Environment and Climate Change Canada
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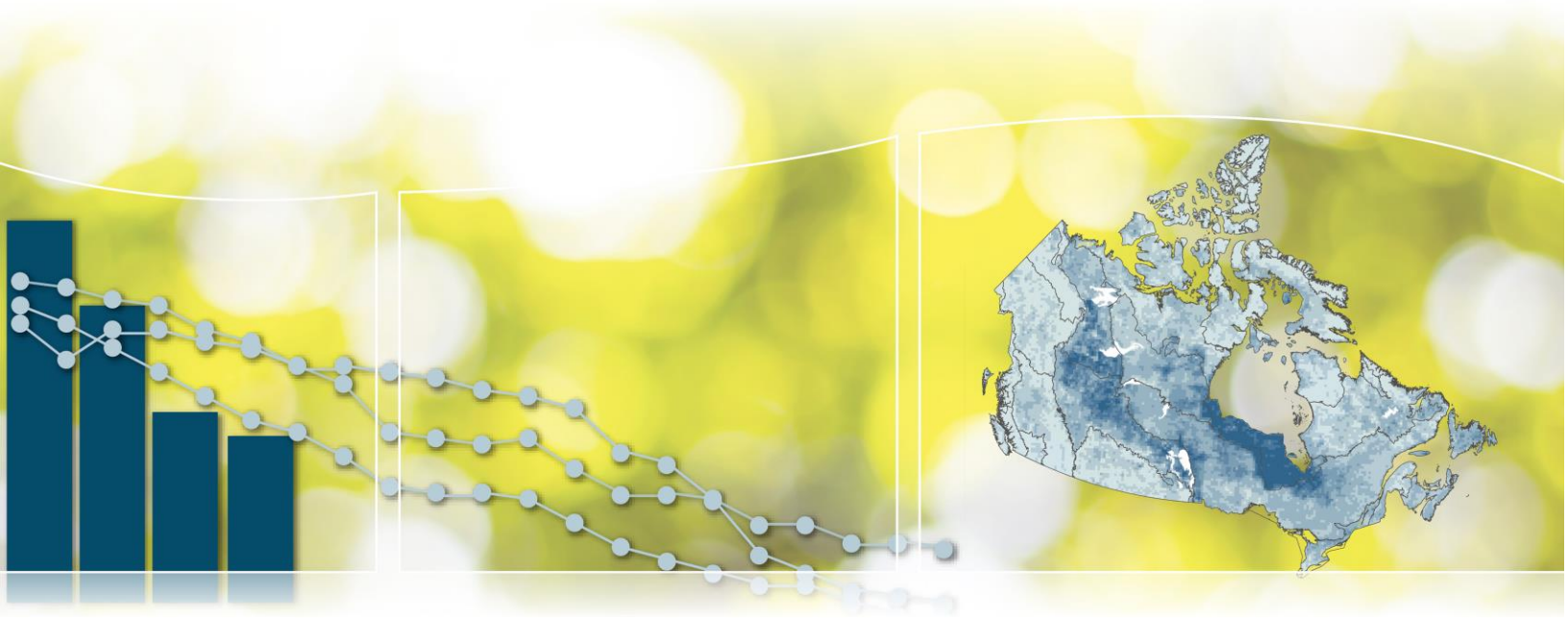
Canadian Environmental Sustainability Indicators

Nutrients in the St. Lawrence River



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Canadian Environmental Sustainability Indicators

