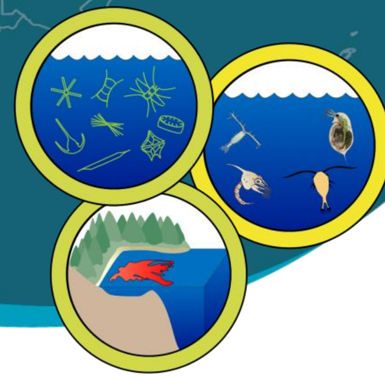
Monitoring the State of the
ST. LAWRENCE RIVER



Phytoplankton, toxic algae and zooplankton in the estuary and Gulf of St. Lawrence

Highlights

Phytoplankton and zooplankton communities in the estuary and Gulf of St. Lawrence remained fairly stable during the 2013–2017 period, according to two decades of monitoring. No significant anomalies were observed in phytoplankton biomass or composition during this period, although variability is high. However, a slight decline in zooplankton biomass was noted and its composition is changing, which could have repercussions on the food web. The prevalence of toxic algae blooms decreased slightly in the last four years.

Issues

Climate change and climate variability and their effects (e.g., warming waters, increased stratification and freshwater inflows, and ocean acidification) represent potential sources of disturbance to the marine environment. In 1999, Fisheries and Oceans Canada (DFO) established the Atlantic Zone Monitoring Program (AZMP) to better understand, describe, and track changes in oceanographic variables and to support the sustainable management of resources and activities. The aim of AZMP is to regularly collect data on such things as the biological variables at the base of the food chain—phytoplankton and zooplankton. Concomitant with the AZMP, the Toxic Algae Monitoring Program (TAMP), which is run by a team at Maurice Lamontagne Institute, monitors the occurrence of toxic and harmful algae at a network of coastal stations in the waters of the estuary and Gulf of St. Lawrence.

Study area

The AZMP data are acquired in twice-yearly sampling (in June and November) at stations along transects, as well as regular twice-monthly sampling (from April to November) at two high frequency stations in more accessible locations (Figure 1). These data are supplemented by toxic algae monitoring, sampled at coastal stations two to four times a month between May and October.

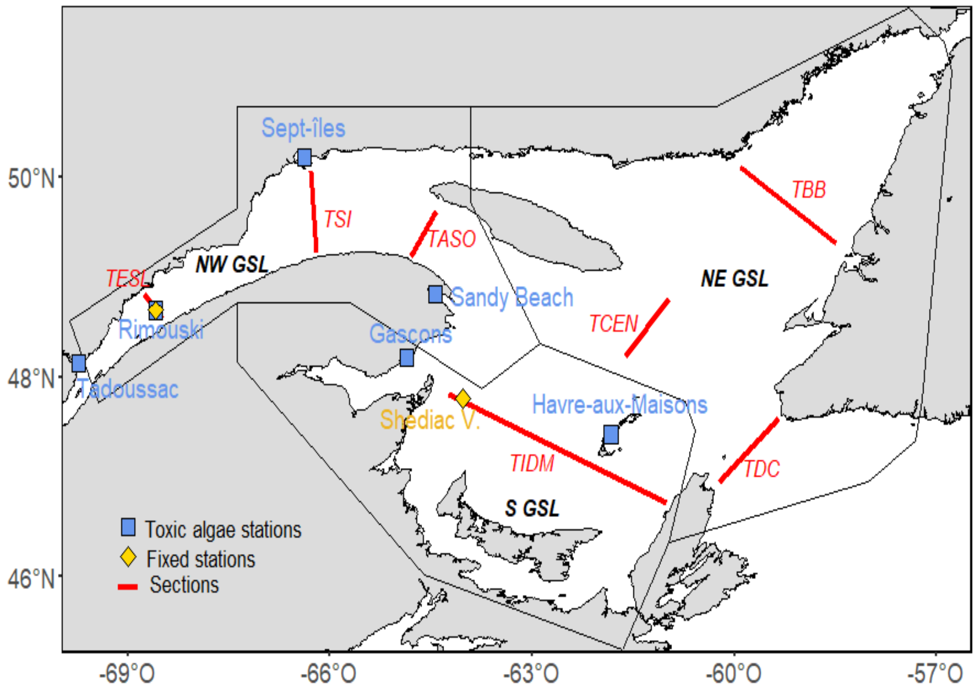
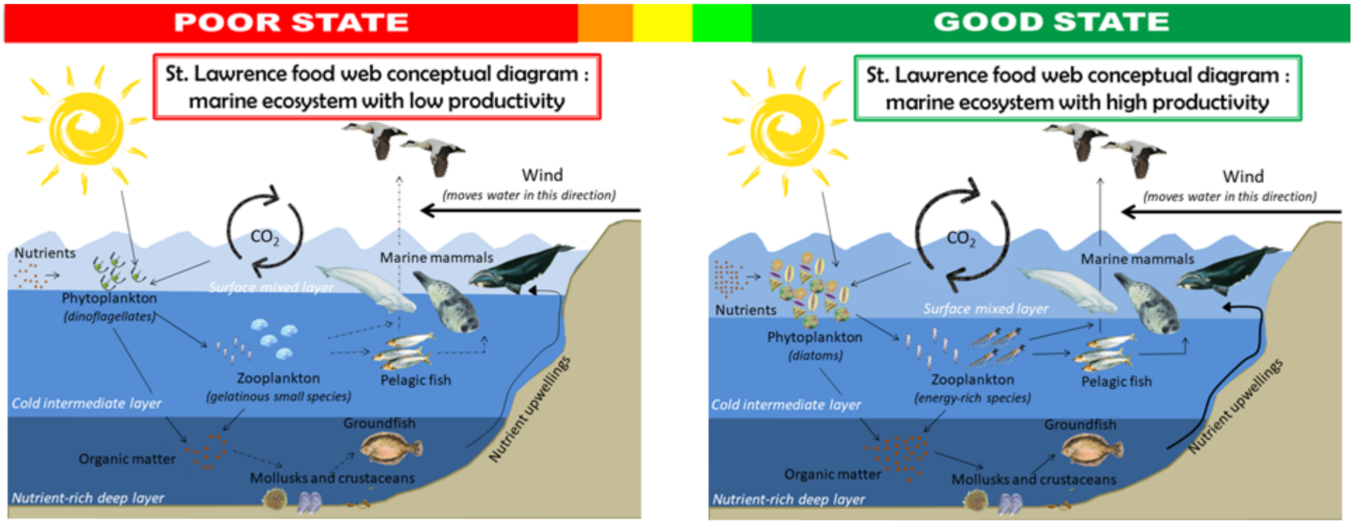


