Monitoring the State of the
ST. LAWRENCE RIVER

Phytoplankton, Toxic Algae and Zooplankton in the Estuary and Gulf of St. Lawrence

Indicator name: Phytoplankton
Status: Moderate in 2020-2024
Trend: Unchanged since 2015-2019

Indicator name: Toxic algae
Status: Moderate–Good in 2020-2024
Trend: Unchanged since 2015-2019

Indicator name: Zooplankton
Status: Poor in 2020-2024
Trend: Deteriorating since 2015-2019

Highlights

Phytoplankton, toxic algae and zooplankton communities in the Estuary and Gulf of St. Lawrence remained stable or declined during the 2020–2024 period. Phytoplankton biomass increased, with spring blooms occurring earlier compared with the reference period. Although the toxic algae indicator was rated Moderate–Good for 2020–2024, a record bloom of *Pseudo-nitzschia* was recorded in 2021. Zooplankton biomass decreased, and the development of *Calanus finmarchicus*, a key species in the marine food web, occurred significantly early.

Problem

The marine food web is sustained at its base by phytoplankton, microscopic plant organisms that generate organic matter through photosynthesis. These phytoplankton are consumed by zooplankton, which, in turn, provide a primary food source for many fish and other marine organisms. Many species of fish, marine mammals and seabirds feeding within the St. Lawrence ecosystem therefore depend on plankton production. Consequently, variations in plankton biomass or phenology can affect the health and survival of numerous marine resources.

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Toxic algae blooms are another recurring environmental issue in the St. Lawrence. They cause annual closures of shellfish harvesting areas and can lead to mass mortality among aquatic organisms, including belugas. Increased precipitation and coastal eutrophication are key factors promoting toxic algae growth.

In 1998, Fisheries and Oceans Canada (DFO) established the Atlantic Zone Monitoring Program (AZMP) to better understand and monitor oceanographic changes, and to support the sustainable management of resources and activities. The purpose of the AZMP is to detect, monitor and predict changes in productivity and state in the Canadian Atlantic zone. Sampling campaigns in the Estuary and Gulf of St. Lawrence provide essential data for marine ecosystem preservation and climate-related research. Alongside the AZMP, the Toxic Algae Monitoring Program focuses specifically on tracking harmful algae in the St. Lawrence ecosystem.

Study area

AZMP biological data are collected through twice-yearly sampling (in June and November) at a network of stations along the Estuary and Gulf of St. Lawrence, and weekly sampling (from April to November) at the Rimouski station in the Estuary. Satellite observations of ocean colour provide continuous data on surface phytoplankton biomass. These data are supplemented by toxic algae monitoring, sampled at coastal stations two to four times a month between May and October.