Nutrients in the St. Lawrence River

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Table of Contents

List of Figures

List of Tables

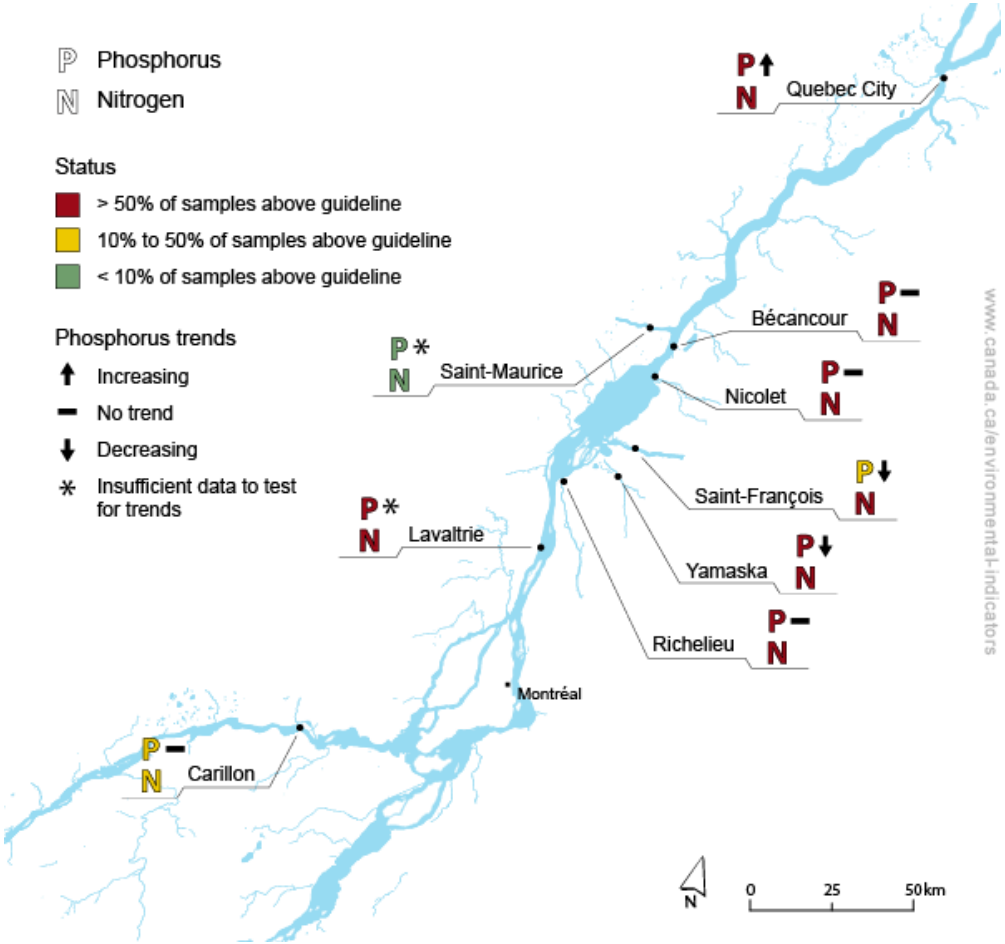
Nutrients in the St. Lawrence River

Phosphorus and nitrogen are essential plant nutrients. When phosphorus or nitrogen levels in a river are too high or too low, however, these nutrients can have harmful effects on the food web. They are an important measure of the health of the river and its surrounding watersheds. This indicator provides the status of phosphorus and nitrogen levels along the St. Lawrence River.

Key results

- During the 2015 to 2017 period:
  - phosphorus and nitrogen levels exceeded water quality guidelines at most monitoring stations (8 out of 9 stations)
  - only at Saint-Maurice did phosphorus and nitrogen level exceedances occur in less than 10% of samples
- From 2008 to 2017:
  - of the 7 sites with sufficient data to estimate trends in phosphorus, Quebec City had increased levels while Saint-François and Yamaska had decreased levels
  - not enough data was available to estimate trends in nitrogen

Figure 1. Status of total phosphorus and total nitrogen levels for the 2015 to 2017 period and total phosphorus level trends in the St. Lawrence River, Canada, 2008 to 2017



Data for Figure 1

Note: Water quality at a monitoring station is considered Green when nutrient levels (phosphorus or nitrogen) exceed the guideline less than 10% of the time. A Yellow status is applied when the guideline is exceeded 10% to 50% of the time. A Red 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 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.
Source: St. Lawrence River Water Quality Monitoring and Surveillance Division (2018) Environment and Climate Change Canada.

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 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. Past Quebec City, the St. Lawrence River flows into the Gulf of St. Lawrence, where the nitrogen and phosphorus levels contribute to harmful algal blooms.

During the 2015 to 2017 period, phosphorus and nitrogen levels at the majority of water quality monitoring stations along the St. Lawrence River were above water quality guidelines more than 50% of the time. There is sufficient data to estimate trends for phosphorus alone at 7 station. One station (Quebec City) shows an increasing trend from 2008 to 2017 while 2 stations show a decrease. The other 4 stations show no trends.