Figure 1. Locations of AZMP transects (red lines), AZMP high frequency stations (yellow diamonds) and TAMP stations (blue squares) in the estuary and Gulf of St. Lawrence. The black polygons represent the oceanographic subregions used for processing phytoplankton and zooplankton indicators (NW GLS = northwestern Gulf of St. Lawrence; NE GSL = northeastern Gulf of St. Lawrence; S GSL = southern Gulf of St. Lawrence).

Background



St. Lawrence marine ecosystem productivity might be altered if changes occur in plankton community composition. In this diagram, we assume that warming and high freshwater inputs increase water column stratification and reduce nutrient upwellings. In this highly-stratified system, small cells, typically flagellates, usually dominate phytoplankton assemblage. Some dinoflagellates species are toxic and could bloom under these conditions. Energy-rich large zooplankton species are replaced by smaller copepods and by gelatinous taxa, leading to the decrease of biomass available for higher trophic levels. Organic matter export to the deep layer is also reduced, what is likely to modify benthic foodweb. We consider that such an ecosystem will impact the productivity of the whole ecosystem even though how the trophic links will be modified is not exactly known (dotted arrows).

This system is considered as being representative of the historical state of the St. Lawrence marine ecosystem, according to data collected by the AZMP program since 1999. Under wind forcing, water column mixing brings nutrient from deep waters to the surface. These nutrients are consumed by large phytoplankton cells, diatoms, that form most of phytoplankton biomass in nutrient-rich and well-mixed marine ecosystems. Energy-rich zooplankton species, such as large calanoids (genus Calanus) as well as krill, feed on large phytoplankton cells. Krill is known to be the main food source for some baleen whales which visit the St. Lawrence ecosystem. The high productivity of the pelagic system leads to an important production of organic matter that will sustain a productive benthic foodweb. Thus, plankton is a key player in the determination of the whole ecosystem productivity. High-productivity ecosystems are more likely to sustain healthy fisheries than low-productivity ones.

Figure 2. Concept diagrams of a relatively unproductive versus a more productive food web in the estuary and Gulf of St. Lawrence.

