

Chemical and Biological Oceanographic Conditions in the Gulf of St. Lawrence During 2025

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by

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ABSTRACT

Blais, M., Clay, S.A., Galbraith, P.S., Bourassa, M.N. 2026. Chemical and Biological Oceanographic Conditions in the Gulf of St. Lawrence During 2025. Can. Tech. Rep. Hydrogr. Ocean. Sci. 425 : vi + 92 p. <https://doi.org/10.60825/2tnm-4r87>

This report provides an overview of chemical and biological oceanographic conditions in the Estuary and Gulf of St. Lawrence in 2025 relative to long-term means, based on data from the Atlantic Zone Monitoring Program (AZMP) and regional programs. Oxygen saturation increased at all locations and depths compared with 2024, reaching near-normal levels across most of the central and eastern Gulf. Nitrate inventories were generally below normal throughout the water column, whereas phosphate and silicate were above normal in the deep layer in most regions. Vertically integrated chlorophyll *a* inventories and remote-sensing estimates of surface chlorophyll *a* both indicated that annual average phytoplankton biomass was generally near normal across the Gulf. Spring bloom timings were earlier than or near normal, while fall bloom timings were near or later than normal. Zooplankton biomass ranged from above normal in the southern Gulf to below normal in the central and eastern Gulf, and was near-normal in the Estuary and northwest Gulf. Record-high abundance of *Calanus finmarchicus* in the southern Gulf and very low levels of *Calanus hyperboreus* in the central and eastern Gulf largely explain this pattern. Small calanoid copepods, non-copepods, and warm-water copepods abundances were mostly below or near normal.

RÉSUMÉ

Blais, M., Clay, S.A., Galbraith, P.S., Bourassa, M.N. 2026. Chemical and Biological Oceanographic Conditions in the Gulf of St. Lawrence During 2025. Can. Tech. Rep. Hydrogr. Ocean. Sci. 425 : vi + 92 p. <https://doi.org/10.60825/2tnm-4r87>

Ce rapport présente un aperçu des conditions océanographiques chimiques et biologiques dans l'estuaire et le golfe du Saint-Laurent en 2025 par rapport aux moyennes à long terme, à partir des données du Programme de monitoring de la zone atlantique (PMZA) et de programmes régionaux. La saturation en oxygène a augmenté à toutes les stations et à toutes les profondeurs par rapport à 2024, atteignant des niveaux près de la normale dans la majeure partie du centre et de l'est du golfe. Les inventaires de nitrate étaient généralement inférieurs à la normale dans l'ensemble de la colonne d'eau, tandis que le phosphate et le silicate étaient supérieurs à la normale dans la couche profonde à la plupart des stations. Les inventaires de chlorophylle *a* intégrés verticalement et les estimations satellitaires de la chlorophylle *a* de surface indiquaient tous deux que la biomasse de phytoplancton annuelle moyenne était généralement près de la normale dans l'ensemble du golfe. Les floraisons printanières étaient plus hâtives que la normale ou près de la normale, tandis que les floraisons automnales étaient plus tardives que la normale ou près de la normale. La biomasse de zooplancton était au-dessus de la normale dans le sud du golfe, en dessous de la normale dans le centre et l'est du golfe, et près de la normale dans l'estuaire et le nord-ouest du golfe. Une abondance record de *Calanus finmarchicus* dans le sud du golfe et des niveaux très faibles de *Calanus hyperboreus* dans le centre et l'est du golfe expliquent en grande partie ces anomalies. Les petits calanoïdes, les non-copépodes et les copépodes d'eaux chaudes présentaient des abondances généralement inférieures ou près de la normale.

1. INTRODUCTION

The Atlantic Zone Monitoring Program (AZMP) was implemented in 1998 (Therriault et al. 1998), with the aim of 1) increasing Fisheries and Oceans Canada's (DFO) capacity to understand, describe, and forecast the state of the marine ecosystem, and 2) quantifying the changes in the ocean's physical, chemical, and biological properties. AZMP provides data to support the sound development of ocean activities. A critical element of the AZMP observational program is the annual assessment of the distribution and variability of physical, chemical and biological properties of the water column. This report focuses on oxygen, nutrients, and plankton communities.

A description of the spatiotemporal distribution of nutrients (nitrate, silicate, and phosphate), and chlorophyll *a* (chl *a*) concentrations provides important information on biogeochemical cycling, water mass movements and on the location, timing, and magnitude of biological production cycles. A description of the phytoplankton and zooplankton communities, distributions and phenologies provides important information on the organisms forming the base of marine food webs. Biogeochemical and plankton production cycles play a pivotal role in supporting healthy marine ecosystems, and their understanding is crucial for an ecosystem approach to fisheries management.

The AZMP assesses the state of the marine ecosystem from *in situ* data collected at a network of sampling locations (high-frequency monitoring stations, cross-shelf sections) in each DFO region (Québec, Gulf, Maritimes, Newfoundland and Labrador; see Figure 1 for section locations in the St. Lawrence Gulf and Estuary) visited at a frequency of weekly to annually (Galbraith et al. 2026a), complemented by satellite remote-sensing products. The sampling design of the zonal AZMP provides valuable information on the natural variability in physical, chemical, and biological properties of the Northwest Atlantic continental shelf. Cross-shelf sections and ecosystem trawl surveys provide a broad-scale overview of the conditions but are limited in their seasonal coverage. Strategically located high-frequency monitoring stations complement the sampling by providing more detailed information on seasonal-scale changes in ecosystem properties. In recent years, automated oceanographic buoys have also complemented core observations, with high temporal resolution data.

Changes in the physical properties of the pelagic environment influence both plankton community composition and annual biological production cycles, with implications for the energy transfer to higher trophic levels. In this document, we only review the chemical and biological oceanographic conditions in the Estuary and Gulf of St. Lawrence in 2025. Readers should refer to Galbraith et al. (2026b) for a complete description of the physical conditions that prevailed in the Estuary and Gulf in 2025. For conciseness, the term Gulf is used to refer to the entire St. Lawrence Estuary and Gulf thereafter in the document.

2. METHODS

2.1 SAMPLING

All sample collection and processing steps meet the standards of AZMP protocols (Mitchell et al. 2002). Field measurements included in this report were collected during dedicated AZMP surveys carried out in winter, early summer, and fall (generally in March, June, and October) of each year, and at two high-frequency monitoring stations (Figure 1). Additional measurements

made during ecosystemic surveys (August and September; hereafter referred to as late summer surveys) (Chamberland et al. 2025; Savoie et al. 2014), and during the mackerel egg survey (June) were included for all years for which data are available (i.e. 2006–2025). In this document, stations were grouped into four main regions for which chemical and biological indices are presented (Figure 1):

- (1) Estuary/northwest Gulf: this region is generally deep (> 200 m) and cold at the surface in summer. It is strongly influenced by freshwater runoff from the St. Lawrence River, by upwelling/mixing of cold intermediate (CIL) waters, and by dense waters inflowing along the Laurentian Channel in deeper waters;
- (2) Northeast Gulf: this region, with deep channels and a relatively wide shelf (shallower than 100 m), is characterized by relatively high surface salinity (> 30 PSU);
- (3) Central Gulf/Cabot Strait: this region is generally deep (> 200 m), and is directly influenced by deep waters that mix at the continental slope (warm North Atlantic Central Water that has a Gulf Stream signature and cold Labrador Current water) and enter the Gulf through Cabot Strait;
- (4) Magdalen Shallows: this region is shallow (<100 m) and warm at the surface in summer. It is largely influenced by the Gaspé Current, which carries low-salinity surface waters from the St. Lawrence Estuary.

These regions are consistent with those used for the DFO Ecosystem Approach to Fisheries Management ([EAFM](#)). Due to sparse data, biogeochemical indices are not reported for Mécatina Trough and Northumberland Strait (Figure 1).

Table 1 lists the 2025 sampling surveys and Figure 2 and Figure 3 summarize the sampling effort during the seasonal surveys and at the high-frequency monitoring stations, respectively. Rimouski station (depth 320 m) has been sampled since 1991—about weekly throughout the summer, once or twice a month in early spring and late fall, and rarely in winter (except during the March survey) due to the presence of sea ice. It is representative of conditions in the Estuary/northwestern Gulf. In 2025, Rimouski station was visited on 26 occasions. Shediac Valley station (depth 84 m) is representative of conditions on the Magdalen Shallows and of the Estuary outflow. Shediac Valley station is at best sampled once monthly between May and November, with little to no coverage from December through April, except during the March survey. Shediac Valley station was visited six times in 2025; however, no visit occurred in July or November. Given the limited number of observations at this station in recent years, annual anomalies and seasonal patterns should be interpreted with caution. In addition to the occupations at the high-frequency monitoring stations, automated oceanographic buoys, which provide surface fluorescence (data collected every 30 minutes), have been deployed at the high-frequency stations since 2002 and 2004 at Rimouski and Shediac Valley stations, respectively. Buoys are typically deployed in late April/early May, and recovered in late October/early November.

Sampling along the oceanographic sections and at the high-frequency monitoring stations includes a Conductivity-Temperature-Depth profile (CTD; temperature, salinity, fluorescence, dissolved oxygen) as well as discrete water sampling using Niskin bottles at multiple depths (~ 2 m, 10 m, 15 m, 25 m, 50 m, 100 m, 200 m, 300 m, 400 m, bottom). Water from the Niskin bottles is collected for the analysis of dissolved oxygen (Winkler method), nutrients (Seal

Analytical AutoAnalyzer 3 or Alpkem AutoAnalyzer), chl *a* concentration (fluorometer), and phytoplankton enumeration (inverted microscopy) (Mitchell et al. 2002). Finally, mesozooplankton (<1 cm, hereafter referred to as zooplankton) is collected with bottom-to-surface vertical ring net tows (75 cm diameter, 200 μ m mesh) for most surveys. During AZMP surveys (early summer and fall), zooplankton nets are typically collected only at section stations. In 2025, approximately ten additional nets were collected at supplementary stations outside the main sections to improve biomass and abundance distribution maps, but were excluded from regional seasonal and annual averages to maintain consistency with the long-term time series. Taxonomists are responsible for the identification, enumeration, and bulk biomass (dry weight) measurements of zooplankton samples collected during regular AZMP surveys (early summer and fall surveys) and the September southern Gulf ecosystemic survey. Zooplankton samples collected during the August ecosystemic survey and mackerel egg survey are processed semi-automatically using the ZoolImage 5.5.2 software package (Grosjean et al. 2018), following the methodology described in Plourde et al. (2019) and Blais et al. (2023). Since methods are different, and considering the larger mesh size of nets deployed during the mackerel egg survey (333 μ m mesh), which prevents the capture of early copepodite stages (CI–CIII, and up to CIV for small species; Nichols and Thompson 1991), ZoolImage derived indices are excluded from annual abundance estimates. September survey results, limited to the Magdalen Shallows and based on a different set of stations each year, are also reported separately and excluded from the annual indices.

2.2 IN SITU METRICS

2.2.1 Oxygen

Oxygen concentration profiles are used to monitor hypoxic conditions in the Gulf. Oxygen concentrations were measured using a Sea-Bird SBE43 probe mounted on the CTD and calibrated against seawater samples, collected from most casts, and analyzed by Winkler titration (for the calibration procedure, see [Sea-Bird application notes 64-1, -2, -3](#)). Spatial interpolation was performed on a gridded 2 km x 2 km fields using the inverse-distance-weighted (IDW) interpolation implemented in the R package *gstat* (Pebesma 2004). The resulting gridded fields were then averaged within each region and season to estimate annual averages and anomalies.

2.2.2 Nutrients and phytoplankton

Nutrient and chl *a* concentrations (a proxy for phytoplankton biomass) collected along the AZMP sections and at high-frequency monitoring stations were depth-integrated (i.e., 0–50 m, 50–150 m, and 150 m–bottom for nutrients; 0–100 m for chl *a*) using the trapezoidal method. In 2016 and 2017, winter vertical profiles of nutrients across the Gulf revealed that nutrient concentrations were relatively homogeneous in the upper 50 m of the water column. Therefore, for typical years when vertical nutrient profiles are not available, including 2025, winter nutrient inventories 0–50m were estimated using surface concentrations, assuming the nutrient concentrations were uniform in the mixed layer. Spring nutrient drawdown was estimated as the difference between the March and June nitrate inventories (0–50 m), and is used as a proxy for phytoplankton spring production since the early summer sampling occurs after the spring bloom. Phytoplankton abundance and taxonomic identification are performed for the high-frequency monitoring stations, and have been since the beginning of the program, and since 2014 across the Gulf of St Lawrence. For the Shediac Valley time series, counts were performed by two different taxonomists throughout the time series. Overlapping counts enabled the estimation of

correction factors to align the counts between taxonomists. Annual mean counts are based on the first taxonomist from 1999 to 2015, both taxonomists from 2016 to 2023, and the second taxonomist since 2024.

2.2.3 Zooplankton

Since zooplankton samples are generally collected over the entire water column (or 0–50 m during the mackerel egg survey), zooplankton indices represent depth-integrated metrics. Only taxonomist-analyzed samples collected during early summer and fall AZMP surveys were included in the calculation of regional zooplankton annual means and anomalies. Appendix 1 lists species included in each copepod index. *Calanus finmarchicus* and *C. glacialis* are distinguished based on prosome length, with species-specific length ranges refined using genetic identification (Parent et al. 2011).

We used the time series at Rimouski station to describe *C. finmarchicus* phenology as adequate sampling and stage identification started 30 years ago. Zooplankton sampling at Rimouski station prior to 2005 and the use of AZMP standard nets (*i.e.*, 75-cm diameter, 200- μ m mesh bottom-to-surface ring net tows; Mitchell et al. 2002) is described in Blais et al. (2024). The phenology of *C. finmarchicus* was characterized using the following steps: (1) stage-relative abundances were normalized (proportion of a copepodite stage/maximum proportion for the stage) within each year for CI–III, CIV, CV, and CVI (male and female) and (2) stage proportions were smoothed using a LOESS function (locally estimated scatterplot smoothing).

2.3 SATELLITE REMOTE SENSING OF OCEAN COLOR AND BLOOM METRICS

Satellite ocean colour data provide large-scale images of chl *a* concentrations, a proxy for surface phytoplankton biomass. Daily satellite composite images within four ocean colour polygons (northwest Gulf, northeast Gulf, Magdalen Shallows, and Cabot Strait; Figure 4) supplement our ship-based observations, especially regarding the spring bloom phenology, and provide seasonal coverage and a large-scale context for interpreting survey data. However, since ocean colour imagery only provides surface coverage (*i.e.*, a few metres at best), it should be used as complementary information to the *in situ* survey data.

Surface chl *a* concentrations were derived from daily composites of satellite images of remote sensing reflectance (4 km spatial resolution) obtained from the Ocean Colour Climate Change Initiative (OC-CCI, 1998–2025) dataset, provided by the Plymouth Marine Laboratory as part of the European Space Agency (ESA) climate change initiative. These composites were converted to chl *a* concentration using the POLY4 algorithm, with coefficients tuned to the Gulf of Saint Lawrence (Clay et al. 2019, Clay 2025). This dataset integrates observations from multiple satellite sensors (*e.g.*, SeaWiFS, MODIS, VIIRS), thereby extending the time series back to 1998 and improving spatial and temporal coverage compared to previous reports that relied solely on data from NASA’s Moderate Resolution Imaging Spectroradiometer (MODIS) “Aqua” sensor, launched in July 2002. By enhancing regional coverage, the use of the OC-CCI product also improves the accuracy of bloom estimates (Sathyendranath et al. 2019).

Characteristics of phytoplankton blooms, including their timing and intensity, are reported here. The timing of the spring phytoplankton bloom was determined by fitting a shifted Gaussian function to the LOESS-smoothed daily chl *a* averages (Zhai et al. 2011), whereas fall bloom

timing was determined using the threshold method described in Layton et al. (2022). To characterize spring and fall bloom intensities, as well as phytoplankton production during other seasons, seasonal chl *a* averages are also presented. Details on the methods and parameters used for the Gaussian fits are provided in Appendix 2.

All ocean-colour polygons are located outside of the St. Lawrence River plume because satellite-based chl *a* concentration estimates in such areas are unreliable due to contamination by river inputs loaded with coloured matter of terrestrial origin. For the same reason, polygons exclude areas within 1 km of the coast, and areas within 5 km of strong freshwater influence. This also explains why spring bloom metrics in the Estuary cannot be derived from ocean colour data. However, high-temporal-resolution information on the phytoplankton dynamics at the surface of the Estuary is available from the surface fluorescence sensor on the oceanographic buoy located at Rimouski station and presented in this document. To increase the accuracy of daily chl *a* concentration estimates, buoy sensor data were screened to exclude daytime measurements (which may be biased by high light intensity effects on phytoplankton pigments) and daily outliers (± 3 SD). The cleaned dataset was $\log_{10}$ -transformed and then calibrated against weekly *in situ* chl *a* concentrations measured at Rimouski station using a linear regression ($R^2 = 0.36$, $p < 0.001$, $n = 1517$).

2.4 ANNUAL ANOMALY SCORECARDS

Standardized anomalies for the chemical and biological indices presented in scorecards were computed for the high-frequency monitoring stations and regions. These anomalies are calculated as the difference between the variable's average for the season or for the complete year and the variable's climatological mean (usually 1999–2025); this number is then divided by the standard deviation over the climatological period. The climatology used this year represents a 5-year extension relative to the previously used climatology that ended in 2020. While this tends to increase standard deviation, it also generally reduces the amplitude of anomalies.