For the St. Lawrence River, water quality at a monitoring station is considered to be minimally impacted by nutrients from human activities 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 watercourse is considered partially impaired by nutrient loading from human activity. In contrast, if more than 50% of the samples exceed the water quality guidelines, total phosphorus and nitrogen concentrations are more consistently above the guidelines and water quality is considered to be impaired by human activity.

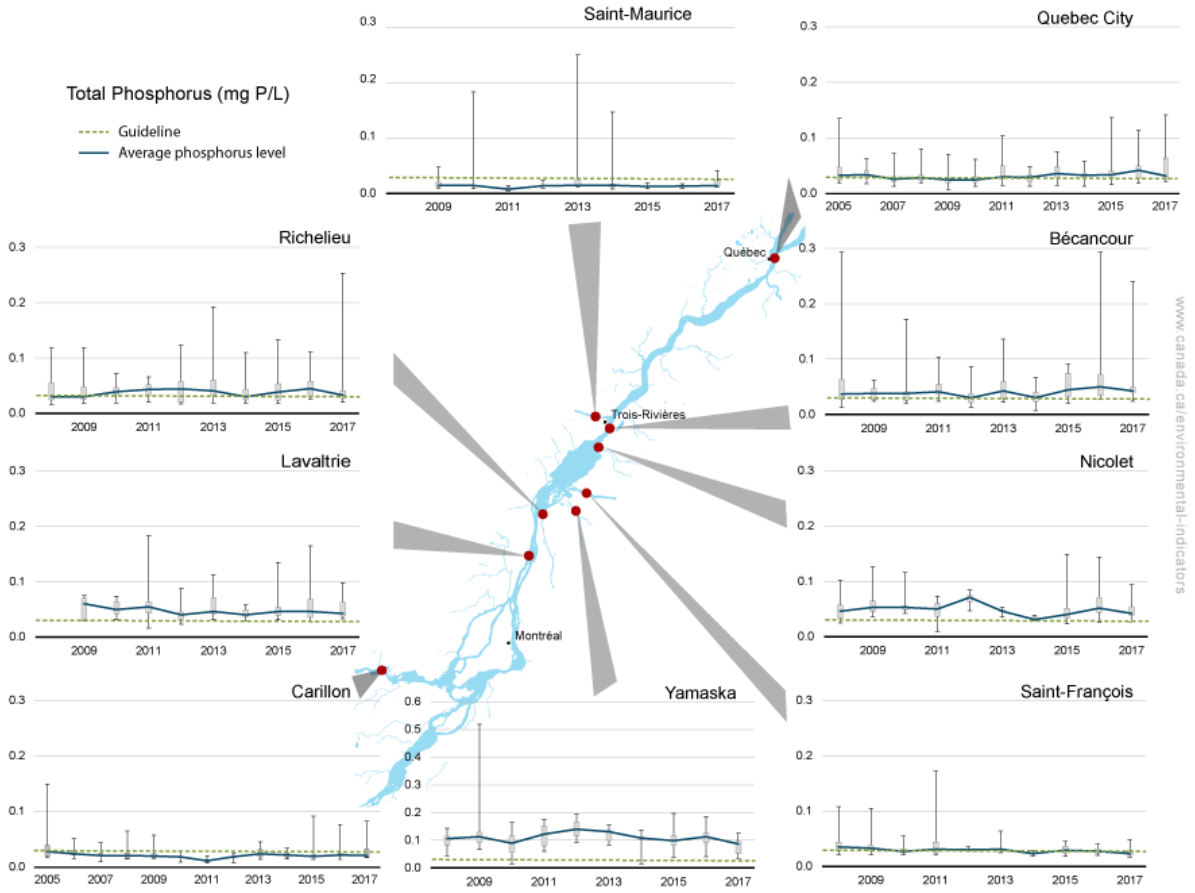
[1] Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques (2009) Critères de qualité de l'eau de surface: phosphore total (en P) (in French only). Retrieved on July 30, 2018.