Methodology

Under the AZMP, water samples taken with a CTD (conductivity, temperature and depth) rosette sampler (Figure 3) are used to measure phytoplankton biomass and determine its species composition. Water samples from the toxic algae stations enable counts of all algae species recognized as toxic, harmful or invasive to be performed. Phytoplankton biomass data are supplemented in all regions by ocean colour data acquired by satellite remote sensing, thus enhancing data acquisition abilities in this area. Zooplankton are sampled with vertical nets, with organisms then being weighed, counted and identified.

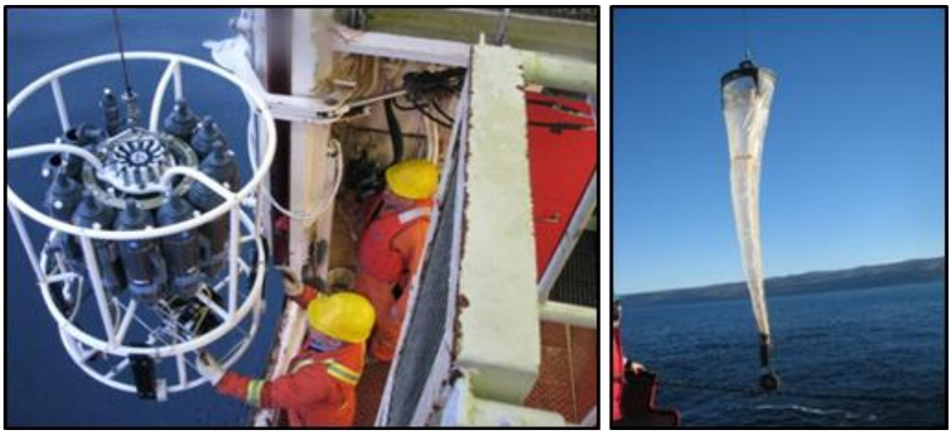


Figure 3. Water column sampling using a CTD rosette sampler (left) and zooplankton net (right). Both instruments are deployed from Canadian Coast Guard vessels. Photo: Fisheries and Oceans Canada, R. Pigeon and P. Galbraith, 2019.

To monitor the status of plankton indicators in the St. Lawrence (phytoplankton, toxic algae and zooplankton), various key measurements taken in the 2013–2017 period, identified in the next section, were compared with the values obtained for the same indicators during the 1999–2010 reference period (1994–2007 in the case of toxic algae). An annual anomaly value was calculated for each measurement. First, the difference between the value of the measurement for the year in question and the average value of the measurement during the reference period is obtained. This difference is then divided by the standard deviation for this parameter for the reference period, yielding a normalized anomaly. A negative (or positive) anomaly signifies that the value of the measurement for the year in question is less (or greater) than the average for the reference period. In biological oceanography, the direction of change (positive or negative) cannot be interpreted as being intrinsically “good” or “bad.” However, assuming that the aim is to preserve the ecosystem as it existed according to the historical data, any significant change (positive or negative) relative to its historical state can be considered “bad” and, conversely, the absence of significant change can be considered “good.” In the case of phytoplankton and zooplankton, the annual sum of the absolute values of anomalies for the key measurements for these taxa was used to determine the state of these communities in the estuary and Gulf of St. Lawrence. The same method was used to determine the rating for the toxic algae indicator. However, in the case of toxic algae, the direction of change can be interpreted as being either “good” or “bad.” Any change in the key measurements that indicates a reduction in the risk of toxic algae blooms (negative anomalies) was therefore considered "good." Since the direction of change must be taken into account in the calculations for toxic algae, the sum of the anomalies themselves rather than the sum of their absolute value was used to describe the state of the system.

Key measurements

Phytoplankton

- **Annual biomass** of phytoplankton estimated from the water samples taken at the high frequency stations.
- **Seasonal biomass** (spring, summer, fall) of phytoplankton estimated from remote sensing data.
- Ratios between the abundance of certain key phytoplankton groups, i.e., the **diatom/flagellate** and **diatom/dinoflagellate** ratios. These taxonomic groups are good indicators of environmental changes since they show a distinct response to environmental factors, particularly nutrient availability and water column stratification.
- The **spring bloom start date** estimated from remote sensing data. In spring, environmental conditions are ideal for phytoplankton production and cells proliferate rapidly. Generally, peak phytoplankton biomass occurs annually at this time. The spring bloom start date varies depending on environmental conditions and may influence the transfer of energy between primary producers (phytoplankton) and secondary producers (zooplankton).