Anomalies are presented as scorecards, with positive anomalies depicted as shades of red, negatives as blues, and anomalies within ± 0.5 SD as white (considered as normal conditions, *i.e.*, similar to the climatology). A standard set of indices representing anomalies of oxygen saturation, nitrate inventories in the mid-layer (50–150 m), phytoplankton biomass and bloom dynamics, mesozooplankton biomass, and the abundance of dominant mesozooplankton species, and groups (*C. finmarchicus*, *Pseudocalanus* spp., total copepods, and total non-copepods) are produced for each AZMP region (Casault et al. 2025; Bélanger et al. 2025). To visualize Northwest Atlantic shelf-scale patterns of environmental variation, a zonal scorecard including observations from all AZMP regions is presented in Galbraith (2026a).

Annual nutrient, phytoplankton, and zooplankton index anomalies are based on the mean annual inventory (mmol m^{-2} for nutrients, $\text{mg chl } a \text{ m}^{-2}$ for phytoplankton biomass), density (cells L^{-1} for phytoplankton abundance, $\text{individuals m}^{-2}$ for zooplankton abundance), or biomass (g m^{-2} for zooplankton biomass), estimated at both high-frequency monitoring stations and in all Gulf regions of Figure 1. These annual estimates are derived from general linear models (GLM) of the form:

$\text{Log}_{10}(y) = \alpha + \beta_{\text{YEAR}} + \delta_{\text{MONTH}} + \varepsilon$ for the high-frequency monitoring stations, and

$\text{Log}_{10}(y) = \alpha + \beta_{\text{YEAR}} + \delta_{\text{STATION}} + \gamma_{\text{SEASON}} + \varepsilon$ for the regions,

Where y is the response variable, either expressed as inventory or density, α is the intercept, and ε is the error (following a gaussian distribution). The GLM is applied to each region separately. For the high-frequency monitoring stations, β and δ are the categorical effects for

year and month, respectively. For the regions, β , δ , and γ are the categorical effects of year, station, and season, respectively. We $\log_{10}$ -transformed inventories and density values before computing anomalies to compensate for the skewed distribution of observations. We added one unit to *Density* terms for the abundance indices (phytoplankton and zooplankton counts) to account for observations with values of zero. An estimate of the least-square means based on type III sums of squares is used as an estimate of the annual average. Results of the GLM (significance of each factor and adjusted coefficients of the regression) are presented in Appendices 3 to 7. Four seasons (winter, early summer, late summer, and fall) are included in the GLM to estimate the annual average of surface nutrient inventories; three seasons are used to estimate the annual average of deeper nutrient inventories and phytoplankton indices (no data collection during winter); and two seasons (early summer and fall) are used to calculate annual estimates of zooplankton indices. Zooplankton data collected during mackerel egg survey or late summer surveys are presented separately, and their time series are based on seasonal arithmetic means.

To test whether trends over the entire Gulf were significant over the time series for some indices, Gulf-wide annual mean anomalies were calculated as area- or volume-weighted averages of regional anomalies. The weighting factors corresponded to the surface area or water volume of each region, depending on whether the variable was expressed per unit area (m^{-2}) or per unit volume (m^{-3}). Linear regression was applied when its assumptions were met; otherwise, the non-parametric Mann–Kendall test was used to assess trend significance. Tested trends and their results are presented in Appendix 8.

3. OBSERVATIONS

3.1 DEEP OXYGEN

3.1.1 Rimouski station

Hypoxic waters (i.e., <30% saturation) were observed as shallow as 125 m in mid-April 2025 at Rimouski station (Figure 5), approximately 40 m shallower than the shallowest hypoxic depth recorded over the past decade. The hypoxic boundary then oscillated around 170 m until November, when hypoxic waters were only found at 190 m and below. Except in April, severely hypoxic waters (i.e., <20% saturation) remained confined below 200 m throughout 2025 (Figure 5). This shoaling of hypoxic waters relative to the climatology is reflected in strong negative oxygen anomalies between approximately 100 m and 250 m depth during the first half of the year. In August, intrusion of better-ventilated waters deeper into the water column produced a positive anomaly at intermediate depths (Figure 5). Near-bottom oxygen levels were consistently near normal throughout the year (Figure 7). Monthly mean oxygen saturation in the bottom layer (270–320 m) at Rimouski station ranged from 18.3% in April to 14.4% in November, which is 3 to 6 percentage points above the 2024 monthly averages (Figure 6). This also represented a return to near-normal conditions in spring and early summer, followed by weak negative anomalies thereafter. Such neutral to weak anomalies had not been observed since 2019 (Figure 6).

3.1.2 Gulf regions

In the Gulf, the lowest oxygen saturation levels are below 15% saturation at 300 m in recent years, and they are observed in the deep waters of the Estuary (Figure 7). At 300 m, hypoxic waters extended along the channel from the Estuary to the centre of Anticosti Island (Figure 7).

Hypoxic waters were nearly absent from the Anticosti and Esquiman channels in 2025, whereas they have been a common feature at the head of these channels since 2020. Detailed vertical profiles along the Laurentian Channel show a clear vertical expansion of the severely hypoxic water mass (<20% saturation) in the Estuary relative to the climatology (Figure 8). However, this water mass did not extend beyond the Estuary, whereas it used to cover the bottom waters of the northwest Gulf in recent years. In the northeast Gulf, only the deepest part of the Esquiman Channel contained hypoxic waters near 300 m (Figure 9 and Figure 10).

There has been a major increase in both the area and the volume covered by hypoxic waters in the Gulf since 2015, with record-high values observed in 2023 (Figure 11). Bottom area and volume of hypoxic (<30% O₂ saturation) and severely hypoxic (<20%) waters in the Gulf of St. Lawrence, 2002–2025 (left panels). The right panels present the proportion of total Gulf area and volume deeper than 100 m affected by these conditions. The area and volume estimated in 2025 therefore represent a decrease from these record highs, but in different proportions. The decrease in hypoxic water area (approximately 35%) is larger than the decrease in volume (approximately 25%). Similarly, the area and volume of severely hypoxic waters across the Gulf decreased in 2025 relative to their record highs in 2023 and 2024, respectively (Figure 11).

3.1.3 Scorecard

Annual mean saturation levels in 2025 were above those measured in 2024 at almost all depths across the Gulf (Figure 12). In the northeast Gulf (i.e. Esquiman and Anticosti), central Gulf, and Cabot Strait, saturation levels returned to normal or above normal, for the first time since the late 2010s in some instances. Anomalies remained negative in the Estuary and the northwest Gulf, though weakly so in most cases. The strongest negative anomalies were recorded at 200 m (Figure 12). Oxygen saturation in the relatively shallow bottom waters of the Magdalen Shallows mainly remained above 80% throughout the time series (Figure 12). In the deep waters of the Estuary, the least oxygenated waters of the St. Lawrence system, annual average dissolved oxygen saturation levels in the Estuary were 16% (50 µM) at 300 m, and 26% (84 µM) in bottom waters (> 100 m) in 2025 (Figure 12).

3.2 NUTRIENTS

Distributions of dissolved inorganic nutrients (nitrate, silicate, phosphate) strongly co-vary in space and time (Brickman and Petrie 2003). For this reason, and because nitrogen availability controls phytoplankton growth in coastal waters of the Gulf, emphasis in this document is given to the variability in nitrate concentrations and inventories, even though the distributions of other nutrients are also briefly discussed. In this document, we use the term “nitrate” to refer to the sum of nitrate and nitrite (NO₃⁻+NO₂⁻).

3.2.1 High-frequency monitoring stations

The two high-frequency monitoring stations typically exhibit a seasonal cycle of surface nitrate inventories: a spring/summer drawdown linked to biological uptake, a summer minimum, and a subsequent increase during fall/winter once water column mixing intensifies due to cooling processes and wind forcing (Figure 13). Seasonal stratification and mixing, together with remineralization processes, influence mid-layer nitrate inventories, which tend to increase during the summer months as stronger stratification reduces exchange with the surface layer (Figure 13). Surface and mid-layer nitrate inventories at Rimouski station are typically two to three times higher and about four to five times higher, respectively, than those at Shediac Valley station (Figure 13).

In 2025, the surface nitrate inventory at Rimouski station was primarily near normal, with a major exception in November when it was strongly below normal (Figure 13). Vertical nitrate profiles show that surface nitrate depletion only became visible from mid-June onward, approximately two weeks later than normal (Figure 14). They also confirm strong nitrate depletion in the upper 70 m of the water column in November, when stratification was lower than normal (see Figure 67 in Galbraith et al. 2026b). The mid-layer nitrate inventory was below normal during most of the year, and was above normal only in April and early May, and again during one sampling in early October (Figure 13). Except for some pockets of above-normal or near-normal anomalies around 100 m depth associated with nitrate replenishment from the deep layer, waters below 50 m showed negative nitrate anomalies throughout the year (Figure 14).

At Shediac Valley station, surface and deep nitrate inventories mostly ranged from below to near normal (Figure 13). Nitrate depletion was observed down to 60 m in early June and was associated with a strong negative anomaly between 40 m and 60 m (Figure 14).

3.2.2 Gulf regions

The winter surface nitrate inventories are calculated from the samples collected at ~2 m depth, assuming that concentrations are uniform over the 0–50 m layer. The spatial distribution of nitrate in the surface layer during winter 2025 was similar to the climatology, with maximum inventories in the Estuary and around the Gaspé Peninsula (Figure 15). However, the plume of elevated nitrate inventories ($> 400 \text{ mmol m}^{-2}$) did not extend as far into the western Magdalen Shallows as usual, resulting in a strong negative anomaly at that location. Strong negative anomalies were also found in the Estuary and near the Strait of Belle-Isle, while most of the Gulf showed weakly negative or neutral anomalies. A positive anomaly was observed near western Anticosti Island. The estimated nitrate drawdown during spring, and by extension the expected spring bloom intensity, was spatially variable (Figure 15). Drawdown was greatest where March nitrate surface inventory was above normal, and lowest where strong negative anomalies occurred.

Surface layer nitrate inventories remained generally below normal throughout the remainder of the year in most of the Gulf (Figure 16–18). However, during late summer, a plume of nitrate-rich surface waters extending from Chaleurs Bay to the northern Magdalen Shallows led to positive nitrate anomalies in these areas (Figure 17). Strongly above-normal nitrate levels were also observed in the surface layer near the Bay of Islands, on the western coast of Newfoundland, during the same season. Mid-layer nitrate inventories were also mostly below normal throughout the year, although the anomalies were generally weaker than in the surface layer and more often approaching near-normal levels (Figure 16–18). Deep nitrate inventories shifted from being mostly above normal in early summer to predominantly below normal in fall, similar to conditions observed in 2024 (Blais et al 2025). Late summer showed mostly near-normal levels accompanied by positive anomalies in the northwestern Gulf and at the head of the Esquiman Channel (Figure 16–18).

3.2.3 Scorecards

Annual mean surface layer nutrient inventories were below normal in the northeast Gulf and the central Gulf/Cabot Strait region, and near normal elsewhere (Figure 19). There is a significant decrease in annual mean surface-layer nitrate inventories across the Gulf over the time series (Appendix 8; Kendall's $\tau = -0.56$, $p < 0.0001$), with the average inventory over the 2010–2025 period being approximately 20% lower than during 1999–2009. In the mid-layer, nitrate

inventories were below normal across the Gulf, while phosphate and silicate inventories were near normal or slightly below normal, resulting in below-normal N:P ratios across the Gulf and record lows at Rimouski station and in the Estuary/northwest Gulf region (Figure 20). In the deep layer, the contrasting pattern among nutrients was even more pronounced; nitrate showed strong negative anomalies across the Gulf for the first time, including a record low at Rimouski station, whereas phosphate and silicate were dominated by positive anomalies, with phosphate reaching a record high in the Estuary/northwest Gulf region (Figure 21).

The Redfield-Brzezinski C:Si:N:P ratio, which assumes equilibrium between phytoplankton composition and the deep-ocean nutrient inventory, is 106:15:16:1 (Redfield 1958; Brzezinski 1985). In the deep waters of the Gulf, the N:P ratio is lower than 16, with climatological averages ranging from 10.0 to 12.6, while the Si:N ratios tend to be higher than the target of 0.94, ranging between 1.3 and 2.2 (Figure 21). The climatological N:P (Si:N) ratio is highest (lowest) at the entrance of the Laurentian Channel and decreases (increases) as water progresses up the deep channel from Cabot Strait to the Estuary. Departures from the Redfield-Brzezinski ratios indicate changes in the relative availability of nutrients compared with the average requirements of marine phytoplankton and may influence phytoplankton growth and community composition. In 2025, deep-layer N:P ratios reached record lows in all regions, continuing an intensification of these anomalous nutrient ratio patterns observed since 2022 (Figure 21).

3.3 PHYTOPLANKTON

3.3.1 High-frequency monitoring stations

Seasonal patterns of water-column integrated chl *a* concentrations differ between the two high-frequency monitoring stations. At Rimouski station, maximum chl *a* is typically reached during early summer, and stays at relatively high levels until late summer/early fall. In contrast, at Shediac Valley station, the chl *a* concentrations reach a maximum in early spring (no chl *a* data are available for March, but high surface nutrient levels typically indicate that the bloom has not yet started at that time of year) before diminishing rapidly, and staying low for until the end of the year. Between June and September, chl *a* inventories are typically two to three times higher at Rimouski station than at Shediac Valley station (Figure 22).

In 2025, chl *a* inventories at Rimouski station were generally below normal, except on two occasions in late summer, and more consistently so during fall, when they reached their highest values of the year (Figure 22). The absence of elevated surface chl *a* concentrations ($> 3 \text{ mg m}^{-3}$) through May and most of June suggests that the spring phytoplankton bloom was delayed until late June/early July, about 2 weeks later than expected (Figure 23). This corroborates nutrient observations indicating delayed bloom initiation, despite strong stratification already prevailing in April (see Figure 67 in Galbraith et al. 2026b). Above-normal chl *a* concentrations throughout the upper 100 m of the water column during fall resulted in a strong positive anomaly in the early November inventory. (Figure 22 and Figure 23).

At Shediac Valley, chl *a* inventories in 2025 were generally close to the monthly climatology, although above-normal levels were observed in June and August and below-normal level in September (Figure 22). While high phytoplankton biomass at this station often extends to the bottom of the water column during the spring bloom, in 2025, it was mostly restricted to the upper 30 m (Figure 23). Deep phytoplankton biomass was also reduced later in the season, with slightly negative anomalies prevailing below 40 m during late summer (Figure 23).

Phytoplankton abundances at the Rimouski station were below normal until September, when they became near-normal (Figure 24). While diatoms typically dominate the phytoplankton community from April to September, in 2025 they did so only in July and September, and at lower levels than usual. Flagellates were particularly dominant during spring, and the proportion of dinoflagellates in November was twice the climatological monthly average (Figure 24).

At Shediac Valley, phytoplankton abundance and taxonomic composition were highly variable. In March, the abundance was below normal and flagellates accounted for more than 95% of phytoplankton cells. Abundances were strongly above normal in May and June. However, the community was dominated by diatoms in May and by flagellates in June (Figure 25). Diatoms again accounted for a substantial proportion of the community in August, but declined to very low levels by October (Figure 25).

3.3.2 Gulf regions

Chlorophyll *a* inventories (0–100 m) are typically highest in the Estuary and around the Gaspé Peninsula during early and late summer. This region becomes less of a phytoplankton hotspot in the fall, as chl *a* inventories decrease and become similar to those observed in the central Gulf and northern Magadalen Shallows (Figure 26). In early summer 2025, chl *a* inventories were mostly near normal to below normal in the northern Gulf, and near normal to above normal in the southern Gulf (Figure 26). The anomaly pattern was somewhat reversed during late summer with negative anomalies being dominant in the southern Gulf and some strong positive anomalies observed along the northern shore (Figure 26). This latter pattern was also observed during fall, but with the positive anomaly expanding to include the entire Estuary and northwest Gulf (Figure 26). Strong positive anomalies along the northern shore during late summer and fall have become an increasingly common feature in recent years.

In 2025, phytoplankton cell abundances were lowest during winter. Winter communities were largely dominated by flagellates, although diatoms accounted for over 50% of cells at the Northumberland Sound station, a composition more typical of bloom conditions (Figure 27). For most of the Gulf, the early summer season typically corresponds to a post-bloom period characterized by relatively low cell abundance and dominance of flagellates. The high phytoplankton biomass observed in the Estuary and northwest Gulf during fall (Figure 26) was associated with a high proportion of diatoms. Flagellates remained the dominant group at other locations (Figure 27). Throughout the year, the highest phytoplankton cell abundances were found in the southern Gulf, where the community was largely dominated by flagellates (Figure 27).

3.3.3 Scorecards

Overall, annual averages of chl *a* inventories were normal in all regions, but above normal at the Shediac Valley station (Figure 28). In the Estuary/northwest Gulf region, the fall bloom was the second largest on record (Figure 28). Over the past decade, positive fall chl *a* anomalies have been common throughout the Gulf, and particularly in the Estuary/northwest Gulf (Figure 28). Across the Gulf, fall biomass increased by nearly 40% from the 1999–2014 to the 2015–2025 period.