Phosphorus levels by water quality monitoring station

Key results

- A trends analysis from 2008 to 2017 showed:
  - Quebec City had increased phosphorus levels
  - Saint-François and Yamaska had decreased phosphorus levels
  - Bécancour, Nicolet, Richelieu and Carillon had no detectable trends
- There was insufficient data to test for trends at Saint-Maurice and Lavaltrie

Figure 2. Annual total phosphorus levels for 9 water quality monitoring stations along the St. Lawrence River



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 Quebec's total phosphorus water quality guideline value of 0.03 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 at the 7 stations that had data from at least 2008 to 2017.
Source: St. Lawrence River Water Quality Monitoring and Surveillance Division (2018) Environment and Climate Change Canada.

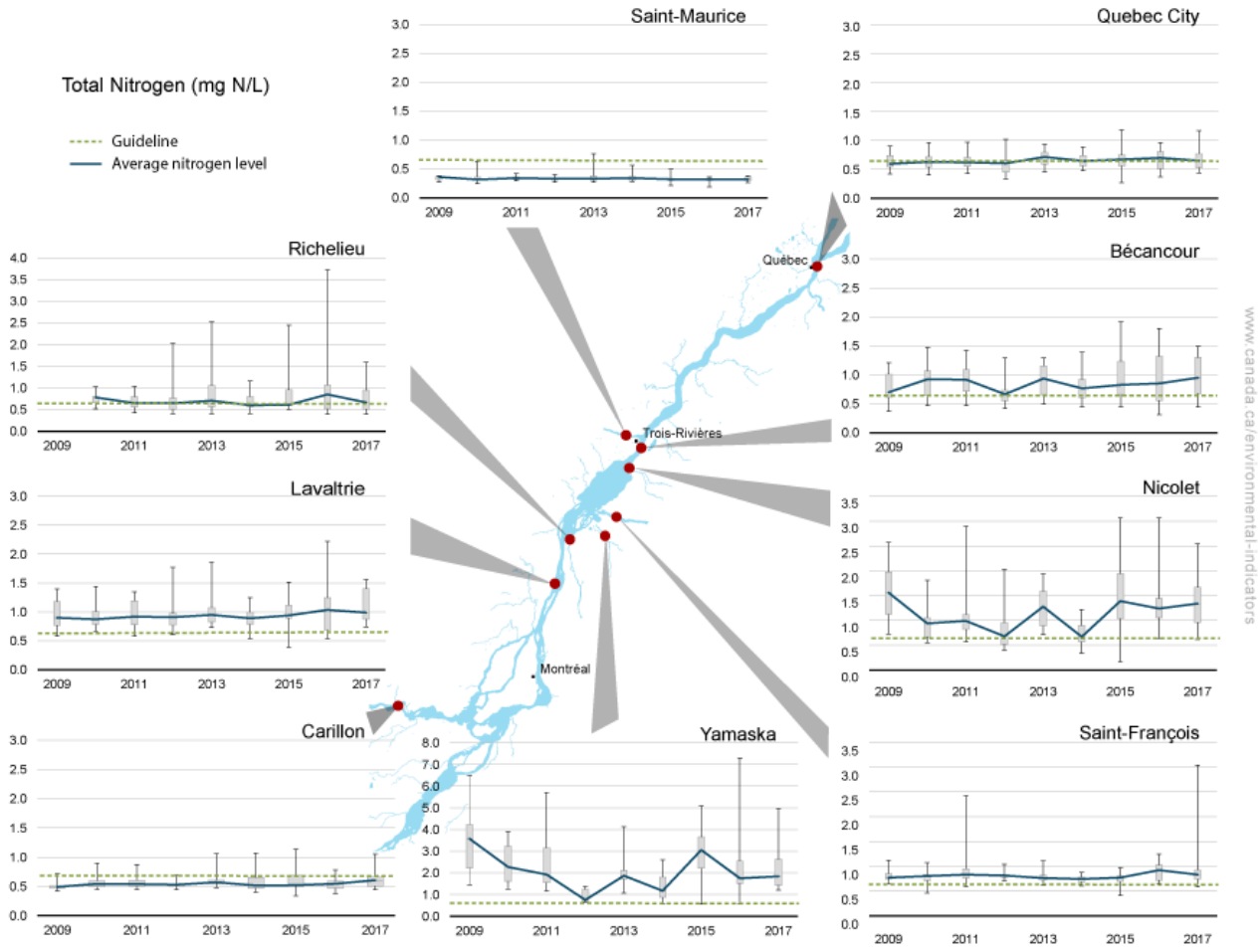
Plotting phosphorus data for each station by year provides a general view of how phosphorus levels are changing along the St. Lawrence River. The worsening trend near Quebec City may be driven by an urban population growth and agriculture expansion upstream of the station.