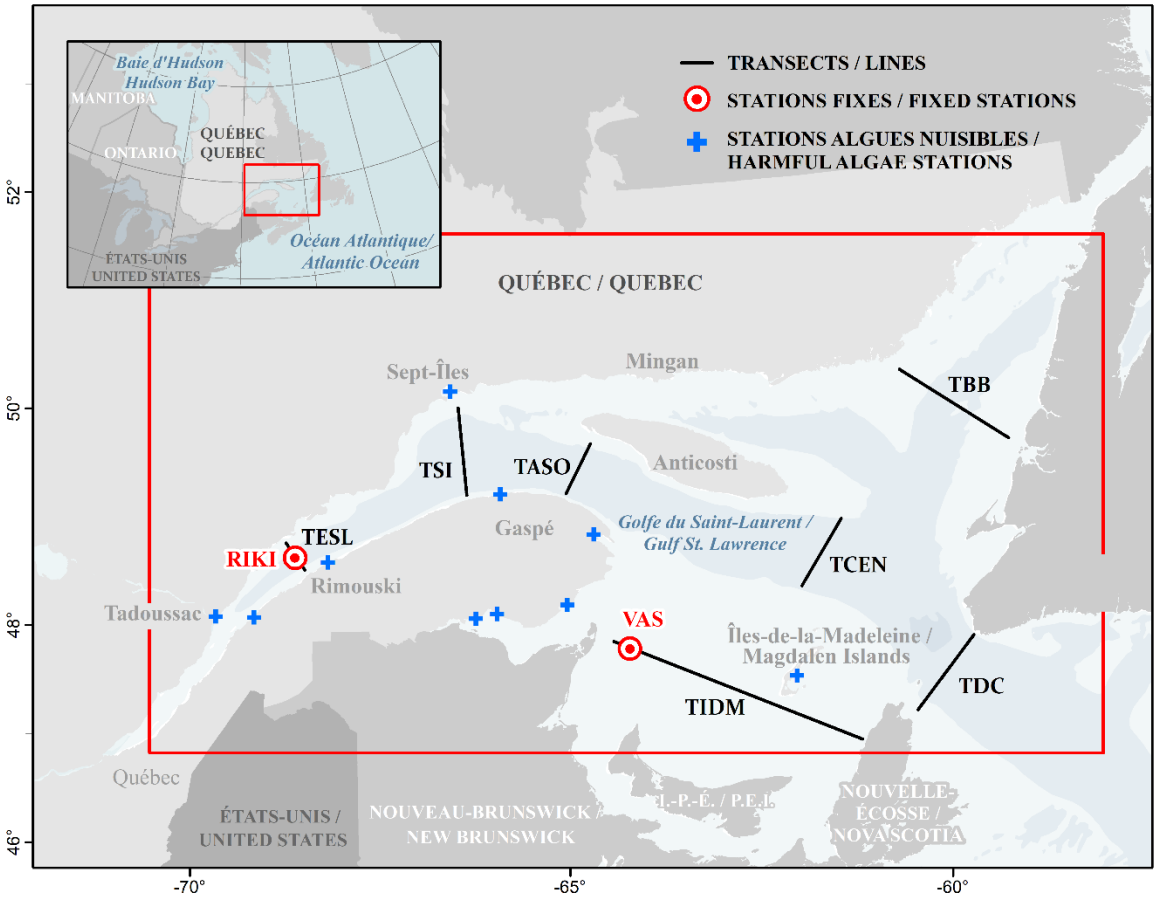

Figure 1. Positions of lines (black) and two fixed stations (red dots) monitored by the AZMP, and the location of harmful algae stations (blue crosses) in the Estuary and Gulf of St. Lawrence.

Key measures

Oceanographic indicators in the St. Lawrence are monitored through a set of key measurements expressed as anomalies—deviations from the average conditions observed during the reference periods (phytoplankton: 1999–2020; toxic algae: 1994–2007; zooplankton: 2001–2020).

A negative (or positive) anomaly indicates that the value of the key measurement for the year in question is less (or greater) than the average for the reference period, or that phenology occurs earlier (or later) than during that period. For the phytoplankton and zooplankton indicators, the direction of change of the anomaly (positive or negative) cannot be interpreted as being intrinsically “good” or “bad.” However, the absence of change (within 0.3 standard deviation) can generally be associated with a Good status. The status of each indicator is determined by the sum of the normalized anomalies of its indices (absolute values). Each increment of 1.2 (0.3 standard deviation × number of key measurements) corresponds to a new status, ranging from Good (sum < 1.2) to Poor (sum > 4.8).

However, in the case of toxic algae, the status is based on the sum of anomalies across all stations: a decline from historical conditions indicates a Good status, and vice versa. Each increment of 12 (0.5 standard deviation × number of stations × number of key measurements) corresponds to an additional level of status decline.

Indicator: Phytoplankton

Average **annual biomass** of phytoplankton in the **Estuary** estimated from chlorophyll *a* data collected at the Rimouski station between (May–November).

Average **annual biomass** of phytoplankton in the **Gulf** estimated from daily remote sensing data.

Average **spring biomass** of phytoplankton in the **Gulf** estimated from daily remote sensing data.

Timing of the **spring bloom** in the **Gulf** estimated from daily remote sensing data.