Since 2018, total phytoplankton abundances have regularly shown positive anomalies, driven by higher-than-normal abundances of flagellates and dinoflagellates in most occasions. During the same period, the Estuary/northwest Gulf region (including the Rimouski station) has been the only area to almost consistently indicate near-normal to positive anomalies in diatom abundance

(Figure 29). However, in 2025, all phytoplankton groups generally showed near-normal to below-normal abundances, the main exceptions being flagellates and dinoflagellates on the Magdalen Shallows and diatoms at Shediac Valley (Figure 29). These two locations were the only ones to show above-normal phytoplankton cell abundances, with the Magdalen Shallows reaching a record-high phytoplankton abundance. Dinoflagellate abundances have been above normal on the Magdalen Shallows over the past four years and reached a record high in 2025. Flagellate abundances also reached record highs in 2025 (Figure 29).

3.3.4 Satellite remote sensing and oceanographic buoy data

Observations from the oceanographic buoy at the Rimouski station are included in this section, as they align well with satellite remote sensing data in terms of both temporal and vertical (thin surface layer) resolution, providing comparable indices of phytoplankton biomass. Surface chl *a* concentrations estimated from the buoy in 2025 suggest a phenology similar to that observed from water samples collected at the Rimouski station (Figure 22), with lower-than-normal concentrations in early May, and peaks in late June and early July, and again in early October (Figure 30). Chlorophyll *a* concentrations from the buoy were above normal during these latter periods and were generally close to normal otherwise (Figure 30).

Winter phytoplankton biomass was near normal in the northern ocean colour polygons and below normal in the southern ones (Figure 30). The spring bloom mostly occurred in April across the Gulf but peaked in May in the northwest Gulf (Figure 31). Phytoplankton biomass peaks during the spring bloom were generally above the climatological average (Figure 30). In the northwest Gulf, smaller phytoplankton biomass peaks were also observed during summer, late summer, and fall, consistent with both *in situ* chl *a* samples and buoy fluorescence observations. Localized but strongly above-normal surface chl *a* concentrations were observed in the eastern Gulf in early September (Figure 32). A stronger-than-normal fall bloom was also observed in November in the northeast Gulf and Cabot Strait polygons (Figure 30 and Figure 32).

Spring bloom timing in 2025 was earlier than normal in Cabot Strait, and near normal in other regions (Figure 33). Since 2016, spring bloom timing has been generally normal or earlier than normal across the Gulf. In contrast, the fall bloom occurred later than normal in most regions, a pattern regularly observed since 2011. Bloom curve fits for 2025 are available in Appendix 2.

Overall, annual averages indicate that surface phytoplankton biomass in 2025 was near normal in most regions, slightly above normal in the northwest Gulf, and slightly below normal in the Cabot Strait (Figure 33). In the northwest Gulf, spring surface phytoplankton biomass was the highest on record (Figure 33). Seasonal anomalies of surface chl *a* have shifted in the mid-2010s from predominantly negative to positive, with the trend especially pronounced in winter and fall (Figure 33). Linear regression indicates a significant increase in annually averaged surface phytoplankton biomass over the time series (Appendix 8; slope = 0.052 year⁻¹, $R^2 = 0.355$, $p = 0.0008$).

3.4 ZOOPLANKTON

3.4.1 High-frequency-monitoring stations

At Rimouski station, zooplankton biomass is typically lowest in late winter and spring, then increases continuously until fall, when it stabilizes. At Shediac Valley, a maximum is typically

reached in June, followed by a small biomass decrease. Biomass then shows a second peak, albeit smaller, in September before declining to low levels during fall (Figure 34). In 2025, zooplankton biomass at Rimouski station was generally close to the climatological average, but slightly below normal during late summer and fall. At Shediac Valley, biomass was mostly above normal, particularly in August and October, when strong positive anomalies were observed (Figure 34).

Copepod abundance was below normal at the Rimouski station throughout the year, except in November (Figure 35). The proportion of *Calanus* spp. was higher than usual from spring through late summer, returning to climatological levels from September onward. The small copepods *Triconia borealis*, *Temora longicornis* and *Pseudocalanus* spp. were not among the dominant taxa in 2025 (Figure 35). Non-copepod abundance at Rimouski station ranged from below to near-normal levels, except in November, when a very high abundance led to a strong positive anomaly. This high abundance was associated with an increased proportion of Tunicata and Euphausiacea (Figure 36). During spring and summer, Ostracoda, Euphausiacea, and Cirripedia sequentially dominated the non-copepod community from April until June, followed by a dominance of Euphausiacea until the fall when Tunicata became dominant (Figure 36).

At Shediac Valley, copepod abundance was above normal in spring and early summer, then normal to slightly below normal afterward (Figure 37). A lower-than-usual proportion of *C. hyperboreus* and a higher-than-normal proportion of *C. finmarchicus* were observed. Similar to the Rimouski station, *T. borealis* and *T. longicornis* were either poorly represented or were not among the copepod taxa accounting for 95% of total copepod abundance in 2025. By contrast, *Centropages* spp. and *Microcalanus* spp. were among the copepod taxa accounting for 95% of total copepod abundance in 2025, although this is not the case in the climatology (Figure 37). Non-copepod abundance was relatively close to the normal, except during late summer, when strong positive anomalies were recorded (Figure 38). In that season, Mollusca occupied nearly 90% of the non-copepod assemblage. Mollusca were also dominant in June and October, whereas Tunicata and Euphausiacea, which typically occupy a significant proportion of the non-copepod assemblage, were either absent from or poorly represented among the dominant taxa (Figure 38).

At Rimouski station, the abundance of *C. finmarchicus* was generally near to below normal (Figure 39). The early copepodite stages (CI–CIII) were first observed in May but were absent from June samples. They were again present in July, in proportions similar to the climatology. A second and more abundant cohort was observed in November, when the proportion of early copepodite stages is typically low (Figure 39). The absence of CI–CIII copepodite stages in April suggests a slightly delayed phenology (Figure 39). At Shediac Valley, some very high *C. finmarchicus* abundances were observed in June and October. These two periods were associated with a relatively large proportion of early CI–CIII copepodite stages.

In 2025, *C. hyperboreus* abundances were near or below normal at Rimouski station (Figure 40). A small peak of early copepodite stages was detected in May, whereas no early copepodite stages were observed throughout 2024 (Blais et al. 2025). Proportions of CIV, CV, and CVI copepodite stages from June onward were similar to the climatology (Figure 40). At Shediac Valley, all *C. hyperboreus* abundances were within the normal range. The timing and proportion of the early stage cohort were similar to the climatology. However, no adult (CVI) was observed in samples collected in 2025 (Figure 40).

At Rimouski station, the abundance pattern and seasonal copepodite assemblage of *Pseudocalanus* spp. closely resembled those of 2024 (Blais et al., 2025). *Pseudocalanus* spp. abundance was below normal during most of the year (Figure 41). Early copepodite stages peaked in May and November but were nearly absent otherwise. At Shediac Valley, *Pseudocalanus* spp. abundances were either near normal or slightly below normal (Figure 41).

Long-term observations in the phenology of *C. finmarchicus* at Rimouski station (1994–2025) show a clear shift toward earlier development (Figure 42). Two indices, defined as the first day of year when the normalized CIV proportion exceeds 35% and the day of year when peak CIV proportion is reached, are used to objectively characterize phenological timing. They both have indicated negative anomalies nearly consistently since 2012, especially during 2021–2024. However, in 2025, the first day index suggested a delayed phenology for the first time since 2006, while the peak day index suggested a near-normal phenology, both contrasting with observations from recent years (Figure 42). The absence of CI–CIII copepodite stages in June, when the early copepodite stage peak is typically observed (Figure 39), likely impacted the anomaly signal, which should therefore be interpreted with caution. A second pulse of early copepodite stages, observed in late summer during 2010–2014 and again in 2021–2024, was present in 2025 as well, albeit with reduced intensity compared to the preceding four years (Figure 42). The early copepodite stage peak in early November is the latest on record (Figure 42).

3.4.2 Gulf regions

Zooplankton biomass is typically concentrated in the deep channels of the Gulf, where the large copepod *C. hyperboreus* is more abundant. As a result, biomass tends to be lower in the coastal stations of each section, and on the Magdalen Shallows. This spatial pattern persisted in 2025, although early summer biomass on the Magdalen Shallows approached levels typically observed in the deep channels at several locations (Figure 43). During early summer, biomass levels were generally near or above normal across the Gulf. By fall, they were mostly near or below normal (Figure 43).

The highest abundances of *C. finmarchicus* were observed in the northeast Gulf and on the western side of the Magdalen Shallows during early summer 2025, resulting in seasonal record-high levels in these two regions (Figure 44). *Calanus finmarchicus* abundances were also above normal in the remaining regions during early summer. In fall, *C. finmarchicus* abundances were generally reduced and relatively homogeneous across the Gulf, with anomalies ranging from near to slightly below normal (Figure 46). In early summer, *C. hyperboreus* was most abundant in the northwest Gulf and on the Magdalen Shallows (Figure 45). Abundances in early summer were within the normal range in all regions, except in the central Gulf and Cabot Strait where they were below normal (Figure 45). In fall, abundances were below normal in most regions, including a record low in the northeast Gulf, and were only near normal on the Magdalen Shallows (Figure 45). *Pseudocalanus* spp. generally exhibited lower-than-normal abundances in 2025 (Figure 46). However, areas of elevated abundances were observed in the eastern Magdalen Shallows and near the Cape Breton Islands in early summer (although being near normal overall in the Magdalen Shallows region) (Figure 46).

The 2025 seasonal averages for zooplankton indices from the mackerel egg survey on the Magdalen Shallows and from the northern Gulf late-summer survey (Zoolmage) generally align with the AZMP time series (Figure 47). *C. finmarchicus* was at record-high levels on the

Magdalen Shallows in early summer, with new record highs set every year since 2022. The abundances of small calanoid copepods also reached a record high in early summer. Since the AZMP time series for this region showed near-normal levels of *Pseudocalanus* spp. during the same period, other small calanoid taxa were likely driving this signal. In the northern Gulf during late summer, only *C. finmarchicus* showed above-normal abundances (Figure 47). *C. hyperboreus* abundances were close to near-normal levels after four years of below-normal values, while small calanoid abundances were among the lowest on record (Figure 47). September zooplankton biomass on the Magdalen Shallows was slightly below normal, driven by below-normal *C. hyperboreus* abundances (Figure 48). *Calanus finmarchicus* and *Pseudocalanus* spp. abundances were near normal (Figure 48).

3.4.3 Scorecards

The time series of annual zooplankton biomass anomalies highlights recent major changes in the community, with mostly near-normal to negative anomalies across the Gulf since 2009 (Figure 49). There is a significant decline in annual zooplankton biomass averages in the Gulf over the time series (Appendix 8, Kendall's $\tau = -0.51$, $p = 0.0004$). Mean biomass during 2009–2025 was approximately 25% lower than during 2001–2008. The Magdalen Shallows is the only region showing consistently normal to above-normal biomass levels in recent years. In 2025, annual zooplankton biomass anomalies were again above normal on the Magdalen Shallows, below normal in the central Gulf/Cabot Strait region, and near normal in the Estuary/northwest Gulf region (Figure 49).

The abundance of large *Calanus* spp. is a dominant contributor to the zooplankton biomass. Annual *C. finmarchicus* abundances were above or near normal in most regions in 2025, continuing the positive anomaly pattern observed since 2023. Abundances reached record highs on the Magdalen Shallows and at Shediac Valley (Figure 50). *C. hyperboreus*, however, showed negative anomalies in most regions (Figure 51), marking the fifth consecutive year of strong and widespread negative anomalies for this species. The Magdalen Shallows and Shediac Valley were exceptions, with *C. hyperboreus* levels near normal and slightly above normal, respectively, in 2025. Large copepod abundances reached record highs at these two locations, while levels were mostly near normal elsewhere in the Gulf (Figure 51).

The general decrease in zooplankton biomass over time has coincided with increases in the abundance of *Pseudocalanus* spp., total copepods, non-copepods, small calanoid copepods, and cyclopoids, for which positive anomalies have been regularly observed since around 2014 (Figure 50 and Figure 51). See Appendix 1 for a detailed list of species included in each of these indices. However, in 2025, these groups mostly exhibited neutral to negative anomalies, consistent with the two preceding years (Figure 50 and Figure 51). *Pseudocalanus* spp. reached a record-low abundance at Rimouski station and in the central Gulf/Cabot Strait region for the second consecutive year (Figure 50).

The abundance of warm-water copepods, which has also increased since 2011, showed negative to neutral anomalies in 2025, continuing the pattern observed in 2024 (Figure 51). Cold-water copepods, which have frequently exhibited positive anomalies in most regions since 2016, continued this trend in 2025 (Figure 51), with *Calanus glacialis* accounting for most of this signal (not shown).

Following a decade of predominantly positive anomalies for most non-copepod taxa, the signals began to weaken in 2021 in the northeast Gulf and the central Gulf/Cabot Strait regions (Figure

52), and more broadly across the Gulf since 2023. This return to near-normal or below-normal non-copepod levels continued into 2025. Only Bryozoa showed slightly positive anomalies in the northeast Gulf and on the Magdalen Shallows (Figure 52).

In general, annual anomalies were consistent among the high-frequency monitoring stations and their associated Gulf regions (Figure 49–52). This suggests a high degree of confidence in our annual estimates throughout the Gulf, even though data collection for the zooplankton indices is limited to early summer and fall surveys.

4. DISCUSSION

4.1 ENVIRONMENTAL CONDITIONS

The timing of the onset of water column stratification and its strength influence spring bloom phenology, phytoplankton production, species succession, and trophic interactions throughout the growth season (Levasseur et al. 1984). At the Rimouski station, stratification typically develops slowly through April and reaches its maximum strength in May. In 2025, however, stratification was weak in March but reached its annual maximum earlier than usual, in April, likely driven by substantial St. Lawrence river runoff during the second half of March (Galbraith et al. 2026b). The lower-than-normal freshwater runoff during late summer and fall, likely contributed to the weak stratification observed in the Estuary and northwest Gulf during fall (Galbraith et al. 2026b). In addition to the effect of water column stratification on phytoplankton dynamics, thermal properties of the surface, cold intermediate layer (CIL; corresponds to the winter surface mixed layer that has been isolated from the atmosphere through seasonal warming and freshening of the surface layer), and deep-water masses play a role in defining zooplankton dynamics (Plourde et al. 2002). Galbraith et al. (2026b) reported on the physical conditions that prevailed in the Gulf during 2025, showing warmer-than-normal conditions for most indices and water column layers, which likely had both direct and indirect effects on the chemical and biological conditions observed.

In the Gulf, dissolved oxygen concentrations below $100 \mu\text{mol L}^{-1}$ at 300 m (below 30% saturation) are considered hypoxic, and can negatively affect species such as Atlantic cod and northern shrimp (Plante et al. 1998; Dupont-Prinet et al. 2013). Long-term AZMP data and historical records (Gilbert et al. 2005) confirm that the deep waters of the Estuary have consistently been hypoxic since 1984. Changes in dissolved oxygen of the deep waters entering the Gulf at the continental shelf are related to the varying proportions of Labrador Current water (LCW; colder/fresher, high dissolved oxygen levels) and North Atlantic Central Water (NACW; warmer/saltier, low dissolved oxygen levels), which together form the source of Gulf deep waters (McLellan 1957, Lauzier and Trites 1958, Gilbert et al. 2005). In recent years, the contribution of NACW to the deep Gulf waters has increased (Gilbert et al. 2005, Galbraith et al. 2026b), and was estimated to contribute nearly 100% in 2021 (Jutras et al. 2023). These deep waters take approximately three to four years to travel from Cabot Strait to the Estuary (Gilbert 2004). The record-high bottom area and volume of hypoxic water measured in 2023 across the Gulf likely reflect this upstream propagation of oxygen-depleted water masses. However, the contribution of NACW to the deep Gulf waters has decreased in recent years, as suggested by the concurrent increase in oxygen levels and decrease in temperature in the deep waters of the Laurentian Channel up to the northwestern Gulf, as well as in the deep channels of the northeastern Gulf. Improved oxygen conditions were also observed in the deep water of the Estuary, although the temperature, which was the warmest on record (Galbraith et al.

2026b), suggested that these cooler, more oxygenated waters had not yet fully reached the Estuary. Vertical profiles at Rimouski station and in the Estuary show that the improvement in oxygen conditions was mainly observed near the seafloor. At the same time, severely hypoxic waters expanded vertically, and strong negative anomalies were observed as shallow as 100 m depth in April at Rimouski station. Physical processes such as localized circulation or turbulent mixing, as well as changes in the type, intensity, and vertical distribution of microbial respiration, including a potential shift from aerobic to anaerobic pathways, could explain why oxygen conditions improved in 2025 despite persistently warm water temperatures in the deep layer of the Estuary.