Nitrogen levels by water quality monitoring station

Key results

- Annual nitrogen levels at Saint-Maurice and Carillon were consistently below the water quality guideline
- There was insufficient data to test for trends at any of the 9 monitoring stations

Figure 3. Annual total nitrogen levels for 9 water quality monitoring stations along the St. Lawrence River



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 mg N/L. The solid line is drawn through the median to give a sense of trends in concentration. None of the stations had enough data to perform a Seasonal Kendall trend analysis.
Source: St. Lawrence River Water Quality Monitoring and Surveillance Division (2018) Environment and Climate Change Canada.

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 below water quality guidelines at stations situated near forested areas with smaller urban populations, such as Carillon and Saint-Maurice.

About the indicator

What the indicator measures

The indicator reports 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.

This indicator assumes that water in the St. Lawrence River would rarely exceed water quality guidelines for phosphorus and nitrogen in the absence of human development. It provides 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 trend analysis provides information about how concentrations are changing over time.

Why this indicator is important

Clean freshwater is an essential resource. It protects the biodiversity of aquatic plants and animals. We use it for drinking, manufacturing, energy production, irrigation, swimming, boating and fishing. Degraded water quality damages the health of freshwater ecosystems and can disrupt economic activities, such as fisheries, tourism and agriculture. When phosphorus and nitrogen levels in water are too high or too low, they can cause harmful effects on the river.

Phosphorus and nitrogen used in chemical fertilizers reach the river through erosion and 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.

This indicator is 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. This indicator also contributes to the measurement of progress towards the 2016–2019 Federal Sustainable Development Strategy.

Related indicators

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 those 2 ecosystems.

The Water quality in Canadian rivers indicators rank water quality at monitoring sites across Canada where human activity is likely to harm a river's ecosystem.

Pristine lakes and rivers

This indicator supports the measurement of progress towards the following 2016–2019 Federal Sustainable Development Strategy long-term goal: Clean and healthy lakes and rivers support economic prosperity and the well-being of Canadians.

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 Freshwater quality monitoring: online data web page.

More information

Sampling

The status of total phosphorus and total nitrogen levels are based on measurements recorded between January 2015 and December 2017. The trend analysis uses total phosphorus data from 2008 to 2017 recorded at 7 monitoring stations (Carillon, Richelieu, Yamaska, Saint-François, Nicolet, Bécancour and Quebec City).

The sampling frequency at the water quality monitoring stations included in this indicator is not uniform. Sampling at the Carillon, Lavaltrie, Richelieu, Bécancour, Saint-Maurice and Quebec City stations is conducted on a monthly basis. At monitoring stations at the mouths of the Nicolet, Saint-François and Yamaska rivers, samples are typically collected on a weekly basis from June until the end of August. Gaps exist in the data due to program changes, weather and mechanical issues with the equipment used to collect the data.

Water quality monitoring station locations

Data were obtained from 9 monitoring stations along the St. Lawrence River from the Quebec-Ontario border 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 indicator

Monitoring station	Station code	Station name	Longitude	Latitude
Carillon	QU02LB9001	Rivière des Outaouais, en aval du barrage de Carillon	-74.379870	45.567570
Lavaltrie	QU02OB9004	Fleuve Saint-Laurent, prise d'eau de l'usine de filtration de Lavaltrie	-73.280645	45.874418
Richelieu	QU02OJ0052	Rivière Richelieu, prise d'eau de l'usine de filtration de Sorel	-73.117582	46.033974
Yamaska	QU02OG3007	Rivière Yamaska, pont de la route 132	-72.910075	46.005059
Saint-François	QU02OF3004	Rivière Saint-François à Pierreville	-72.812180	46.066375
Nicolet	QU02OD3004	Rivière Nicolet à Nicolet	-72.651229	46.245373
Bécancour	QU02OD9009	Fleuve Saint-Laurent, prise d'eau de l'usine de filtration de Bécancour	-72.546012	46.311578
Saint-Maurice	QU02NG3013	Rivière Saint-Maurice, prise d'eau de l'usine de filtration de Trois-Rivières	-72.610500	46.382000
Quebec City	QU02PH9024	Fleuve Saint-Laurent, prise d'eau de l'usine de filtration de Lévis	-71.190009	46.807123