Indicator: Toxic algae

Frequency of ***Alexandrium*** spp. blooms (>1000 cells/L), producers of of paralytic toxins, in the Gulf of St. Lawrence.

Intensity of ***Alexandrium*** spp. blooms, based on maximum cell density.

Frequency of ***Pseudo-nitzschia*** spp. blooms (>30,000 cells/L), producers of amnesic toxins, in the Gulf of St. Lawrence.

Intensity of ***Pseudo-nitzschia*** spp. blooms, based on maximum cell density.

Indicator: Zooplankton

Average **annual biomass** of mesozooplankton (<1 cm) collected by vertical nets in the Estuary and Gulf of St. Lawrence.

Average annual **abundance** of **copepods** collected by vertical nets in the Estuary and Gulf of St. Lawrence.

Average annual **abundance** of **non-copepods** collected by vertical nets in the Estuary and Gulf of St. Lawrence.

Phenology of ***Calanus finmarchicus*** at the Rimouski station, estimated by the day when the proportion of copepodite stage CIV exceeds 0.3.

Status and trends

Phytoplankton: Stable status, upward annual biomass trend

The phytoplankton indicator status has fluctuated between Moderate–Good and Moderate–Poor over the past five years (2020–2024), resulting in an overall Moderate rating for the entire period (Figure 2). In 2022, elevated phytoplankton biomass and early spring blooms in the Estuary and Gulf produced a marked deviation from reference period conditions (1999–2020), leading to a Moderate–Poor status for that year (Figure 2). Despite increased variability during the current period, the trend continues to reflect the Moderate status recorded in the previous five-year period (2015–2019).

Since phytoplankton respond very rapidly to environmental changes and grazing pressure from zooplankton, their key measurements fluctuate considerably from year to year, making consistent trends difficult to identify. Nevertheless, most phytoplankton biomass indicators have shown positive anomalies over the past decade, whereas they were predominantly negative before 2014 (Figure 2). Overall, phytoplankton biomass has been higher in recent years; however, this does not necessarily indicate increased production—it may instead reflect reduced zooplankton grazing.

In addition, 8 of the past 10 years have recorded negative anomalies in spring bloom timing, confirming a trend toward earlier blooms (Figure 2). As phytoplankton form the primary food source in the system, these shifts in phenology could influence energy transfer throughout the food web.