Toxic algae

- **Frequency of *Alexandrium* spp. blooms** (*Alexandrium catenella* [formerly *A. tamarense], A. pseudogonyaulax, A. ostenfeldii*) (bloom defined as >1,000 cells/L). These blooms are known to cause Paralytic Shellfish Poisoning, or PSP, in the Gulf of St. Lawrence, producing saxitoxin and its many derivatives, which are the paralyzing toxins responsible for this type of poisoning.
- **Maximum cell density of *Alexandrium* spp.** observed during the year: an indication of bloom intensity
- **Frequency of *Pseudo-nitzschia* spp. blooms** (*P. pseudodelicatissima* and *P. seriata*) (bloom defined as 10,000 cells/L). These blooms are known to cause Amnesic Shellfish Poisoning, or ASP, in the Gulf of St. Lawrence, producing domoic acid, which is the amnesic toxin responsible for this type of poisoning.
- **Maximum cell density of *Pseudo-nitzschia* spp.** observed during the year: an indication of bloom intensity

Zooplankton

- **Annual dry biomass** of zooplankton collected in the nets. This parameter gives an indication of the quantity of energy that can be transferred to the higher trophic levels. The carbon weight of the large copepod species (those considered to be energy rich) can be two orders of magnitude greater than that of the smallest copepod species.

- **Total annual abundance of copepods** collected in the nets. This measurement, combined with the biomass measurement, enables changes in the size structure of the copepod community to be evaluated.
- **Annual abundance of warm-water species** collected in the nets. This key measurement, along with the following one, enables the direct impact of changes in water temperature on the species composition of zooplankton communities to be measured.
- **Annual abundance of cold-water species** collected in the nets

Overview of the situation

Phytoplankton

Results

In general, the indices for phytoplankton remained relatively stable, resulting in an overall rating of Moderate-Good for this indicator (Figures 4 and 5).

However, at the Rimouski station, diatom/dinoflagellate ratios in the past five years were significantly above the historical average, owing mainly to below-normal dinoflagellate abundance since 2013, hence the Moderate rating for the Rimouski station.

In the southern and northeastern Gulf of St. Lawrence, the spring bloom start date was highly variable, occurring either earlier or later than in the reference period. Although no clear trend was found, the variability was great enough that this index was rated Moderate for both subregions.

Lastly, satellite data show that, overall, phytoplankton biomass was lower throughout the Gulf in all three seasons compared to the reference period. However, the difference is small, and these indices were generally rated Moderate-Good.

Trends

A slight improvement in the overall trend was noted, considering that the overall rating was Moderate-Good for the current study period, compared to just Moderate for the 2008–2012 period. The previous report noted an increase in dinoflagellates, while the current data point to a decline in the abundance of this taxon at the Rimouski station.

In the northwestern Gulf region, all parameters are near the long-term average, helping to boost the overall rating.