Methods

The status of phosphorus and nitrogen levels at each monitoring station was ranked 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 at stations with 10 years of data.[2]

More information

Water quality guidelines

Total phosphorus

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 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 Nutrients in the St. Lawrence River indicator. 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 A for more detail about how the total nitrogen guideline was derived.

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

The phosphorus status at each of the 9 water quality monitoring stations was computed by comparing total phosphorus concentrations at each station with Quebec's 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 A).

The number of times total phosphorus and total nitrogen concentrations exceeded the guidelines were summed from 2015 to 2017, 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. Stations with fewer than 10% of samples exceeding the guidelines were given a Green water quality status. Stations with 10% to 50% exceedances were given a Yellow water quality status. Stations with more than 50% of samples exceeding the guidelines were given a Red water quality status.

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[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 July 30, 2018.

[3] Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques (2009) Critères de qualité de l'eau de surface : phosphore total (en P) (in French only). Retrieved on July 30, 2018.

[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.

Trend Analysis

Stations sampled monthly

Within the dataset, each sample was assigned to a month. One sample per month (approximate 30-day interval) was used for the analysis. This was done in order to correct sampling frequency variation in the data and to minimize analytical issues associated with serial correlation in the data. The analysis was run using the Kendall package within the R software environment.

Stations sampled weekly

Within the dataset, 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.

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. Total phosphorus concentrations are strongly correlated with the river's flows because high flows transport more suspended sediment with bound phosphorus.

These data requirements were met by 7 stations (Table 2).

Table 2. Seasonal Kendall analysis output for total phosphorus, 2008 to 2017

Monitoring station	Parameter	Tau	Score	2-sided p-value	Seasonal Kendall slope
Carillon	Total phosphorus	0.1345029	69	0.06694428	0.0003
Richelieu	Total phosphorus	0.005747126	3	0.9576477	0
Yamaska	Total phosphorus	-0.1717452	-62	0.04937288	-0.002
Saint-François	Total phosphorus	-0.2777778	-105	0.001080528	-0.001
Nicolet	Total phosphorus	-0.1428571	54	0.09701621	-0.001
Bécancour	Total phosphorus	0.1055556	57	0.1460782	0.0006666667
Quebec City	Total phosphorus	0.2042802	105	0.005416289	0.00125

Recent changes

Total phosphorus trends are reported for all monitoring stations that met the trend data requirements. Refer to the Methods for more information on the trend analysis.

A correction was made to the data for phosphorus level status at Quebec City for the 2012 to 2014 period. The status was changed from Yellow (10% to 50% of phosphorus samples were above the guideline) to Red (over 50% of phosphorus samples were above the guideline).

Caveats and limitations

The indicator reflects 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 this indicator 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 July 30, 2018.

Chambers PA, Guy M, Dixit SS, Benoy GA, Brua RB, Culp JM, McGoldrick D, Upsdell BL, 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.

Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques (2009) Critères de qualité de l'eau de surface : phosphore total (en P) (in French only). Retrieved on July 30, 2018.

United States Environmental Protection Agency (2000a) Nutrient Criteria Technical Guidance Manual: Rivers and Streams. Report No. EPA-822-B-00-002. Retrieved on July 30, 2018.

United States Environmental Protection Agency (2000b) Ecoregional Nutrient Criteria Documents for Rivers and Streams in Nutrient Ecoregion VII: Mostly Glaciated Dairy Region (PDF; 331 kB). Report No. EPA-822-B-00-018. Retrieved on July 30, 2018.

United States Environmental Protection Agency (2001) Ecoregional Nutrient Criteria Documents for Rivers and Streams in Nutrient Ecoregion VIII: Nutrient-Poor, Largely Glaciated Upper Midwest and Northeast (PDF; 2.53 MB). Report No. EPA-822-B-01-015. Retrieved on July 30, 2018.