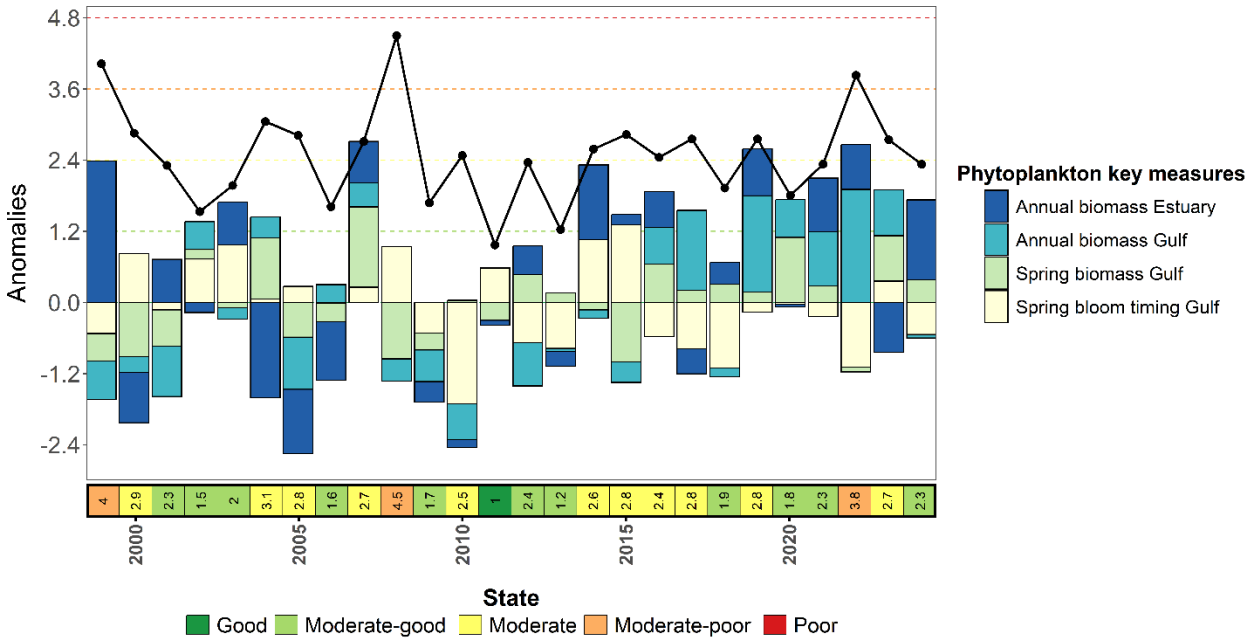

Figure 2. Time series of anomalies in key measurements of the Phytoplankton indicator in the Estuary and Gulf of St. Lawrence. The black line shows the sum of the absolute values of anomalies for all key measurement, enabling a status assessment ranging from Good (dark green) to Poor (red), based on the method outlined in the Key measurements section.

Toxic algae: Record bloom frequence in 2021

The toxic algae indicator status fluctuated between Good and Moderate–Poor from 2020 to 2024, resulting in an overall Moderate–Good rating for the entire period (Figure 3), consistent with the status observed in the previous five-year period (2015–2019). Note that large interannual variations in the abundance of certain toxic algae species also contribute to the variability in the overall indicator.

The *Alexandrium* spp. (*Alexandrium catenella, A. pseudogonyaulax, A. ostenfeldii*), dominated by *A. catenella*, produces saxitoxin and its derivatives responsible for paralytic shellfish poisoning. The abundance of this dinoflagellate increases significantly in the lower St. Lawrence estuary following heavy rainfall and river discharge; however, relatively dry summers over the past decade may account for the almost exclusively negative anomalies in key measurements associated with this species complex (Figure 3). Yet, it should be noted that an intensification of the hydrological cycle is expected in the coming decades in this region. Therefore, the current lull in *Alexandrium* abundance may represent only a temporary respite rather than a long-term trend.

In contrast, key measurements for the *Pseudo-nitzschia* spp. showed record positive anomalies in 2021, indicating that blooms of these diatoms reached unprecedented levels of intensity and frequency (Figure 3). This exceptional year for *Pseudo-nitzschia* was particularly evident in the St. Lawrence Seaway and Chaleur Bay. Unlike *Alexandrium*, *Pseudo-nitzschia* diatoms thrive in more saline and less stratified conditions, which prevailed in the lower St. Lawrence Estuary in 2021. However, the exceptional magnitude of the *Pseudo-nitzschia* blooms in 2021 remains poorly understood and warrants further investigation into the causes of this unprecedented event within the time series. Note that *Pseudo-nitzschia* blooms are not always highly toxic; they may be only mildly so, even though the dominant species is capable of toxin production. Therefore, despite the magnitude of anomalies observed in 2021, the actual toxic effects may have been less severe than the anomalies suggest. These events highlight the importance of ongoing monitoring of toxic algae and their toxicity in the Estuary and Gulf of St. Lawrence.