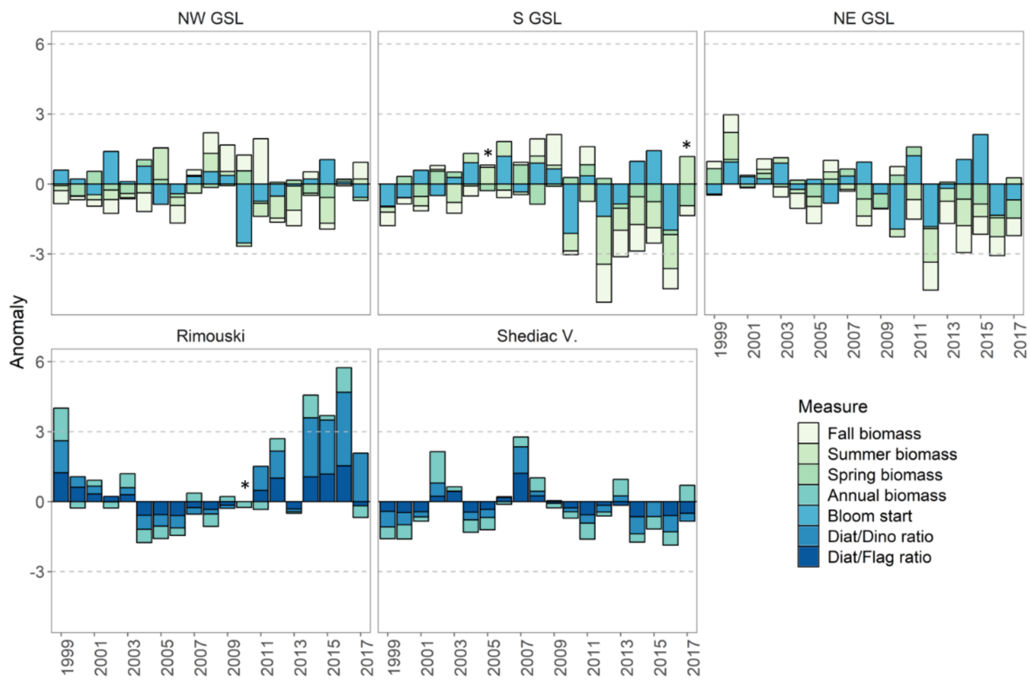


Figure 4. Annual anomaly observed for each key phytoplankton measurement relative to the 1999–2010 reference period. The measurements at high frequency stations included annual biomass and the diatom/flagellate and diatom/dinoflagellate ratios, while those in the oceanographic subregions included seasonal biomass (spring, summer and fall) and the spring bloom start date. Years in which certain key measurements were not available are indicated with an asterisk (*).

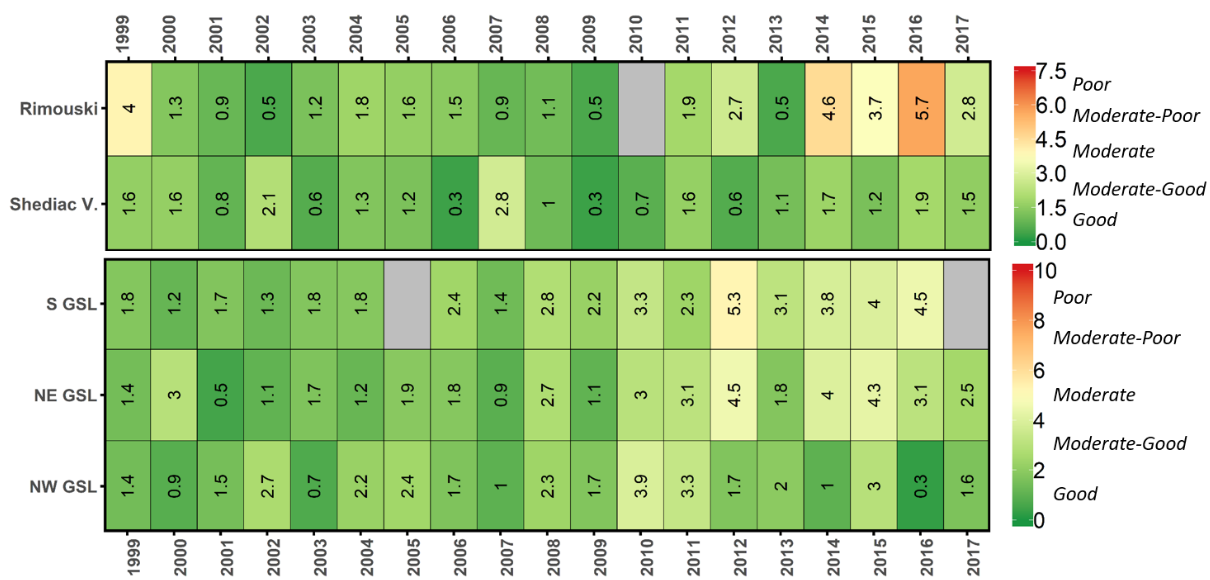


Figure 5. Sum of the absolute values of anomalies for all key phytoplankton measurements. This amount was not calculated when a key measurement was missing. Ratings were assigned to each region based on the average of the sum of anomalies in the last five years (2013–2017).

Toxic algae

Results

This indicator was rated Moderate-Good, with all the indices related to toxic algae showing roughly the same result (Figures 6 and 7).

Since 1994, large *Alexandrium catenella* (formerly *A. tamarense*) blooms have been observed in the lower estuary of the St. Lawrence in certain years (1998, 2002, 2006, 2008 and 2013). Although these blooms have been infrequent, a clear upward trend in their amplitude can be observed. Moreover, in 2012, *Pseudo-nitzschia* abundance in the estuary and Gulf was very much above the historical average, for the first time since 1994.

