for each season (Table B.3). The median value from the 4 seasonal 25th percentile values is considered the standard. This analysis generated a guideline of 0.65 mg N/L (Table B.4).

Table B.3. Total nitrogen data summary for the St. Lawrence River

Monitoring station	Season	Number of records for total nitrogen	Minimum (milligrams of nitrogen per litre)	25th percentile (milligrams of nitrogen per litre)	Median (milligrams of nitrogen per litre)	75th percentile (milligrams of nitrogen per litre)	Maximum (milligrams of nitrogen per litre)
Carillon	Whole year	79	0.400	0.490	0.530	0.600	1.070
Carillon	Spring	31	0.440	0.499	0.550	0.625	1.070
Carillon	Summer	17	0.400	0.470	0.490	0.510	0.670
Carillon	Fall	16	0.434	0.494	0.510	0.607	0.770
Carillon	Winter	15	0.470	0.533	0.560	0.624	0.897
Lavaltrie	Whole year	69	0.540	0.780	0.900	1.070	1.860
Lavaltrie	Spring	19	0.650	0.795	0.890	1.240	1.860
Lavaltrie	Summer	15	0.540	0.615	0.750	0.825	0.900
Lavaltrie	Fall	21	0.690	0.790	0.940	1.040	1.660
Lavaltrie	Winter	14	0.930	0.973	1.045	1.158	1.440
Bécancour	Whole year	69	0.370	0.610	0.780	1.060	1.470
Bécancour	Spring	18	0.600	0.705	0.780	1.033	1.320
Bécancour	Summer	17	0.420	0.490	0.610	0.720	1.420
Bécancour	Fall	19	0.370	0.580	0.700	1.060	1.470
Bécancour	Winter	15	0.750	0.840	1.010	1.125	1.390
Quebec City	Whole year	96	0.330	0.540	0.630	0.735	1.020
Quebec City	Spring	29	0.540	0.620	0.680	0.840	1.020
Quebec City	Summer	30	0.400	0.480	0.520	0.660	0.890
Quebec City	Fall	23	0.330	0.515	0.570	0.660	0.920
Quebec City	Winter	14	0.610	0.653	0.720	0.780	0.960
Whole river	Whole year	313	0.330	0.540	0.670	0.890	1.860
Whole river	Spring	97	0.440	0.590	0.690	0.890	1.860
Whole river	Summer	79	0.400	0.480	0.540	0.695	1.420
Whole river	Fall	79	0.330	0.550	0.680	0.915	1.660

Monitoring station	Season	Number of records for total nitrogen	Minimum (milligrams of nitrogen per litre)	25th percentile (milligrams of nitrogen per litre)	Median (milligrams of nitrogen per litre)	75th percentile (milligrams of nitrogen per litre)	Maximum (milligrams of nitrogen per litre)
Whole river	Winter	58	0.470	0.653	0.810	1.018	1.440

Table B.4. Twenty-fifth (25th) percentiles of seasonal medians for each station along the St. Lawrence River as well as the all stations combined (whole river)

Monitoring station	25th percentile of seasonal medians (milligrams of nitrogen per litre)
Carillon	0.505
Lavaltrie	0.855
Bécancour	0.678
Québec City	0.558
Whole river	0.645

The U.S. EPA also suggests using reference reaches to establish criteria. For this approach, it recommends using the 75th percentile of the nutrient frequency distribution for reference sites. As Carillon is the most upstream station,[8] it can be considered the reference site for the dataset, even though technically its water quality is not degraded, as it is situated at the mouth of the Ottawa River. Total nitrogen is at its lowest here until the water reaches Quebec City. The 75th percentile of Carillon's total nitrogen concentrations is 0.60 mg N/L (Table B.3).

Step 7. Establishment of guidelines

In the absence of more detailed analyses to assess the relationship between nitrogen and aquatic plant growth in the St. Lawrence River, the analysis presented here helps point toward a total nitrogen guideline. Based on the recommended total nitrogen guideline values summarized in the table below, the values calculated using Canadian data for the area result in a total nitrogen guideline in the 0.60 to 0.65 mg N/L range (Table B.5). The mid-point of the range, 0.63 mg N/L, is the value used to calculate of the Nutrients in the St. Lawrence River indicator.

Table B.5. Comparison of possible total nitrogen standards

Value type	Guideline analysis reference	Recommended total nitrogen guideline (milligrams of nitrogen per litre)	Notes or comments
Calculated value	U.S. EPA 2000a	0.65	25th percentile of seasonal medians for all sites in an ecoregion
Calculated value	U.S. EPA 2000a	0.60	75th percentile of reference site (Carillon)
Literature value	Chambers et al. 2009	0.63	For large rivers in the Mixedwood Plains Ecozone
Literature value	U.S. EPA 2000b	0.54	Streams in Aggregate ecoregion VII, Mostly Glaciated Dairy Region
Literature value	U.S. EPA 2001	0.38	Streams in Aggregate ecoregion VII, Nutrient Poor Largely Glaciated Upper Midwest and Northeast

[8] The guideline methodology was developed in 2016 when Carillon was the most upstream station presented in the indicators.

Additional information can be obtained at:

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