Given the inherent properties of the Gulf source waters (NACW vs. LCW; Gilbert et al. 2005), changes in their mixing ratio at Cabot Strait imply that a decrease of $1.46 \mu\text{mol L}^{-1}$ of oxygen might be expected for each 0.1°C temperature increase. However, deep oxygen concentrations at Cabot Strait in 2025 represent a decline of ca. $40 \mu\text{mol L}^{-1}$ compared to their levels in the early 1970s (ca. $190 \mu\text{mol L}^{-1}$ at 300 m; Gilbert et al. 2005), for a nearly 1.3°C increase in temperature over the same period (Figure 49 in Galbraith et al. 2026b). In the Estuary, deep-water temperature at 300 m has increased by 2.1°C over the past 50 years (Fig. 49 in Galbraith et al. 2026b), while oxygen concentration has decreased from ca. $105 \mu\text{mol L}^{-1}$ (Gilbert et al. 2005) to $50.2 \mu\text{mol L}^{-1}$. This oxygen decline is more than what would be expected from the temperature changes according to the mixing ratio of source waters. Oxygen depletion driven by *in situ* respiration and microbial oxidation of organic matter during transit through deep channels accounts for some of the changes that cannot be attributed solely to bottom water warming and reduced initial oxygen saturation from shifts in source water mixing ratios. Additional contributing factors that can cause variability in oxygen concentration of deep waters include changes in the vertical flux of organic matter, enhanced microbial respiration under warmer conditions, and a reduction of deep inflow transport and bottom water ventilation via increased stratification (Jutras et al. 2023).

Winter mixing is a critical process for bringing nutrient-rich deep water to the surface. In the Gulf, winter convection is driven by buoyancy loss of surface waters attributable to cooling and reduced freshwater runoff, brine rejection associated with sea-ice formation, and wind-driven mixing prior to ice formation (Galbraith 2006). Warmer-than-normal surface waters during the winter of 2025 both limited sea-ice formation and reduced the volume of winter mixed layer (Galbraith et al. 2026b), thereby decreasing the availability of nutrients for spring primary production. Since 2010, various temperature and ice-cover indices have indicated important warming of the Gulf (Galbraith et al. 2026b). These anomalies are tied to a large decrease in the nitrate content of the surface layer over the time series.

The freshwater inflow from the St. Lawrence River also contributes to the nutrient surface layer inventory in areas under its influence, typically accounting for up to 35% of nutrient input to the Estuary (Lavoie et al. 2021). The intensity of freshwater inflow, and the resulting stratification, also influence the strength of upwelling at the head of the Laurentian Channel. Consequently, weak freshwater runoff during fall 2025 (Galbraith et al. 2026b) may have favoured upwelling and nutrient replenishment in the surface layer, contributing to the very strong fall bloom observed in the Estuary and northwest Gulf. Similarly, weak stratification in August drove upwelling in the central Gulf and northeast Gulf (near Belle-Isle and the head of the Anticosti Channel), as evidenced by negative sea surface temperature anomalies (Figure 20 in Galbraith

et al. 2026b), resulting in surface nutrient enrichment in the former and phytoplankton biomass accumulation in the latter.

Since 2020, positive anomalies in deep-water nutrients have regularly been observed in the central Gulf/Cabot Strait region in association with greater contribution of NACW to the water masses composition (Galbraith et al. 2026b, Jutras et al. 2023). In addition to water mass signatures, enhanced stratification over the past decade may have contributed to this signal by reducing exchanges between the upper layer and the CIL and favouring nutrient accumulation in the deep layers. However, the return to negative deep nitrate anomalies, and the weakening of silicate and phosphate anomalies in the central Gulf/Cabot Strait region since 2024, suggests a reduced contribution of NACW, consistent with the increase in dissolved oxygen.

Notably, 2025 marked the fourth consecutive year of record-low N:P ratios at Rimouski station and in the Estuary and northwest Gulf. Strong nutrient ratio anomalies have also been observed across the Gulf over the same period, with N:P ratios reaching record lows in all regions for the second consecutive year. Deep-water masses entering the Gulf through Cabot Strait possess distinct nutrient ratio signatures. However, as the water masses travel through the Laurentian Channel, their nutrient signatures are altered by microbial processes involved in nitrogen cycling, particularly denitrification, which typically occurs in hypoxic to anoxic conditions (see review by Hutchins and Capone 2022). The changes in nutrient ratios observed between Cabot Strait and the Estuary, along with concurrent decreases in nitrate concentrations and oxygen levels, point to denitrification as a key driver of nitrate loss in deep waters. A recent study by Pascal et al. (2024) further supports this interpretation, highlighting an intensification of fixed-nitrogen removal processes in the Estuary over the past decade, linked to the expansion of the hypoxic zone.

4.2 PHYTOPLANKTON

Except at Rimouski station, where sampling regularly covers the spring bloom period, phytoplankton production during the spring bloom must be inferred either from indirect indices, such as the difference between the nutrient inventory of the surface mixed layer from winter to early summer (drawdown), or from satellite observations. In 2025, spring nutrient drawdown generally corroborated spring bloom intensity estimates from satellite observations. In the northwest Gulf, higher-than-normal drawdown in the 0–50 m surface layer was associated with the most intense spring bloom on record in that region. In the Estuary, weak nutrient drawdown was consistent with the late-spring low chl *a* inventories observed at the Rimouski station, indicating a very low-intensity spring bloom. Although it is generally assumed that the intensity of the spring bloom is largely controlled by nutrient availability at the onset of stratification, overwintering copepod abundance and their grazing pressure are also key drivers of spring bloom dynamics (Sommer and Lengfellner 2008). Considering the low zooplankton biomass in several regions of the Gulf in 2025, and particularly the below-normal abundances of *C. hyperboreus*, a major consumer of spring bloom production (Plourde et al. 2003), reduced grazing during spring may have played a key role in promoting a relatively strong spring bloom in most regions of the Gulf in 2025 despite the low nitrate inventory in March.

Although only Cabot Strait indicated an earlier-than-normal spring bloom timing in 2025, the spring bloom timing time series suggest a trend toward earlier timing since 2016. Under global warming scenarios, an earlier onset of stratification is expected to trigger an earlier spring bloom. Moreover, the increase in light availability resulting from the important reduction in sea-

ice concentration is another factor that can contribute to an earlier phytoplankton bloom in the Gulf (Mei et al. 2024). However, the anticipated increase in precipitation and freshwater runoff could delay blooms by hindering the accumulation of phytoplankton biomass in the water column in regions influenced by freshwater (Levasseur et al. 1984, Zakardjian et al. 2000). In 2025, the spring freshet was near normal in intensity, but substantial freshwater runoff in late March led to an early onset of stratification at Rimouski in April. Despite this, the phytoplankton bloom was delayed at Rimouski station, while timing was near-normal in regions under freshwater influence, namely the northwest Gulf and Magdalen Shallows.

Another foreseen outcome of the increased stratification under warmer conditions is the larger contribution of smaller-sized cells, known to perform better in nutrient-poor and highly stratified waters, to the phytoplankton assemblage (Legendre and Rassoulzadegan 1995). The taxonomic composition data presented in this report supports this hypothesis, with mostly positive flagellate anomalies observed across the Gulf since 2019, although in 2025 a positive anomaly was only recorded on the Magdalen Shallows, where it reached a record high. Warmer conditions, combined with increased freshwater input, may also promote harmful algal blooms (HABs) of toxin-producing dinoflagellates (Boivin-Rioux et al. 2021, Boivin-Rioux et al. 2022). The proportion of dinoflagellates was at record-high in 2025 on the Magdalen Shallows.

For most seasons, ocean colour data retrieved from remote sensing are complemented by *in situ* observations. These two data sources have often yielded differing seasonal anomaly patterns in phytoplankton biomass. Such divergences can be explained by several factors, including the vertical structure of phytoplankton in the water column; methodological differences in calculating seasonal anomalies (e.g., full seasonal coverage within ocean-colour polygons versus fewer discrete sampling days per Gulf region for *in situ* data, with AZMP survey timings shown in Figure 30); the alignment of *in situ* sampling with key phenological phases of phytoplankton; differences in the volume of water sampled by each method; and limitations such as cloud cover for remote sensing. Despite these divergences, both data sources suggest an increase in annual phytoplankton biomass since the mid-2010s, driven at least in part by higher fall biomass. This trend may have implications for higher trophic levels. The increased frequency of fall post-tropical storms in recent years (Galbraith et al. 2026b), and the associated nutrient injections into the surface layer likely create favourable growth conditions for phytoplankton, especially when combined with reduced grazing pressure. The weak to normal stratification in the northern Gulf during fall 2025 (Galbraith et al. 2026b) likely favoured high phytoplankton biomass during that period.

4.3 ZOOPLANKTON

Zooplankton biomass has generally been below normal in recent years, with several record-low levels in 2016–2017, and again in 2021–2024. This pattern of low biomass weakened in 2025, although biomass remained slightly below normal in a few regions. Lower biomass is typically associated with a decrease in the abundance of large copepod species. The mean weight of large calanoid copepods (e.g., *C. hyperboreus*: 3.5 mg per adult female) is between one and two orders of magnitude greater than that of small calanoid copepods (e.g., *Pseudocalanus* spp.: 0.02 mg per adult female) (Conover and Huntley 1991, Plourde et al. 2003). Thus, low abundance of large calanoid copepods has a greater impact on total zooplankton biomass than the high abundances of *Pseudocalanus* spp., which have been regularly observed over the 2014–2022 period. In these years, the increase in small calanoid copepods often coincided with an increase in non-copepod abundance. Environmental factors such as temperature, food

availability, phytoplankton size structure, interspecific competition, and predation pressure likely influence the dominance of distinct community types (Hall et al. 1976; Daewel et al. 2014). These community types, dominated either by large calanoids or by small calanoids and non-copepods, may have implications for pelagic food-web dynamics and pelago-benthic coupling. However, as in 2024, the community composition in 2025 resembled that of the 2000–2009 decade; *C. finmarchicus* was abundant, while the small calanoid copepods and non-copepod community were primarily near or below average.

Life cycle strategies vary among large copepod species, and so do the environmental drivers influencing their phenology. For instance, interannual variations in the abundance of *C. hyperboreus* and its phenology are mostly influenced by spring conditions, including timing of sea-ice retreat and water temperature (Plourde et al. 2003, Lehoux et al. 2021). In contrast, late summer and early fall environmental conditions influence the phenology of *C. finmarchicus*, as part of its population remains in the active, non-diapause phase during that period. Moreover, the timing of reproduction of each taxon relative to the freshet, considering its impact on water-mass circulation and transport (Runge et al. 1999), can considerably influence zooplankton spatial distribution. As a result, species may exhibit distinct spatial patterns depending on how their life cycles align with hydrological dynamics (Brennan et al. 2021).

In 2025, negative anomalies of *C. hyperboreus* abundance across all regions except the Magdalen Shallows were likely driven by unfavorable environmental conditions. The Gulf represents the southernmost part of this species' distribution range (Conover 1988), and despite recent cooling, bottom temperatures remained above normal across the Gulf in 2025 (Galbraith et al. 2026b). Warming of the St. Lawrence is the main driver expected to cause a large decline of *C. hyperboreus* in the Gulf over the coming century (Lehoux et al. 2024).

However, *C. hyperboreus* levels were not as low in 2025 than in 2024 in the Estuary and northwest Gulf. Despite the early sea-ice retreat, the population structure at both high-frequency monitoring stations suggested near-normal phenology for *C. hyperboreus*. This near-normal phenology may have favored their residence time in the Estuary and northwest Gulf, although some export likely still occurred. In contrast, during early-phenology years, the peak of early copepodite stages often coincides with peak freshwater runoff, promoting downstream export to the Magdalen Shallows. Consistent with this hypothesis, *C. hyperboreus* abundance at the Rimouski station increased throughout the year, and the proportion of early copepodite stage was lower than usual at Shediac Valley in May. Furthermore, the proportion of diapausing CIV individuals at Rimouski station was near normal and higher than in 2024, suggesting better recruitment in the Estuary in 2025 (Blais et al. 2025). On the Magdalen Shallows, where the high proportion of diapausing CIV and CV stages in early summer promotes their retention in the region, exported individuals are particularly vulnerable to predation due to the shallow bottom depths (Brennan et al. 2019).

The peak timing of *C. finmarchicus* early copepodite stages is typically coupled with the spring bloom to enhance their survival rates (Plourde et al. 2009). However, in 2025, phytoplankton biomass was particularly low throughout spring in the Estuary, only increasing in late June to early July. The resulting food limitation may have reduced the survival of early copepodite stage, which, combined with the slightly above-normal freshwater runoff in May (Galbraith et al. 2026b), may explain their absence in June. The very high abundance of *C. finmarchicus* recorded in June at Shediac Valley and on the western side of the Magdalen Shallows section confirms that downstream transport occurred. Under favourable conditions, *C. finmarchicus* can

produce a second cohort that typically develops in late summer, a phenomenon observed with increasing frequency and strength since 2010. In 2025, the second cohort was exceptionally late, peaking in November, coinciding with the only period of elevated phytoplankton biomass inventories recorded that year.

The northeast Gulf and the central Gulf/Cabot Strait regions are less influenced by freshwater inputs; zooplankton communities in these regions are likely shaped by factors such as CIL conditions, the volume and temperature of cold and saline Labrador Shelf water that flows into northeast Gulf through the Strait of Belle Isle, and the mixing ratio of source waters that enters the deep Laurentian Channel via Cabot Strait (Shaw and Galbraith 2023). Variability in these environmental drivers might explain why these two regions often show distinct zooplankton anomaly patterns compared to other parts of the Gulf. In 2025, however, anomaly patterns were relatively consistent for most zooplankton taxa and groups across the deep channel regions. However, the northeast Gulf and central Gulf/Cabot Strait were the only regions with negative zooplankton biomass anomalies, driven by the strong negative anomalies of *C. hyperboreus* observed there.

4.4 PERSPECTIVES

While 2025 showed some improvement in oxygen conditions and a return to near-normal Gulf-wide zooplankton biomass, oxygen levels remain well below normal and *C. hyperboreus*, a key prey species, continued to show negative anomalies in most regions. These persistent trends highlight the urgent need for continued research on the ecological impacts of deoxygenation and shifting planktonic communities in the St. Lawrence system. The drivers behind the observed changes in nutrient inventories, phytoplankton biomass, and zooplankton community composition and size structure, how they interact and may evolve, remain incompletely understood. Recent modelling efforts have nonetheless provided valuable insights into the nature and direction of these changes (Mei et al. 2024, Lavoie et al. 2021, Lehoux et al. 2024). While the roles of predation and changes in community structure remain to be clarified, some insight into the environmental influences on biological components can be gained from a simple correlation matrix (Figure 53).

Among other things, this matrix shows that a cold CIL, typically associated with a stronger winter convection and delayed stratification, correlates with a later bloom start and high surface nitrate inventories. Zooplankton biomass is strongly and positively correlated with communities dominated by large copepods, and negatively correlated with non-copepod abundance, which in turn is positively correlated with small copepod abundance. Thermal properties of the water column and phytoplankton dynamics could be major drivers of zooplankton assemblage. Indeed, it seems that a cold water column favours high zooplankton biomass (negative correlation at all depths) while a cold deep layer reduces the abundance of non-copepods (positive correlation). Higher annual nitrate inventories are associated with both late spring blooms and early fall blooms, as well as with high zooplankton biomass, supporting the hypothesis that phytoplankton dynamics are also a major driver of zooplankton assemblage in the Gulf. Changes in phytoplankton community composition and species succession may also be important drivers for the zooplankton assemblage, though these variables were excluded from the correlation matrix due to limited time series outside of the high-frequency monitoring stations. It is possible that the highly stratified and nutrient-poor conditions have promoted the proliferation of flagellates in the Gulf, especially during years when reduced grazing pressure is expected (Cloern 2018, Cushing 1989, Ward et al. 2012). These environmental drivers may also

trigger changes in the developmental timing of zooplankton taxa (not illustrated in Figure 53), such as the earlier development of large *Calanus* in recent years. Overall, these preliminary analyses highlight the importance of bottom-up controls in shaping zooplankton communities, although the relative importance of these processes, and potential interactions, is not yet well understood.

5. SUMMARY

This document summarizes the chemical and biological (plankton) conditions observed in the Gulf of St. Lawrence in 2025, within the broader context of warmer-than-normal conditions prevailing since 2010.

- Deep dissolved oxygen saturation returned to near- or slightly above-normal levels in Cabot Strait, central and northeastern Gulf. Levels remained below normal in the Estuary and northwest Gulf but improved relative to 2024. Annual average saturation in the Estuary was 16% ($50 \mu\text{mol L}^{-1}$) at 300 m and 26% ($84 \mu\text{mol L}^{-1}$) in bottom waters.
- Nutrient inventories were generally near to below normal in the surface and mid layers, and above normal in the deep layer, except for nitrate, which was below normal and reached a record low at Rimouski station for the third consecutive year.
- Since 2022, and increasingly through 2025, strong anomalies in deep nutrient content have been associated with negative N:P ratio anomalies and positive Si:N ratio anomalies, with record-low N:P ratios observed across the Gulf.
- Annual *in situ* chl *a* inventories were near normal across the Gulf. The fall bloom in the Estuary and northwest Gulf was the second highest on record.
- Phytoplankton group abundances were generally near or below normal in 2025, except on the Magdalen Shallows (including Shediac Valley), where most taxonomic groups showed positive anomalies, including a record high for flagellates.
- Annual surface chl *a* concentrations were mostly near normal but above normal during spring when they reached a record high in the northwest Gulf.
- Spring bloom timing was mostly normal, except in Cabot Strait where it occurred early, while fall blooms were later than normal in most regions.
- Zooplankton biomass was near normal in the Estuary and northwest Gulf, below normal in the northeast Gulf and central Gulf/Cabot Strait, and above normal on the Magdalen Shallows.
- *Calanus finmarchicus* abundances were near to above normal across the Gulf, reaching record highs on the Magdalen Shallows and at Shediac Valley.
- *Calanus hyperboreus* abundances were below normal in the deep Gulf regions but near normal on the Magdalen Shallows.
- Large *Calanus* phenology at Rimouski station was generally near normal, contrasting with the predominantly earlier-than-normal phenology observed in recent years.