On the other hand, a sizeable positive anomaly of the maximum cell density of *Alexandrium* blooms was observed only once, in 2013, during the 2013–2017 period. The Moderate-Good rating assigned is due mainly to the frequency and amplitude of *Alexandrium* blooms, which were below the historical average in the last four years.

Trends

The Moderate-Good rating for toxic algae represents a slight improvement over the Moderate rating given in the 2008–2012 period. However, the improvement of this indicator in the last four years could represent a temporary phenomenon, rather than a long-term trend. The monitoring of toxic algae during the next few years will allow us to answer this question.

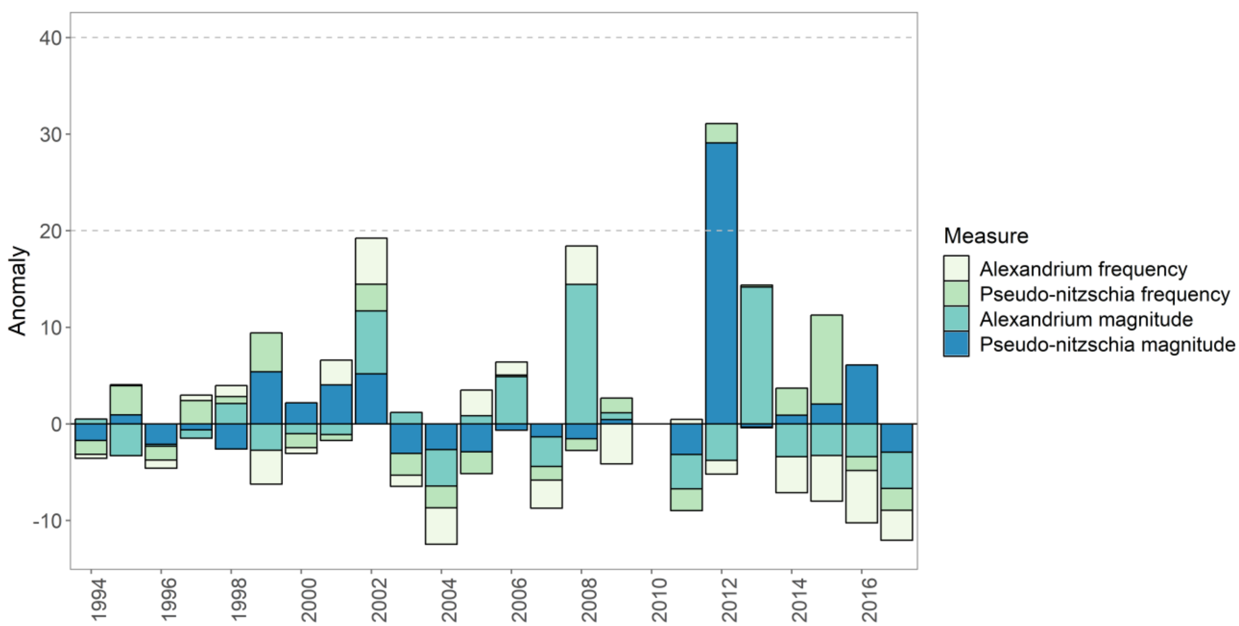


Figure 6. Annual anomaly observed for each key toxic algae measurement relative to the 1994–2007 reference period. Since regular sampling was not carried out in 2010, no indices were calculated for that year. For each key measurement, the sum of the anomalies at the six toxic algae monitoring stations was calculated.

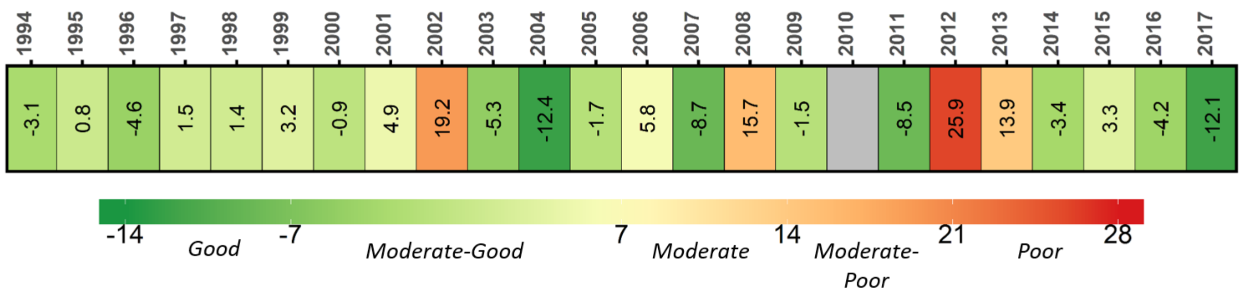


Figure 7. Sum of the anomalies for all the key toxic algae measurements. Ratings were assigned based on the average of the sum of anomalies for the last five years (2013–2017).