Related information

Environment and Climate Change Canada (2015) Phosphorus in aquatic ecosystems. Retrieved on July 30, 2018.

Governments of Canada and Quebec (2015) St. Lawrence Action Plan 2011-2026. Retrieved on July 30, 2018.

Environment and Climate Change Canada (2017) St. Lawrence River: phosphorus at the mouths of Lake Saint-Pierre tributaries. Retrieved on July 30, 2018.

Annexes

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

Neither the Quebec government nor the Canadian Council of Ministers of the Environment (the council) 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 council'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 indicator 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 indicator and the analysis performed, the St. Lawrence River is defined as extending from the Ontario-Quebec border 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.

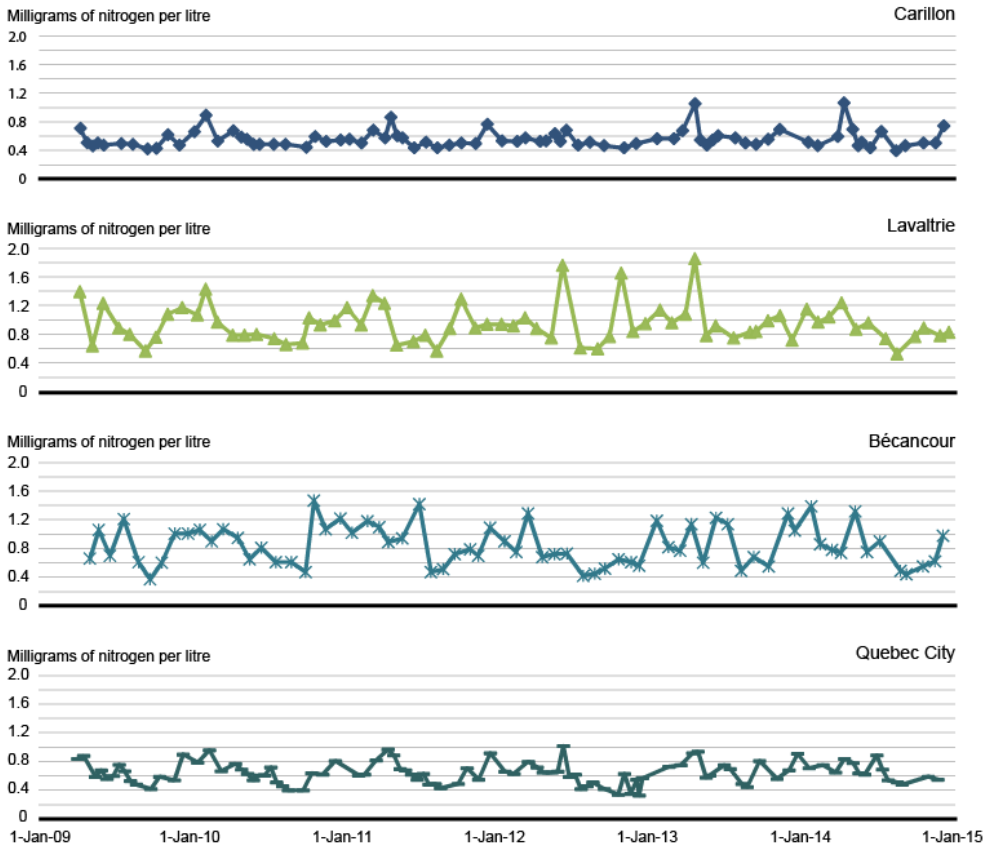
Step 4. Collection and analysis of data

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 A.1; Table A.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 A.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 U.S. EPA's 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 A.1).

Table A.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 A.2).

Table A.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 A.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 A.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 A.4).