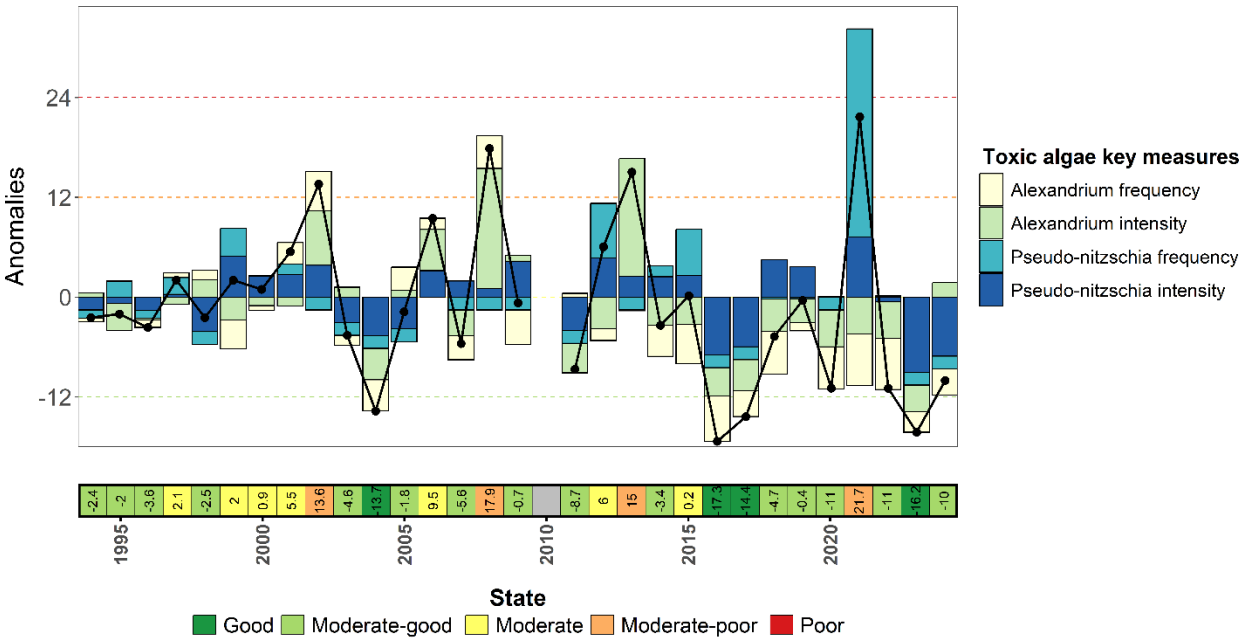

Figure 3. Time series of anomalies in key measurement of the toxic algae indicator in the Estuary and Gulf of St. Lawrence. The black line shows the sum of anomaly values across all key measurements, enabling a status assessment ranging from Good (dark green) to Poor (red), based on the method outlined in the Key measurements section.

Zooplankton: Declining biomass and early development of a key species

The zooplankton indicator was rated Poor for three years of the 2020–2024 period, resulting in an overall Poor rating for this period (Figure 4). Missing spring data in 2020 prevented the estimation of the key measure “Phenology of *Calanus finmarchicus*,” and consequently no status could be assigned for that year. Compared with 2015–2019, when the indicator was generally rated as Moderate, this period shows a clear deterioration (Figure 4).

This deterioration is largely due to strongly negative anomalies in *Calanus finmarchicus* phenology—indicating early development since 2021 at the Rimouski station in the estuary (Figure 4). As a dominant copepod with high energy content, *Calanus finmarchicus* plays a vital role in the St. Lawrence marine food web. However, changes in its life cycle affect prey availability for various species, as its size and depth in the water column vary by developmental stage.

Zooplankton biomass has also shown the most pronounced negative anomalies of the entire time series over the past four years (Figure 4). Since about 2010, zooplankton biomass anomalies have been mostly negative. However, until 2019, these were offset by positive anomalies in copepod and non-copepod abundance (Figure 4). This apparent contradiction reflects a shift in community composition toward smaller copepod species, characterized by lower biomass. From 2020 onward, copepod abundance and,

in 2023 and 2024, non-copepod abundance show negative anomalies, indicating an overall decline in individual numbers.