Zooplankton

Results

This indicator was rated Moderate owing to higher anomalies observed for a number of indices (Figures 8 and 9).

The main factor responsible for the Moderate rating was the substantial increase in the abundance of warm-water zooplankton species in the last five years compared with the 1999–2010 reference period. Increases were particularly sizeable at the Rimouski station and in the northwestern Gulf. Concomitant with the increased abundance of warm-water copepods, we observed a decrease in the abundance of cold-water copepods.

In the last five years, we also observed a decline in zooplankton biomass in all areas, accompanied by an increase in total copepod abundance. This finding is attributable to the change in the size structure of the zooplankton community. Indeed, the increased abundance of small copepods, coupled with a decreased abundance of large copepods, was noted. The increased abundance of small species exceeded the declines observed for large species. However, the biomass of small species is generally several orders of magnitude smaller than that of large species. Therefore, despite the greater total abundance of copepods, the quantity of food available for the higher trophic levels (i.e., zooplankton biomass) declined.

Trends

The trend remained unchanged from the previous overall rating of Moderate.

However, although the rating has remained the same, anomalies involving the abundance of warm-water species (positive) have tended to be greater during the last five years, mainly in the northwestern Gulf and at the Rimouski station.

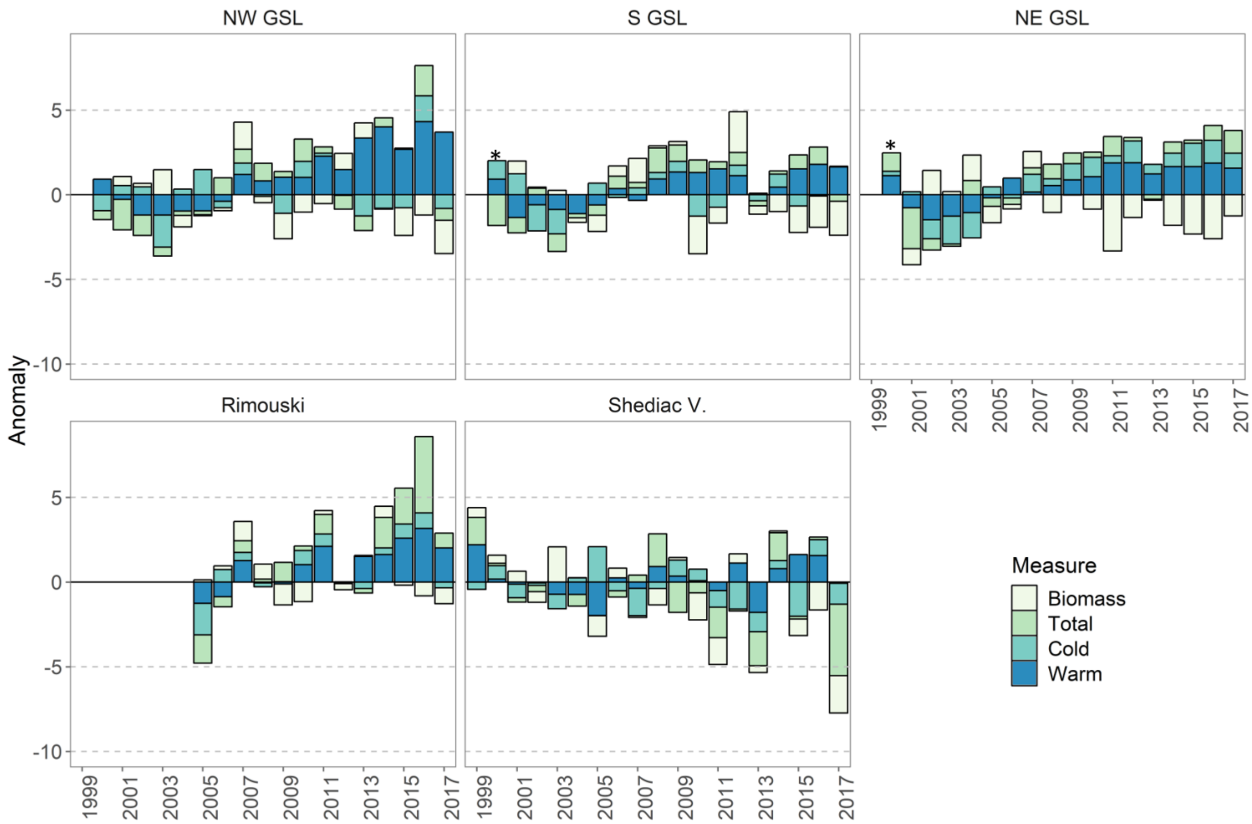


Figure 8. Annual anomaly observed for each key zooplankton measurement relative to the 1999–2010 reference period. Years in which biomass data were not available are indicated with an asterisk (*).

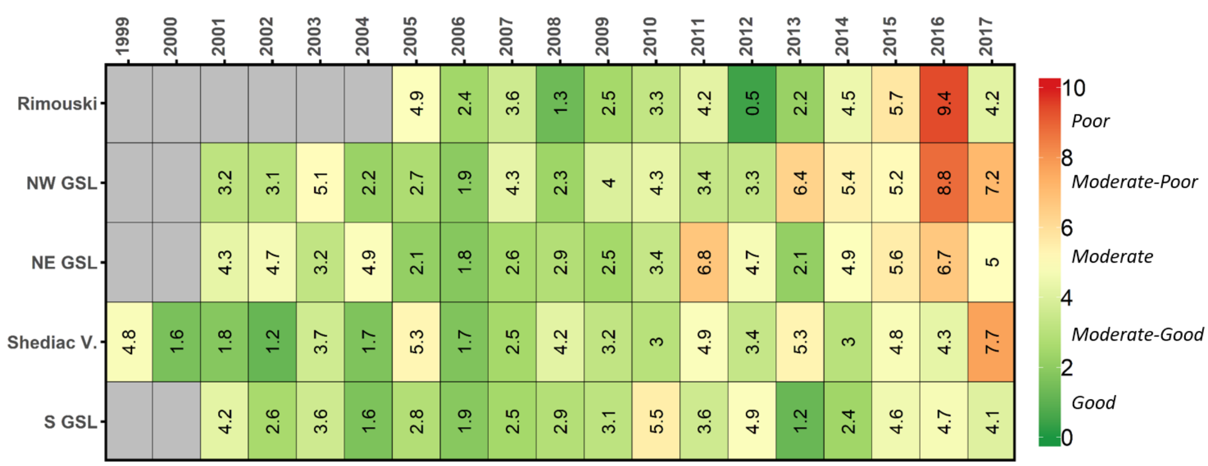