- The zooplankton community composition in 2025 resembled that of the 2000–2009 decade, with abundant *C. finmarchicus* and near- to below-normal small calanoid copepod and non-copepod abundances.

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REFERENCES

- Bélangier, D., Maillet, G., Dalton, B., Fudge, A., Ramsay, D., and Rastin, S. 2025. Biogeochemical Oceanographic Conditions on the Newfoundland and Labrador Shelf during 2021 and 2022. Can. Tech. Rep. Fish. Aquat. Sci. 3711: ix + 34 p. <https://doi.org/10.60825/esn6-7677>
- Blais, M., Clay, S.A., Galbraith, P.S., and Starr, M. 2025. Chemical and Biological Oceanographic Conditions in the Gulf of St. Lawrence During 2024. Can. Tech. Rep. Hydrogr. Ocean. Sci. 405: vi + 87 p. <https://doi.org/10.60825/gmbq-jf70>
- Blais, M., Galbraith, P.S., Lizotte, M., Clay, S.A., and Starr, M. 2024. Chemical and Biological Oceanographic Conditions in the Estuary and Gulf of St. Lawrence during 2023. Can. Tech. Rep. Hydrogr. Ocean Sci. 385 : v + 84 p.
- Blais, M., Galbraith, P.S., Plourde, S., Lehoux, C. and Devine, L. 2023. Chemical and Biological Oceanographic Conditions in the Estuary and Gulf of St. Lawrence during 2021. DFO Can. Sci. Advis. Sec. Res. Doc. 2023/045. iv + 74 p.
- Boivin-Rioux, A., Starr, M., Chassé, J., Scarratt, M., Perrie, W., and Long, Z. 2021. Predicting the effects of climate change on the occurrence of the toxic dinoflagellate *Alexandrium catenella* along Canada's east coast. Front. Mar. Sci. 7:608021. doi:10.3389/fmars.2020.608021
- Boivin-Rioux, A., Starr, M., Chassé, J., Scarratt, M., Perrie, W., Long, Z., and Lavoie, D. 2022. Harmful algae and climate change on the Canadian East Coast: Exploring occurrence predictions of *Dinophysis acuminata*, *D. norvegica*, and *Pseudo-nitzschia seriata*. Harmful Algae 112: 102183. doi: 10.1016/j.hal.2022.102183
- Brennan, C.E., Maps, F., Gentleman, W.C., Plourde, S., Lavoie, D., Chassé, J., Lehoux, C., Krumhansl, K.A., and Johnson, C.L. 2019. How transport shapes copepod distributions in relation to whale feeding habitat : Demonstration of a new modelling framework. Prog. Oceanogr. 171: 1–21. doi:10.1016/j.pocean.2018.12.005.
- Brennan, C.E., Maps, F., Gentleman, W.C., Lavoie, D., Chassé, J., Plourde, S., and Johnson, C.L. 2021. Ocean circulation changes drive shifts in Calanus abundance in North Atlantic right whale foraging habitat: A model comparison of cool and warm year scenarios. Prog. Oceanogr. 197:102629. <https://doi.org/10.1016/j.pocean.2021.102629>
- Brickman, D., and Petrie, B. 2003. [Nitrate, silicate and phosphate atlas for the Gulf of St. Lawrence](#). Can. Tech. Rep. Hydrogr. Ocean Sci. 231: xi + 152 pp.
- Brzezinski, M. A. 1985. The Si:C:N ratio of marine diatoms: interspecific variability and the effect of some environmental variables. J. Phycol. 21: 347–357.
- Casault, B., Johnson, C.L., Devred, E., Clay, S., and Beazley, L. 2025. Chemical and Biological Oceanographic Conditions on the Scotian Shelf and in the Eastern Gulf of Maine during 2024. Can. Tech. Rep. Fish. Aquat. Sci. 3744: vi + 58 p. <https://doi.org/10.60825/p6ad-1k52>
- Chamberland, J.-M., Bourdages, H., Desgagnés, M., Galbraith, P., Isabel, L., Ouellette-Plante, J., Roux, M.-J., Scallon-Chouinard, P.-M., and Senay, C. 2025. Preliminary Results from

- the 2024 August Ecosystemic Survey in the Estuary and Northern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc. 2025/032. iv + 101 p.
- Clay, S. 2025. oceancolouR: Various Functions for Satellite and Data Analysis. R package version 0.0.0.9000, <https://github.com/BIO-RSG/oceancolouR>.
- Clay, S., Peña, A., DeTracey, B., and Devred, E. 2019. Evaluation of satellite-based algorithms to retrieve chlorophyll-a concentration in the Canadian Atlantic and Pacific Oceans. *Remote Sens.*, 11(22), 2609. <https://doi.org/10.3390/rs11222609>
- Cloern, J.E. 2018. Why large cells dominate estuarine phytoplankton. *Limnol. Oceanogr.* 63: S392-S409. doi: 10.1002/lno.10749
- Conover, R. J. 1988. Comparative life histories in the genera *Calanus* and *Neocalanus* in high latitudes of the northern hemisphere. *Hydrobiologia* 167/168:127–142
- Conover, R. J., and Huntley, M. 1991. Copepods in ice-covered seas - Distribution, adaptations to seasonally limited food, metabolism, growth patterns and life cycle strategies in polar seas. *J. Mar. Syst.* 2: 1–41.
- Cushing, D.H. 1989. A difference in structure between ecosystems in strongly stratified waters and in those that are only weakly stratified. *J. Plankton Res.* 11(1): 1–13.
- Daewel, U., Hjøllø, S.S., Huret, M., Ji, R., Maar, M., Niiranen, S., Travers-Trolet, M., Peck, M.A., and van de Wolfshaar, K. E. 2014. Predation control of zooplankton dynamics: a review of observations and models. *ICES J. Mar. Sci.* 71(2): 254–271.
- Dupont-Prinet, A., Pillet, M., Chabot, D., Hansen, T., Tremblay, R., and Audet, C. 2013. Northern shrimp (*Pandalus borealis*) oxygen consumption and metabolic enzyme activities are severely constrained by hypoxia in the Estuary and Gulf of St. Lawrence. *J. Exp. Mar. Biol. Ecol.*, 448, 298–307. <https://doi.org/10.1016/j.jembe.2013.07.019>
- Galbraith, P.S. 2006. Winter water masses in the Gulf of St. Lawrence. *J. Geophys. Res.* 111, C06022, doi: 10.1029/2005JC003159.
- Galbraith, P.S., Blais, M., Lizotte, M., Bélanger, D., Casault, B., Clay, S., Layton, C., Penney, J., Gabriel, C.-E., Ringuette, M., Azetsu-Scott, K., Chassé, J., Coyne, J., Devred, E., Johnson, C.L., Maillet, G., Shaw, J.-L., Starr, M. 2026a. Oceanographic Conditions in the Atlantic Zone in 2025. *Can. Tech. Rep. Hydrogr. Ocean. Sci.* 420: v +49 p.
- Galbraith, P.S., Chassé, J., Shaw, J.-L., Lefavre, D. and Bourassa, M.-N. 2026b. Physical Oceanographic Conditions in the Gulf of St. Lawrence during 2025. *Can. Tech. Rep. Hydrogr. Ocean Sci.* 418: v + 94 p. <https://doi.org/10.60825/a1qy-zx55>
- Gilbert, D. 2004. Propagation of temperature signals from the northwest Atlantic continental shelf edge into the Laurentian Channel. *ICES CM*, 2004/N: 7, 12 pp.
- Gilbert, D., Sundby, B., Gobeil, C., Mucci, A., and Tremblay, G.-H. 2005. A seventy-two-year record of diminishing deep-water oxygen in the St. Lawrence estuary: The Northwest Atlantic connection. *Limnol. Oceanogr.*, 50(5): 1654–1666.
- Grosjean, P., Denis K., and Wacquet G. 2018. ZoolImage: Analysis of numerical plankton images. R package version 5.5.2. <https://CRAN.R-project.org/package=zooimage>

- Hall, D.J., Threlkeld, S.T., Burns, C.W., and Crowley, P.H. 1976. The size-efficiency hypothesis and the size structure of zooplankton communities. *Annu. Rev. Ecol. Evol. Syst.* 7: 177–208.
- Hutchins, D.A., and Capone, D.G. 2022. The marine nitrogen cycle: new developments and global change. *Nat Rev Microbiol.* 20: 401–414. <https://doi.org/10.1038/s41579-022-00687-z>
- Jutras, M., Mucci, A., Chaillou, G., Nesbitt, W.A., and Wallace D.W.R. 2023. Temporal and spatial evolution of bottom-water hypoxia in the St. Lawrence estuarine system. *Biogeosciences.* 20: 839–849.
- Lavoie, D., Lambert, N., Starr, M., Chassé, J., Riche, O., Le Clainche, Y., Azetsu-Scott, K., Béjaoui, B., Christian, J.R., and Gilbert, D. 2021 The Gulf of St. Lawrence biogeochemical model: A modelling tool for Fisheries and Ocean management. *Front. Mar. Sci.* 8:732269, doi: 10.3389/fmars.2021.732269.
- Lauzier, L.M., and Trites, R.W. 1958. The deep waters of the Laurentian Channel. *J. Fish. Res. Board Can.* 15: 1247–1257.
- Layton, C., Devred, E., DeTracey B. 2022. A Comparison of Phytoplankton Spring Bloom Fitting Methods Using MODIS Satellite-Derived Chlorophyll-a Concentration for the Maritimes Region. *Can. Tech. Rep. Hydrogr. Ocean Sci.* 340: vii +22 p.
- Legendre L., and Rassoulzadegan, F. 1995. Plankton and nutrient dynamics in marine waters. *Ophelia.* 41(1): 153–172. doi: 10.1080/00785236.1995.10422042.
- Lehoux, C., Lavoie, D., Johnson, C. L., Plourde, S. 2024. End-of-Century Projections of *Calanus* Species Biomass in the Gulf of St. Lawrence, Southern Newfoundland, Scotian Shelf and Northeast Gulf of Maine. *DFO Can. Sci. Advis. Sec. Res. Doc.* 2024/040. iv + 53 p.
- Lehoux, C., Plourde, S., Chamberland, J.-M., and Benoît, H. 2021. Linking Interannual Variations of Capelin Abundance Indices in the Gulf of St. Lawrence to Environmental Proxies of Bottom-up Regulation of Cohort Strength. *DFO Can. Sci. Advis. Sec. Res. Doc.* 2021/068. iv + 51 p.
- Levasseur, M., Therriault, J.-C., and Legendre, L. 1984. Hierarchical control of phytoplankton succession by physical factors. *Mar. Ecol. Prog. Ser.* 19: 211–222.
- McLellan, H.J. 1957. On the distinctness and origin of the slope water off the Scotian Shelf and its easterly flow south of the Grand Banks. *J. Fish. Res. Board Can.* 14: 213–239.
- Mei, Z.-P., Lavoie, D., Lambert, N., Starr, M., Chassé, J., Perrie, W. and Long, Z. 2024. Modelling the bottom-up effects of climate change on primary production in the Gulf of St. Lawrence and eastern Scotian Shelf. *Front. Mar. Sci.* 11:1416744. <https://doi.org/10.3389/fmars.2024.1416744>
- Mitchell, M. R., Harrison, G., Pauley, K., Gagné, A., Maillet, G., and Strain, P. 2002. [Atlantic Zonal Monitoring Program sampling protocol](#). *Can. Tech. Rep. Hydrogr. Ocean Sci.* 223: iv + 23 pp.

- Nichols, J.H. and Thompson, A.B. 1991. Mesh selection of copepodite and nauplius stages of four calanoid copepod species. *J. of Plankton Res.*, 13(3): 661–671.
<https://doi.org/10.1093/plankt/13.3.661>
- Pascal, L., Cloutier-Artiwat, F., Zanon, A., Wallace D.W.R., and Chaillou, G. 2024. Fixed-nitrogen loss in a deoxygenating coastal ocean: Insights from the Estuary and Gulf of St. Lawrence. *ESS Open Archive*. doi: 10.22541/essoar.171560871.19656696/v1
- Parent, G.J., Plourde, S. and Turgeon, J. 2011. Overlapping size ranges of *Calanus* spp. off the Canadian Arctic and Atlantic coasts: impact on species' abundances. *J. Plankton Res.* 33:1654–1665
- Pebesma, E. J. 2004. Multivariable geostatistics in S: The gstat package. *Computers & Geosciences*, 30, 683–691. <https://doi.org/10.1016/j.cageo.2004.03.012>
- Plante, S., Chabot, D., and Dutil, J.-D. 1998. Hypoxia tolerance in Atlantic cod. *J. Fish Biol.* 53: 1342–1356.
- Plourde, S., Dodson, J. J., Runge, J. A., and Therriault, J.-C. 2002. Spatial and temporal variations in copepod community structure in the lower St. Lawrence Estuary, Canada. *Mar. Ecol. Prog. Ser.* 230: 221–224.
- Plourde, S., Joly, P., Runge, J.A., Dodson, J., and Zakardjian B. 2003. Life cycle of *Calanus hyperboreus* in the lower St. Lawrence Estuary and its relationship to local environmental conditions. *Mar. Ecol. Prog. Ser.* 255: 219–233.
- Plourde, S., Maps, F., and Joly, P. 2009. Mortality and survival in early stages control recruitment in *Calanus finmarchicus*. *J. Plankton Res.* 31(4): 371–388.
- Plourde, S., Lehoux, C., Johnson, C. L., Perrin, G., and Lesage, V. 2019. North Atlantic right whale (*Eubalaena glacialis*) and its food: (I) a spatial climatology of *Calanus* biomass and potential foraging habitats in Canadian waters. *J. Plankton Res.* 41(5): 667–685.
- Redfield A. C. 1958. The biological control of chemical factors in the environment. *Am. Sci.* 46, 205–221.
- Runge, J. A., Castonguay, M., de Lafontaine, Y., Ringuette, M., and Beaulieu, J. L. 1999. Covariation of climate, zooplankton biomass and mackerel recruitment in the southern Gulf of St. Lawrence. *Fish. Oceanogr.* 8(2): 139–149.
- Sathyendranath, S., Brewin, R. J. W., Brockmann, C., Brotas, V., Calton, B., Chuprin, A., Cipollini, P., Couto, A. B., Dingle, J., Doerffer, R., Donlon, C., Dowell, M., Farman, A., Grant, M., Groom, S., Horseman, A., Jackson, T., Krasemann, H., Lavender, S., Martinez-Vicente, V., ... Platt, T. (2019). An Ocean-Colour Time Series for Use in Climate Studies: The Experience of the Ocean-Colour Climate Change Initiative (OC-CCI). *Sensors* (Basel, Switzerland), 19(19), 4285. <https://doi.org/10.3390/s19194285>
- Savoie, L. 2014. Preliminary Results from the September 2012 and 2013 Bottom-Trawl Surveys of the Southern Gulf of St. Lawrence and Comparisons with Previous 1971 to 2011 Surveys. *DFO Sci. Advis. Sec. Res. Doc.* 2014/053. v + 127 p.

- Shaw, J.-L. and Galbraith, P.S.. 2023. [Climatology of transport in the Strait of Belle Isle](https://doi.org/10.1029/2022JC019084). J. Geophys. Res. Oceans, 128, e2022JC019084. <https://doi.org/10.1029/2022JC019084>
- Sommer, U., and Lengfellner, K. 2008. Climate change and the timing, magnitude, and composition of the phytoplankton spring bloom. Glob. Change Biol. 14: 1199–1208.
- Therriault, J.-C., Petrie, B., Pépin, P., Gagnon, J., Gregory, D., Helbig, J., Herman, A., Lefaivre, D., Mitchell, M., Pelchat, B., Runge, J., and Sameoto, D. 1998. Proposal for a Northwest Atlantic Zonal Monitoring Program. Can. Tech. Rep. Hydrogr. Ocean Sci. 194: vii + 57 pp.
- Ward, B. A., Dutkiewicz, S., Jahn, O., and Follows, M.J. 2012. A size-structured food-web model for the global ocean. Limnol. Oceanogr. 57: 1877–1891. doi:10.4319/lo.2012.57.6.1877.
- Zakardjian, B.A., Gratton, Y., Vézina, A.F. 2000. Late spring phytoplankton bloom in the Lower St. Lawrence Estuary: the flushing hypothesis revisited. Mar. Ecol. Prog. Ser. 192: 31–48.
- Zhai, L., Platt, T., Tang, C., Sathyendranath, S., and Hernández Walls, R. 2011. Phytoplankton phenology on the Scotian Shelf. ICES J. Mar. Sci. 68: 781–791, doi:10.1093/icesjms/fsq175.

TABLES

Table 1. List of oceanographic surveys with dates and sampling activities for each Gulf region/subregion. While numbers of CTD/bottle are indicated for each subregion, numbers of nets are only indicated for main regions (see region vs. subregion in Figure 1). Zooplankton net tows conducted during the Mackerel egg survey in June, and in the Mecatina Through during late summer, are shown in brackets because they are not included in the regional annual averages.