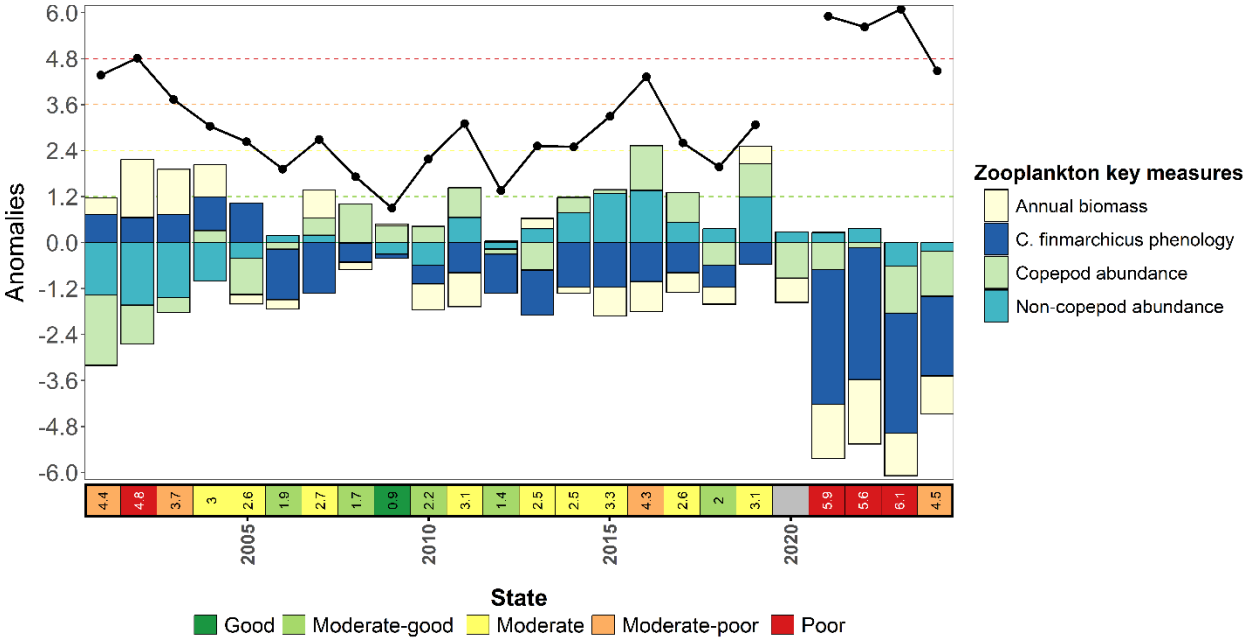

Figure 4. Time series of anomalies in key measurements of the zooplancton indicator in the Estuary and Gulf of St. Lawrence. The black line shows the sum of the absolute values of anomalies for all key measurements, enabling a status assessment ranging from Good (dark green) to Poor (red), based on the method outlined in the Key measurements section.

Outlook

For 2020–2024, plankton indicator ratings for the Estuary and Gulf of St. Lawrence ranged from Moderate for phytoplankton, Moderate–Good for toxic algae and Poor for zooplankton. The concerning status of zooplankton largely reflects shifts in the life cycle of a key species, *Calanus finmarchicus*.

Many environmental factors—including temperature, freshwater runoff and the timing of ice breakup—affect the dynamics of plankton communities as well as the risks of toxic algae blooms. Changes in plankton production can have consequences for recruitment processes in, and the productivity of, higher trophic levels, including commercially valuable species. These variations in plankton production dynamics, along with toxic algae blooms, combine with other environmental stressors, which have a direct impact on commercially valuable organisms, such as rising temperatures, hypoxia and ocean acidification.

For more information

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State of the St. Lawrence Monitoring Program

Five government partners—Environment and Climate Change Canada; Fisheries and Oceans Canada; Parks Canada; the Ministère de l'Environnement et de la Lutte contre les changements climatiques, de la Faune et des Parcs du Québec; and the Ministère des Ressources naturelles et des Forêts du Québec,—and Stratégies Saint-Laurent, a non-governmental organization that works actively with riverside communities, are pooling their expertise and efforts to provide Canadians with information on the state of the St. Lawrence and the long-term trends affecting it.

For more information about the State of the St. Lawrence Monitoring Program, please consult our website: https://www.planstlaurent.qc.ca/en/developing-knowledge/state-st-lawrence-monitoring-program.

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