Figure 9. Sum of the absolute anomaly values for all key zooplankton measurements. This amount was not calculated when a key measurement was missing. Ratings were assigned to each region based on the average of the sum of anomalies in the last five years (2013–2017).

Outlook

Summary

Results for plankton indices in the estuary and Gulf of St. Lawrence range from Moderate-Good for phytoplankton and toxic algae to Moderate for zooplankton. However, a downward trend in plankton biomass was observed, particularly for zooplankton, along with a change in species composition. On a more positive note, the 2013–2017 period saw a letup in toxic algae blooms.

Causes and consequences

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 on 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 hypoxia and ocean acidification,.

To Learn More

BLAIS, M., GALBRAITH, P.S., PLOURDE, S., SCARRATT, M., DEVINE, L. and LEHOUX, C. 2019. Chemical and Biological Oceanographic Conditions in the Estuary and Gulf of St. Lawrence during 2017. DFO Can. Sci. Advis. Sec. Res. Doc. 2019/009. iv + 56 p.

STARR, M., et al. 2017. Multispecies mass mortality of marine fauna linked to a toxic dinoflagellate bloom. PLoS ONE 12(5): e0176299.

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 du Québec and the Ministère des Forêts, de la Faune et des Parcs 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, and long-term changes in, the St. Lawrence.

For more information on the State of the St. Lawrence Monitoring Program, please consult our website: http://planstlaurent.qc.ca/en/state_monitoring.html.

Written by

Marjolaine Blais
Maurice Lamontagne Institute, Fisheries and Oceans Canada

Cat. no.: En154-126/2021E-PDF
ISBN: 978-0-660-37119-1

Également disponible en français sous le titre : Le phytoplancton, les algues toxiques et le zooplancton de l'estuaire et du golfe du Saint-Laurent