Main survey	Dates (2025)	Main vessel	Station/Region/Subregion	CTD/Bottle	Net
High-frequency monitoring stations	Mar. 3–Nov. 13	<i>Beluga II</i> (+ others)	Rimouski	26	24
	Mar. 9–Oct. 25	Multiple	Shediac Valley	6	5
Convection	Mar. 3–19 Winter	GC-945 Helicopter	Estuary	5	0
			Northwest Gulf	9	
			Northeast Gulf	23	0
			Central Gulf	8	0
			Cabot Strait	7	
			Magdalen Shallows	31	0
Total			83	0	
AZMP (Mackerel egg)	May 31– 7 Jul Early summer	Capt. Jacques Cartier	Estuary	18	18(0)
			Northwest Gulf	14	
			Northeast Gulf	14	7(0)
			Central Gulf	14	9(1)
			Cabot Strait	5	
			Magdalen Shallows	41	11(49)
Total			106	45	
Northern and southern Gulf multidisplinary	Aug. 8–20 Sep. Late summer	John Cabot/Capt. Jacques Cartier	Estuary	11	21
			Northwest Gulf	7	
			Northeast Gulf	13	17
			Central Gulf	16	12
			Cabot Strait	6	
			Magdalen Shallows	95	14
Total			148	64(3)	
AZMP	Oct. 15– 4 Nov. Fall	Coriolis II	Estuary	16	19
			Northwest Gulf	14	
			Northeast Gulf	14	7
			Central Gulf	11	9
			Cabot Strait	5	
			Magdalen Shallows	18	12
Total			78	47	

FIGURES

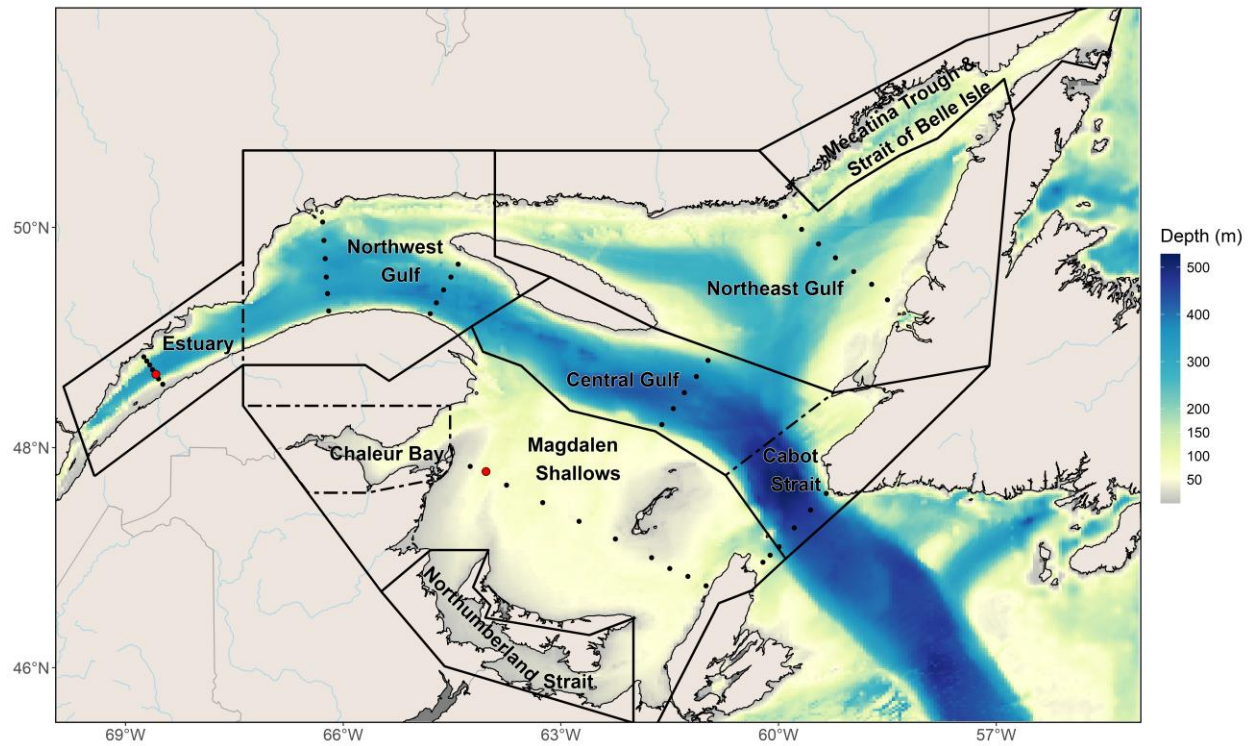


Figure 1. Bathymetric map of the Estuary and Gulf of St. Lawrence showing core AZMP sampling stations on the different sections (black circles), and high-frequency Rimouski and Shediac Valley stations (red circles). Solid lines indicate region boundaries, and dashed lines indicate regional subdivisions.

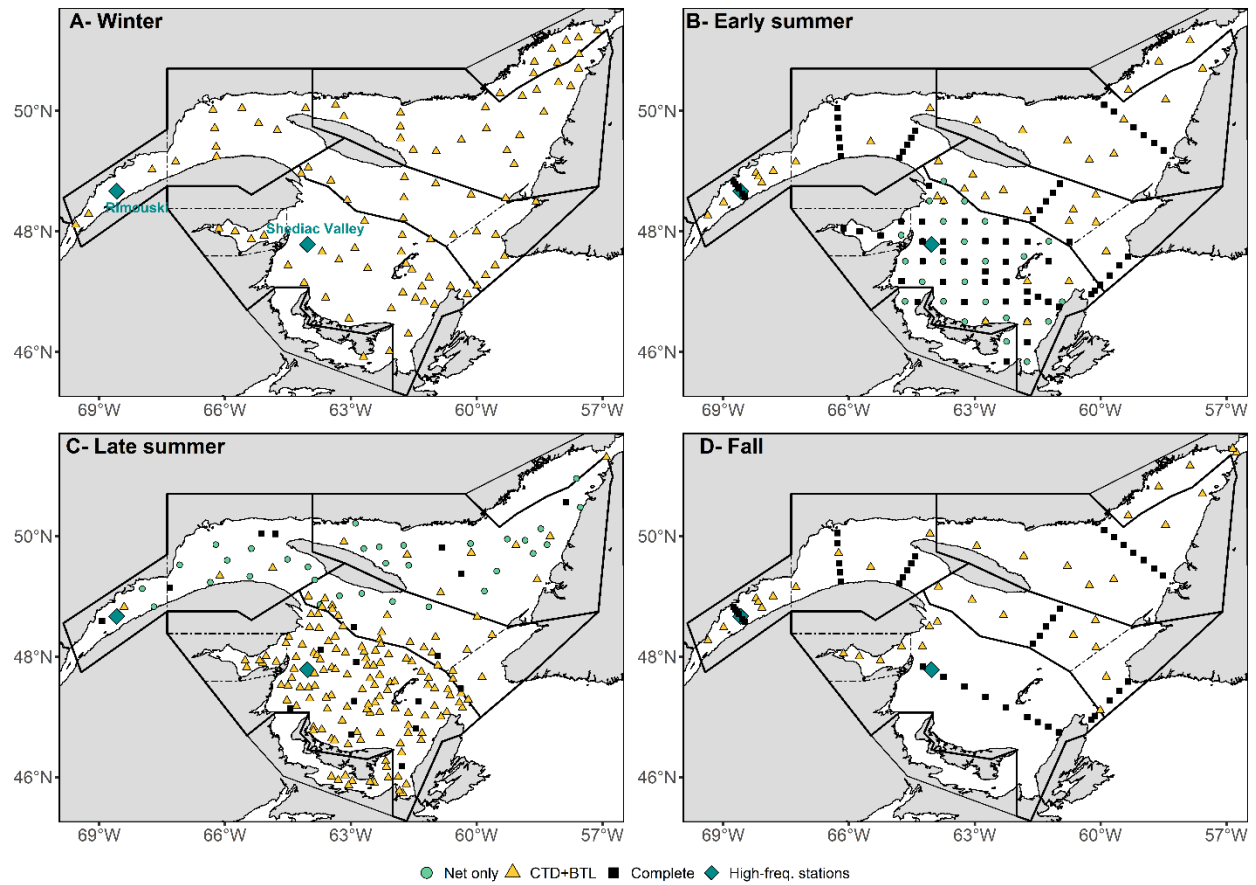


Figure 2. Location of stations sampled during winter (A), early summer (B), late summer (C), and fall (D) 2025 (see Figure 1 for region and subregion descriptions). A complete station indicates that a CTD profile, water collection, and zooplankton net tows were performed.

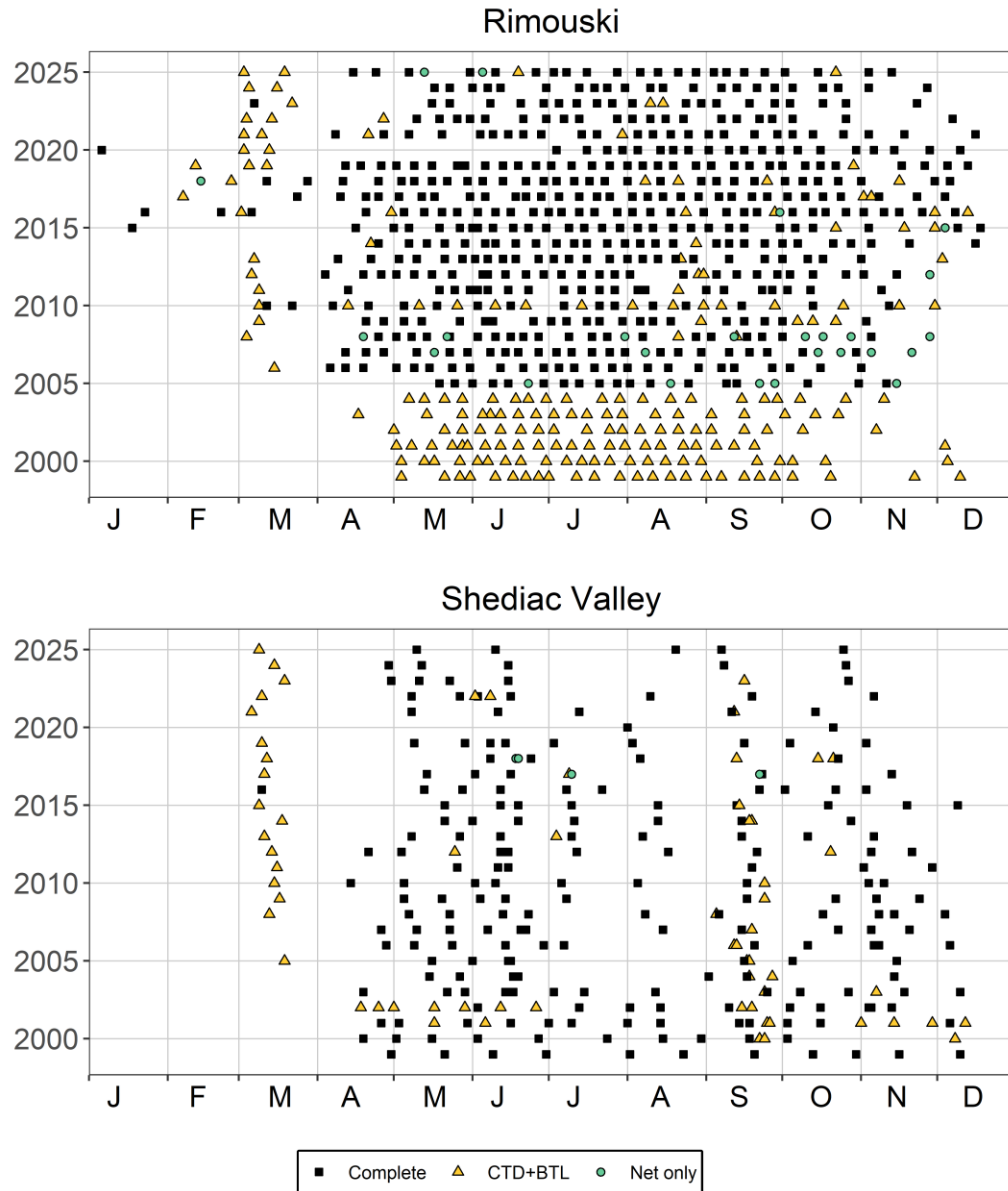


Figure 3. Sampling frequency at Rimouski and Shediac Valley stations from 1999 to 2025. Sampling included CTD/bottle as well as plankton net tows most of the time (weather permitting).

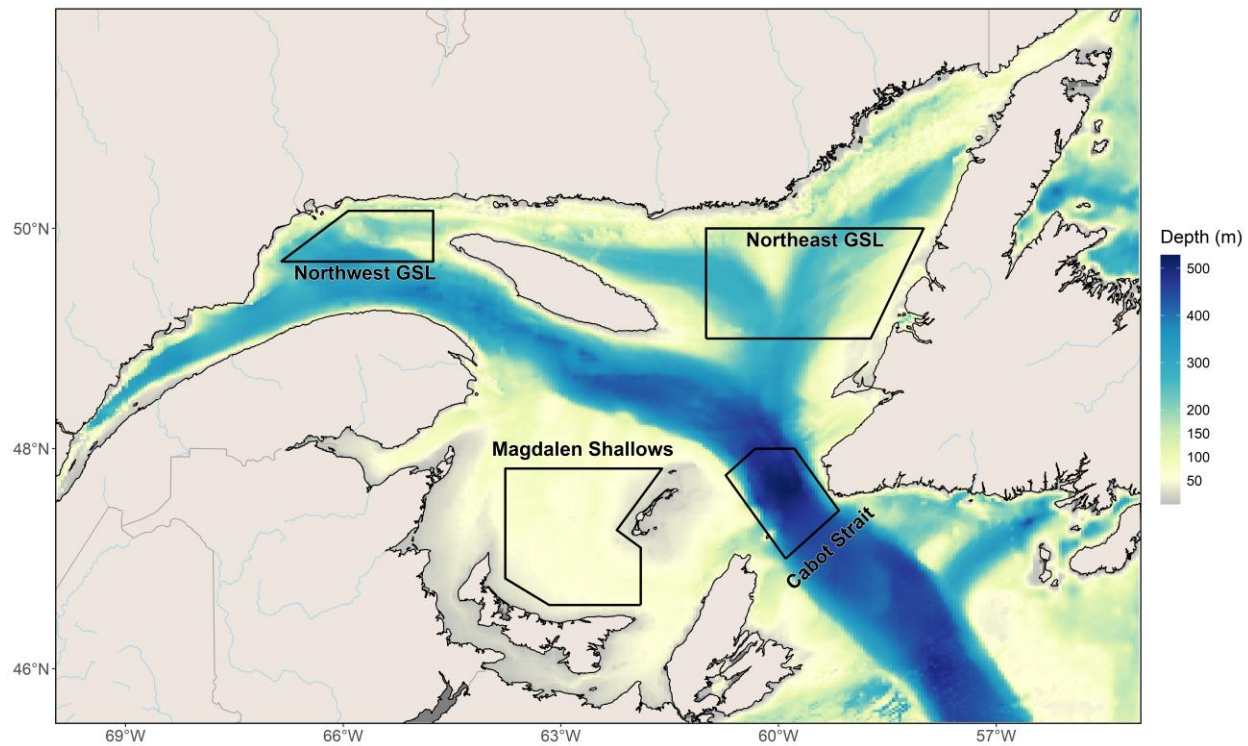


Figure 4. Ocean colour polygons used for the spatial/temporal analysis of satellite ocean colour data.