Table A.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

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)
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
Whole river	Winter	58	0.470	0.653	0.810	1.018	1.440

Table A.4. Twenty-fifth percentiles of seasonal means 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, 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 A.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 A.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 A.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

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

Table B.1. Data for Figure 1. Status of total phosphorus and total nitrogen levels for the 2015 to 2017 period and total phosphorus level trends in the St. Lawrence River, Canada, 2008 to 2017

Monitoring station	2015 to 2017 total phosphorus guideline exceedance (percentage)	Total phosphorus status	2015 to 2017 total nitrogen guideline exceedance (percentage)	Total nitrogen status	2008 to 2017 total phosphorus trends
Carillon	24	Yellow	33	Yellow	Phosphorus levels show no trend
Lavaltrie	94	Red	91	Red	Insufficient data to test for trends
Richelieu	72	Red	56	Red	Phosphorus levels show no trend
Yamaska	100	Red	96	Red	Phosphorus levels are decreasing
Saint-François	33	Yellow	96	Red	Phosphorus levels are decreasing
Nicolet	89	Red	95	Red	Phosphorus levels show no trend
Saint-Maurice	8	Green	0	Green	Insufficient data to test for trends
Bécancour	83	Red	72	Red	Phosphorus levels show no trend
Quebec City	68	Red	63	Red	Phosphorus levels are increasing

Note: Water quality at a monitoring station is considered Green when nutrient levels (phosphorus or nitrogen) exceed the guideline less than 10% of the time. A Yellow status is applied when the guideline is exceeded 10% to 50% of the time. A Red 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 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.
Source: St. Lawrence River Water Quality Monitoring and Surveillance Division (2018) Environment and Climate Change Canada.

Table B.2. Data for Figure 2. Annual total phosphorus levels for 9 water quality monitoring stations along the St. Lawrence River

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
Carillon	2005	0.028	0.018	0.150	23
Carillon	2006	0.024	0.016	0.051	20
Carillon	2007	0.021	0.010	0.044	20
Carillon	2008	0.021	0.015	0.065	14
Carillon	2009	0.020	0.016	0.058	17
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
Lavaltrie	2009	0.060	0.030	0.075	9
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	0.046	0.027	0.165	12
Lavaltrie	2017	0.043	0.033	0.098	12
Richelieu	2008	0.030	0.016	0.118	12
Richelieu	2009	0.030	0.018	0.118	10
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	13
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
Yamaska	2008	0.106	0.044	0.143	19

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
Yamaska	2009	0.113	0.066	0.520	17
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
Saint-François	2008	0.035	0.021	0.108	15
Saint-François	2009	0.033	0.021	0.105	15
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
Nicolet	2008	0.046	0.025	0.102	15
Nicolet	2009	0.053	0.036	0.126	15
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
Bécancour	2008	0.037	0.013	0.293	12
Bécancour	2009	0.038	0.024	0.062	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

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
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
Saint-Maurice	2009	0.015	0.010	0.048	10
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
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
Quebec City	2005	0.033	0.019	0.135	16
Quebec City	2006	0.034	0.019	0.135	16
Quebec City	2007	0.026	0.013	0.072	18
Quebec City	2008	0.029	0.020	0.080	18
Quebec City	2009	0.025	0.008	0.070	17
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

Note: Samples from the mouths of the Yamaska, Saint-François and Nicolet rivers are collected from May to September only.
Source: St. Lawrence River Water Quality Monitoring and Surveillance Division (2018) Environment and Climate Change Canada.

Table B.3. Data for Figure 3. Annual total nitrogen levels for 9 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
Carillon	2009	0.492	0.426	0.713	11

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
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
Lavaltrie	2009	0.900	0.580	1.400	9
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	1.040	0.540	2.220	12
Lavaltrie	2017	0.990	0.740	1.560	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
Yamaska	2009	3.580	1.460	6.480	15
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	3.060	0.560	5.090	12
Yamaska	2016	1.750	0.580	7.300	16
Yamaska	2017	1.840	1.200	4.970	17
Saint-François	2009	0.770	0.650	1.120	15

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-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
Nicolet	2009	1.560	0.730	2.570	15
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
Bécancour	2009	0.855	0.370	1.210	9
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
Saint-Maurice	2009	0.360	0.270	0.380	9
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
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

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
Quebec City	2009	0.595	0.420	0.900	14
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

Note: Samples from the mouths of the Yamaska, Saint-François and Nicolet rivers are collected from May to September only.
Source: St. Lawrence River Water Quality Monitoring and Surveillance Division (2018) Environment and Climate Change Canada.

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