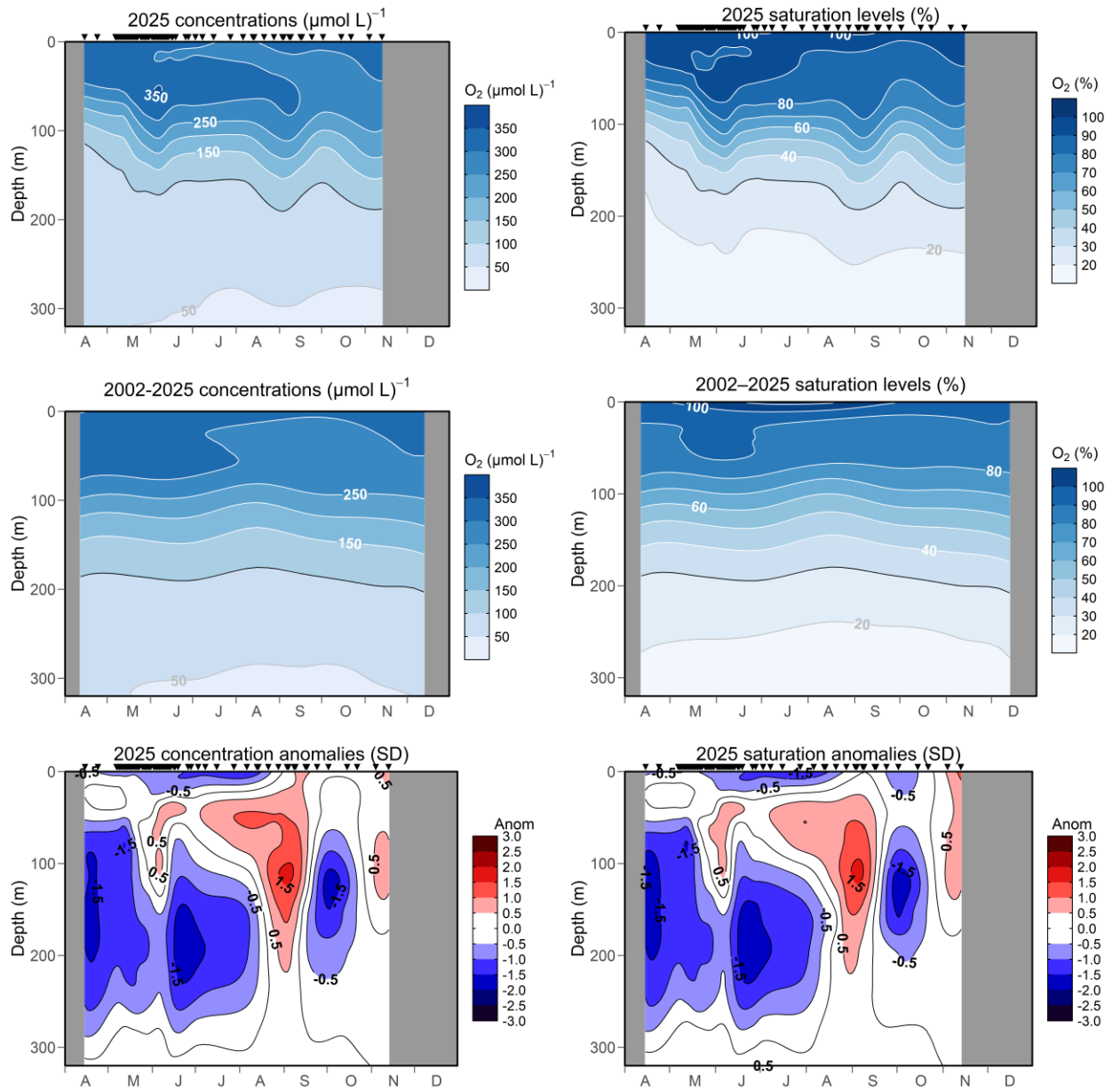


Figure 5. Vertical profiles of oxygen concentration (left panels) and saturation (right panels) at Rimouski station in 2025 (upper panels), climatology 2002–2025 (middle panels), and standardized anomalies for 2025 (bottom panels). For anomalies, blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels. Black triangles indicate the timing of the station occupation and include vertical profiles from the oceanographic buoy. The hypoxia threshold contour line ($100 \mu\text{mol L}^{-1}$ or 30%) is shown in black.

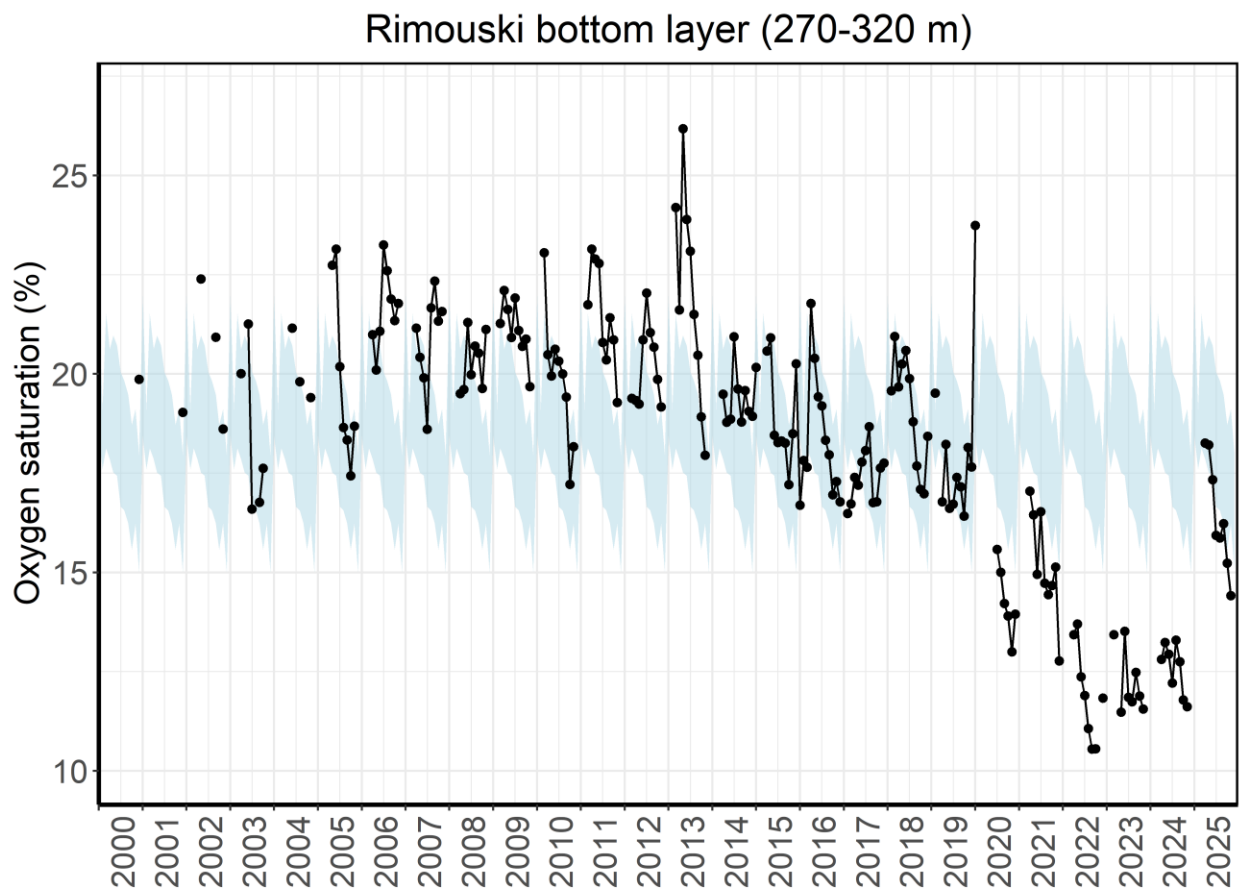


Figure 6. Time series of the monthly average oxygen saturation in the deep waters (> 270 m) of Rimouski station. The blue shading shows the monthly climatology for the 2002–2025 period.

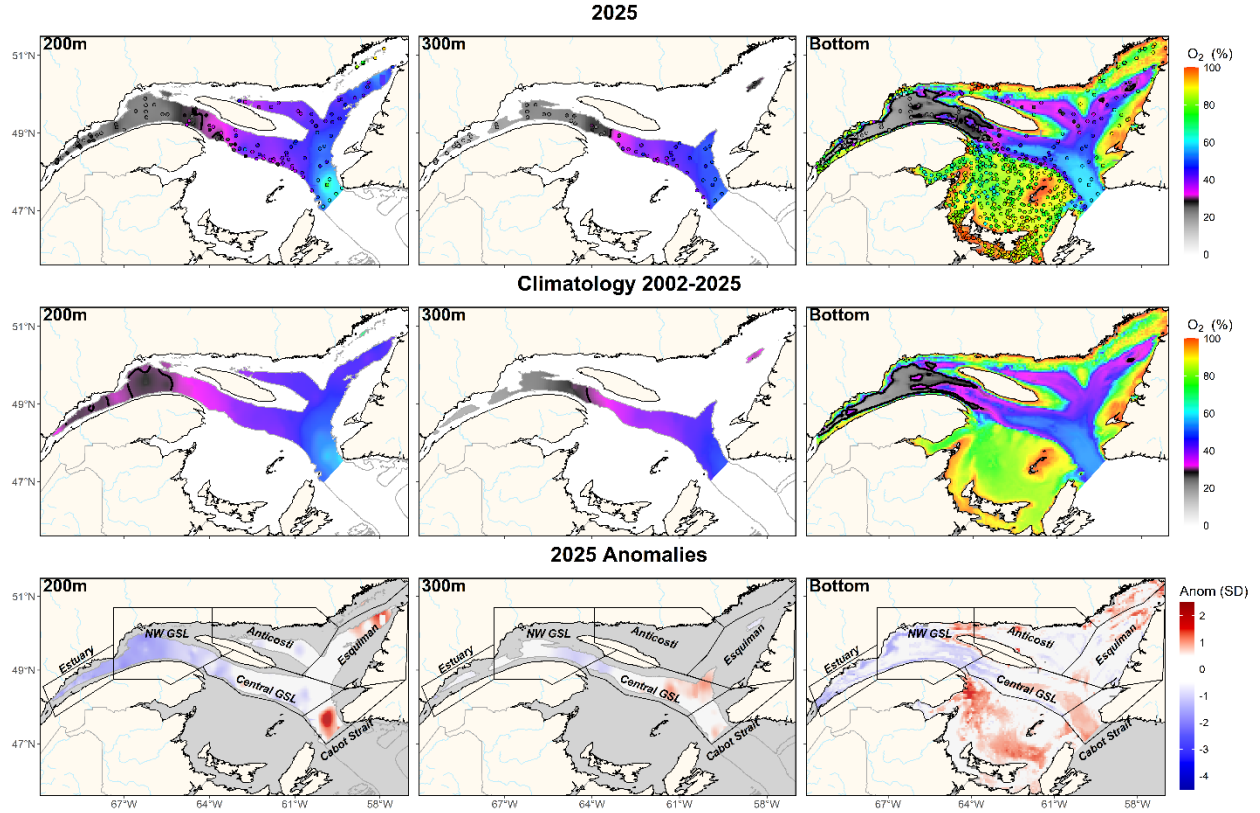


Figure 7. Annual averaged distribution of dissolved oxygen saturation at depths of 200 m, 300 m, and at the bottom in the Estuary and Gulf of St. Lawrence during 2025 (upper panel). The climatology (2002–2025; middle panel), and standardized anomalies (SD; lower panel) are also shown. The black contour lines identify areas associated with hypoxic waters (<30%). In the bottom panels, blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels. Open circles show station locations in 2025.

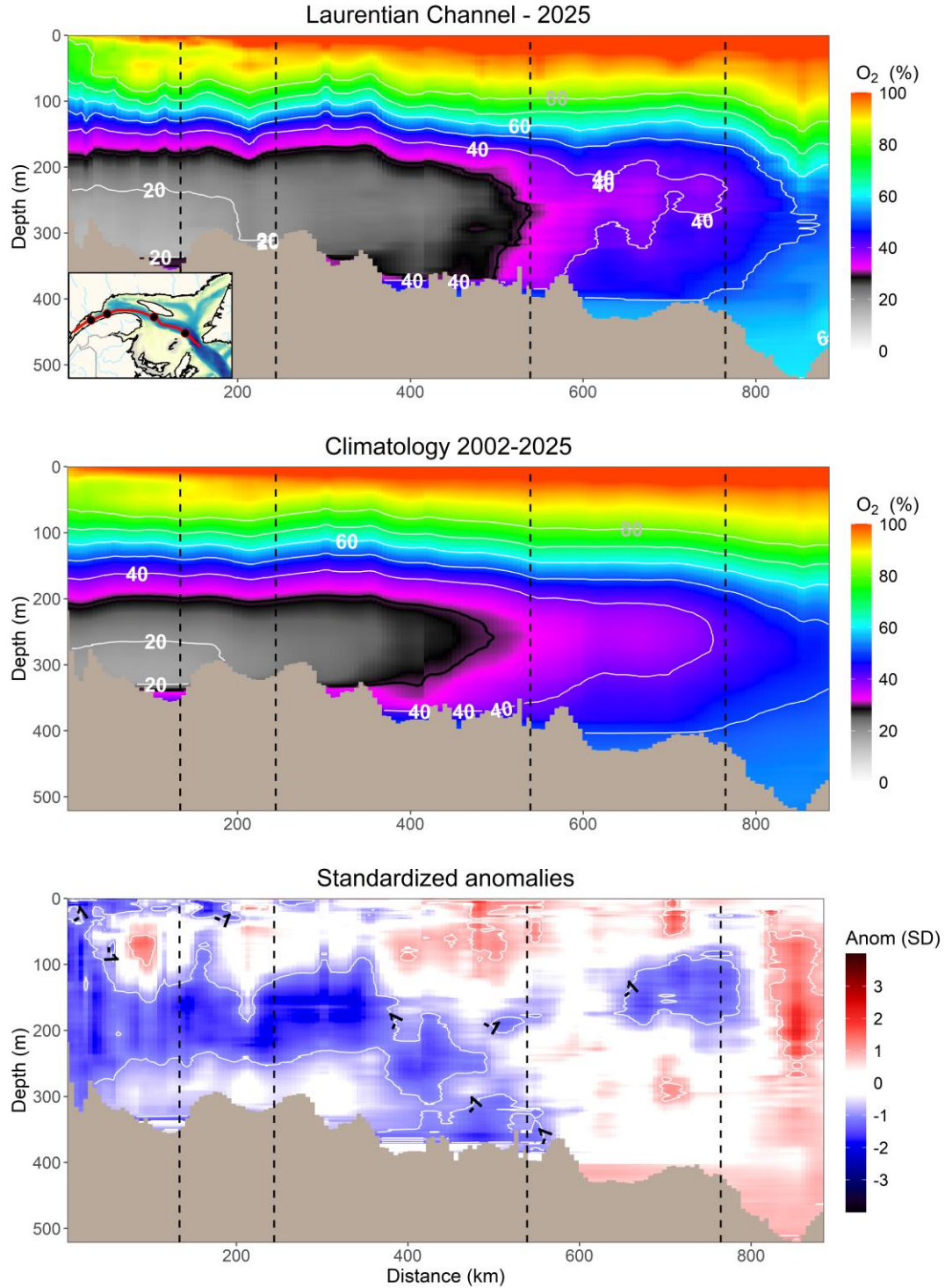


Figure 8. Mean annual vertical distribution of oxygen saturation along the Laurentian Channel in 2025 (upper panel), and for climatology (2002–2025; middle panel). The black contour lines identify areas associated with hypoxic waters ($<30\%$). Standardized anomalies (SD) are presented in the bottom panel where blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels. Section is presented from the head of the Laurentian Channel (Estuary) to Cabot Strait. The dashed black vertical lines are geographical markers corresponding to the black points on the map (left bottom corner of the upper panel).

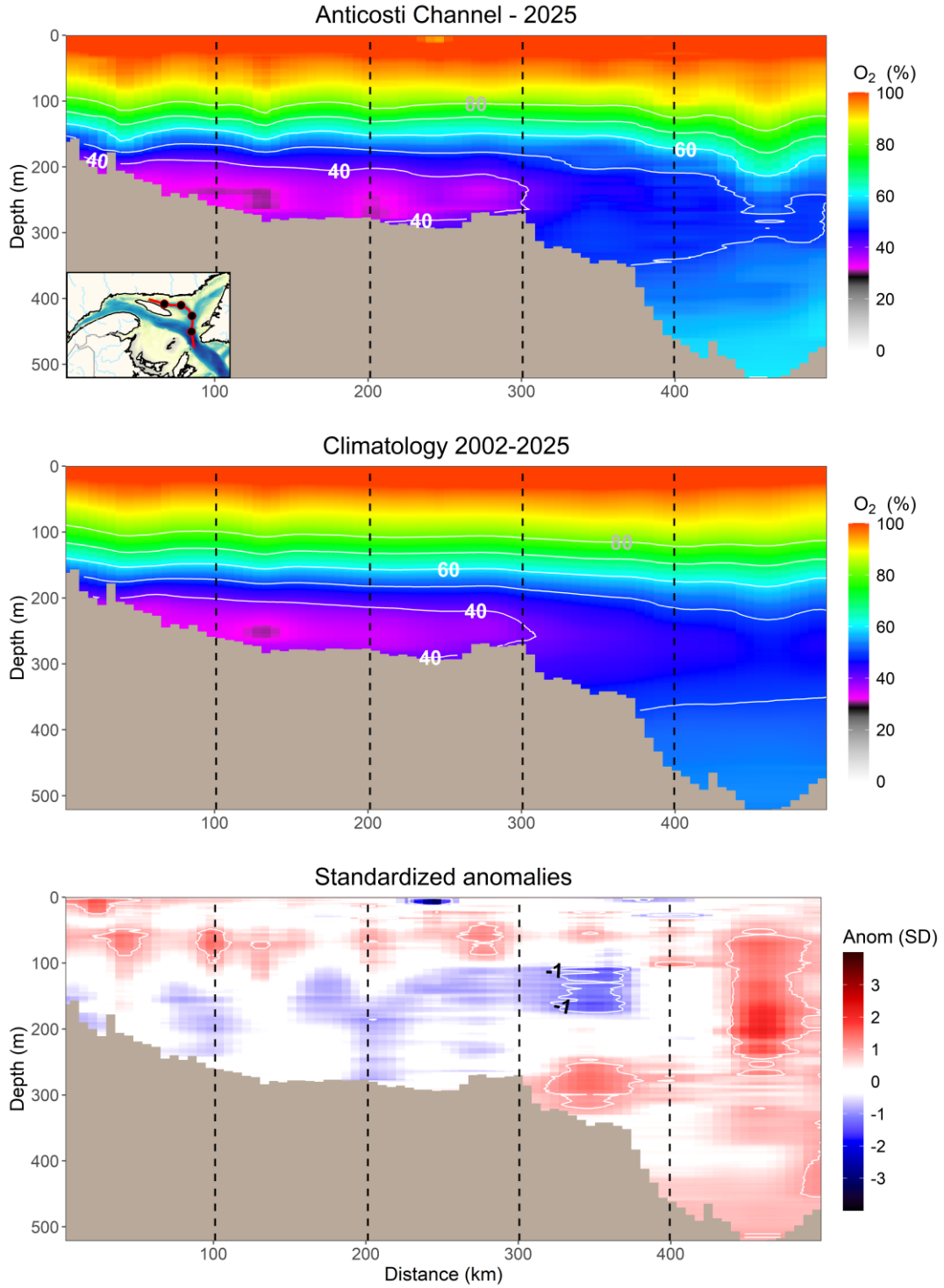


Figure 9. Mean annual vertical distribution of oxygen saturation along the Anticosti Channel in 2025 (upper panel), and for climatology (2002–2025; middle panel). Standardized anomalies (SD) are presented in the bottom panel where blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels. Section is presented from the head of the Anticosti Channel to Cabot Strait. The dashed black vertical lines are geographical markers corresponding to the black points on the map (left bottom corner of the upper panel).

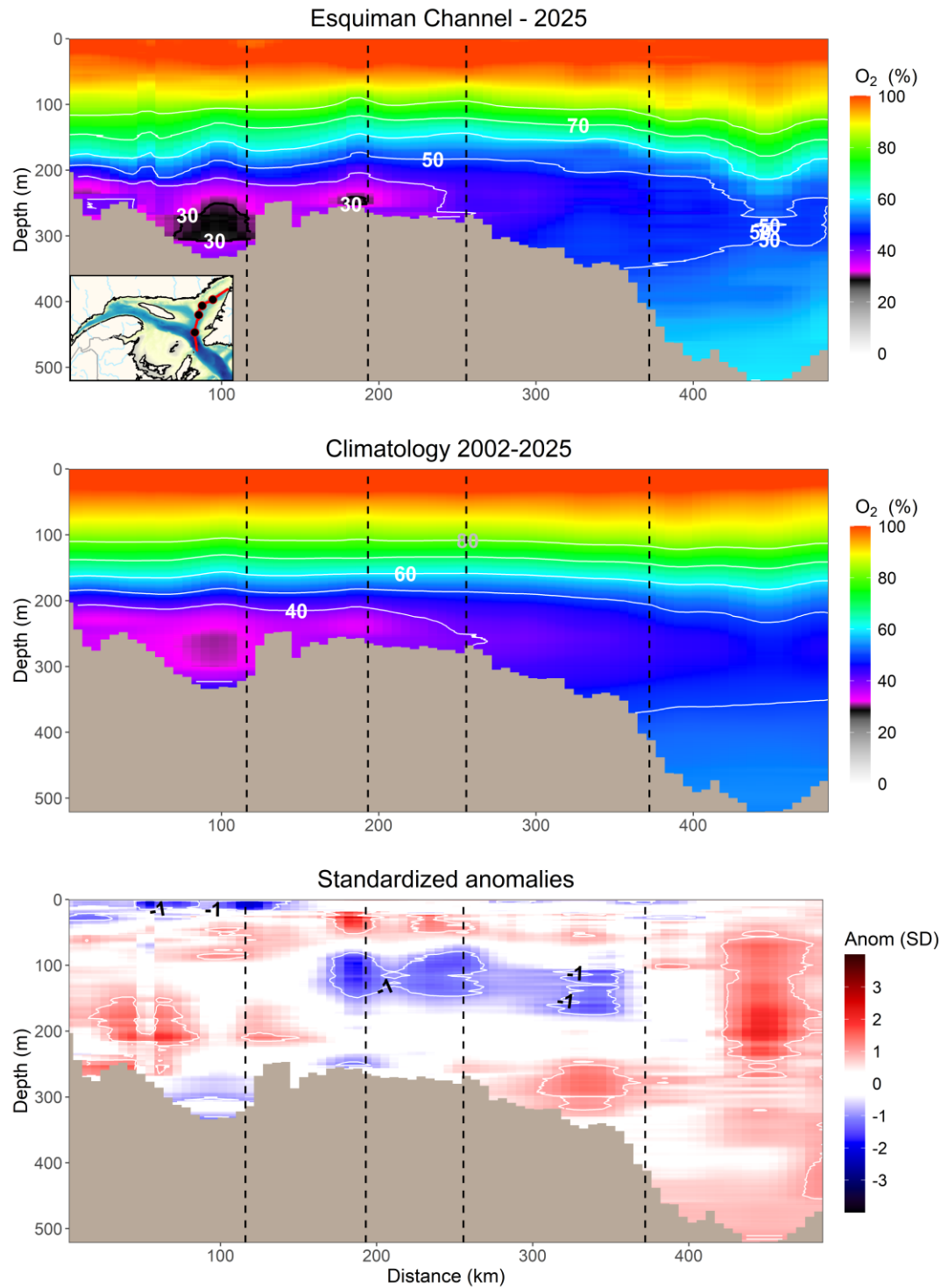


Figure 10. Mean annual vertical distribution of oxygen saturation along the Esquiman Channel in 2025 (upper panel), and for climatology (2002–2025; middle panel). The black contour lines identify areas associated with hypoxic waters (<30%). Standardized anomalies (SD) are presented in the bottom panel where blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels. Section is presented from the head of the Esquiman Channel to Cabot Strait. The dashed black vertical lines are geographical markers corresponding to the black points on the map (left bottom corner of the upper panel).

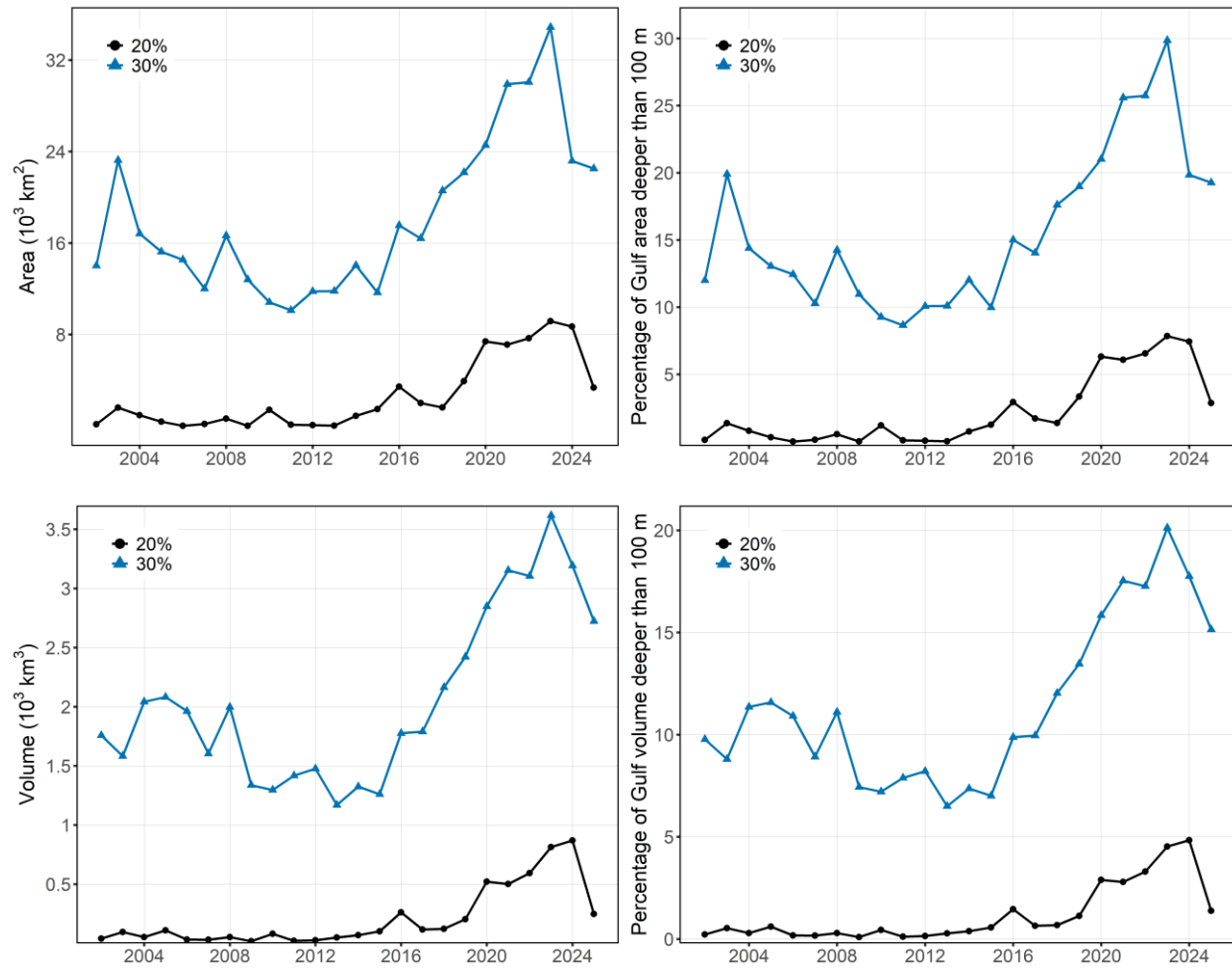


Figure 11. Bottom area and volume of hypoxic (<30% O_2 saturation) and severely hypoxic (<20%) waters in the Gulf of St. Lawrence, 2002–2025 (left panels). The right panels present the proportion of total Gulf area and volume deeper than 100 m affected by these conditions.

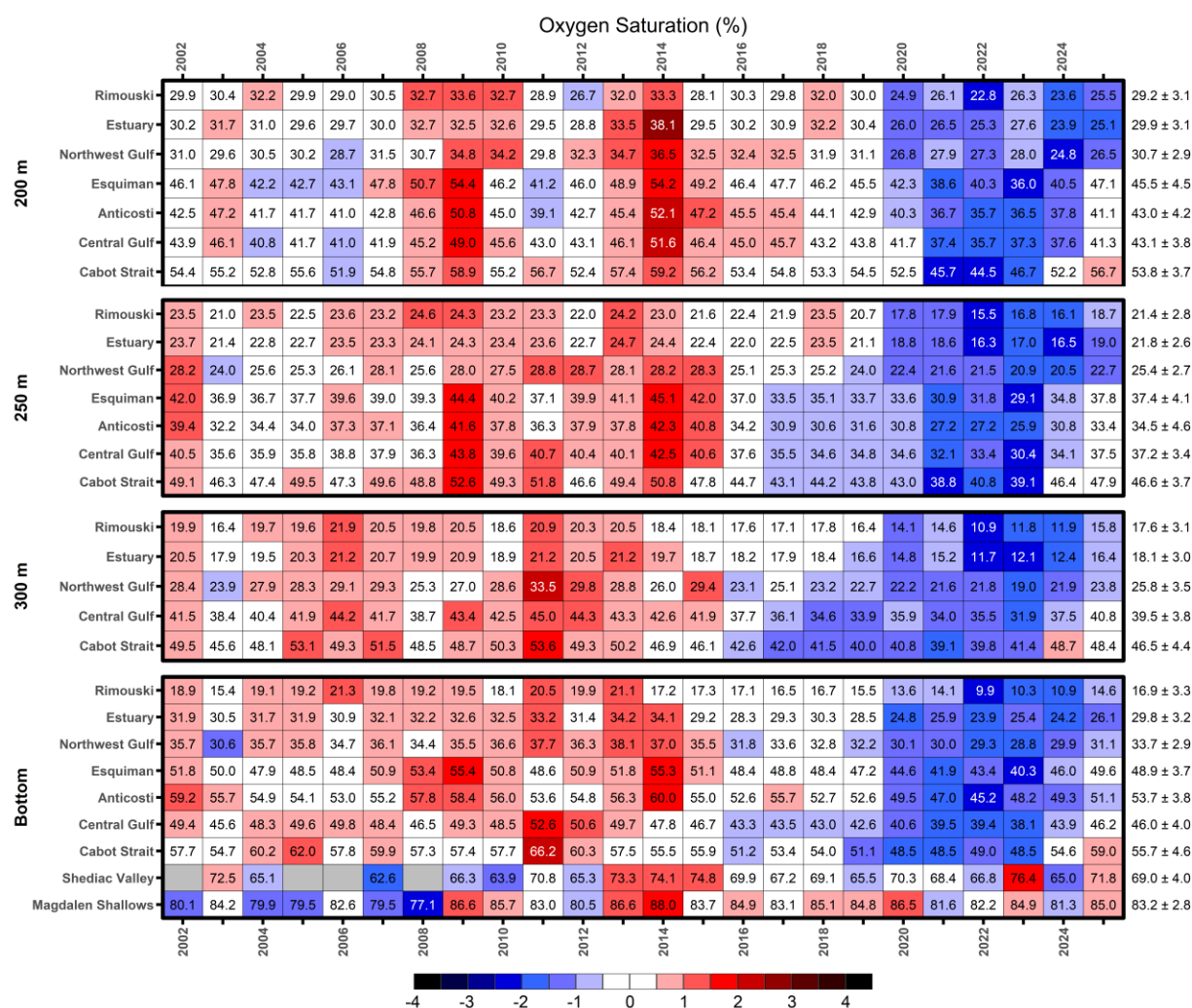


Figure 12. Annual averages of deep-layer dissolved oxygen saturation (%) at 200 m, 250 m, and 300 m, and at the bottom. For all sub-regions except the Magdalen Shallows, bottom values are averaged only over grid points deeper than 100 m; in the Magdalen Shallows, all grid points were included. The numbers on the right are the 2002–2025 climatological means and standard deviations, and the numbers in the boxes are the oxygen saturation levels. The scorecard is colour-coded according to the annual standardized anomalies (SD). Blue colours indicate below-normal levels, reds are above-normal levels, and white cells represent normal levels. White text is used for readability purposes when anomalies are higher (lower) than +2 SD (-2 SD) throughout this document.

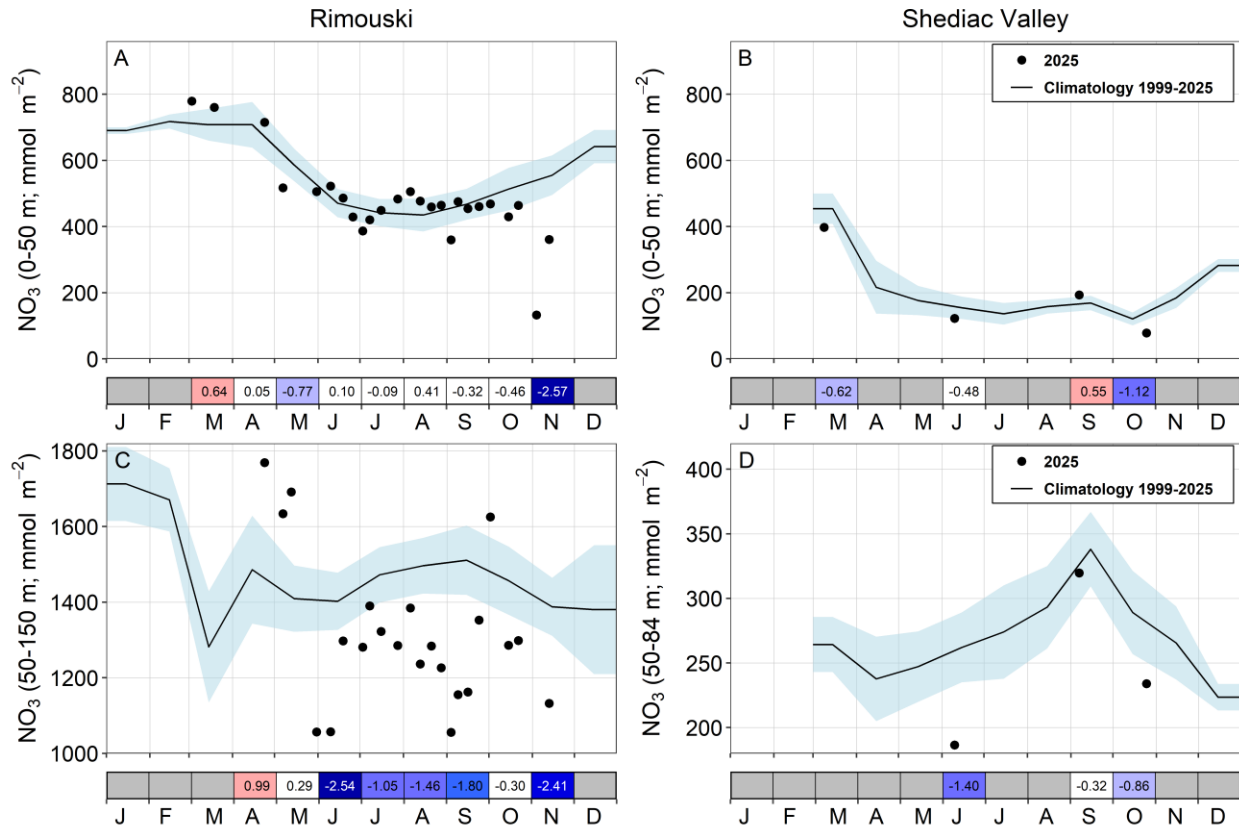


Figure 13. Surface nitrate inventories (0–50 m; top panels), and mid-layer nitrate inventories (50–150 m for Rimouski and 50–84 m for Shediac Valley; bottom panels) in 2025 (black circles) with monthly mean conditions (± 0.5 SD) for the 1999–2025 climatology (black line with blue shading) at Rimouski and Shediac Valley stations. The scorecards show monthly nitrate inventory standardized anomalies (SD), where blue indicates below-normal values, red indicates above-normal values, and white indicates normal values.

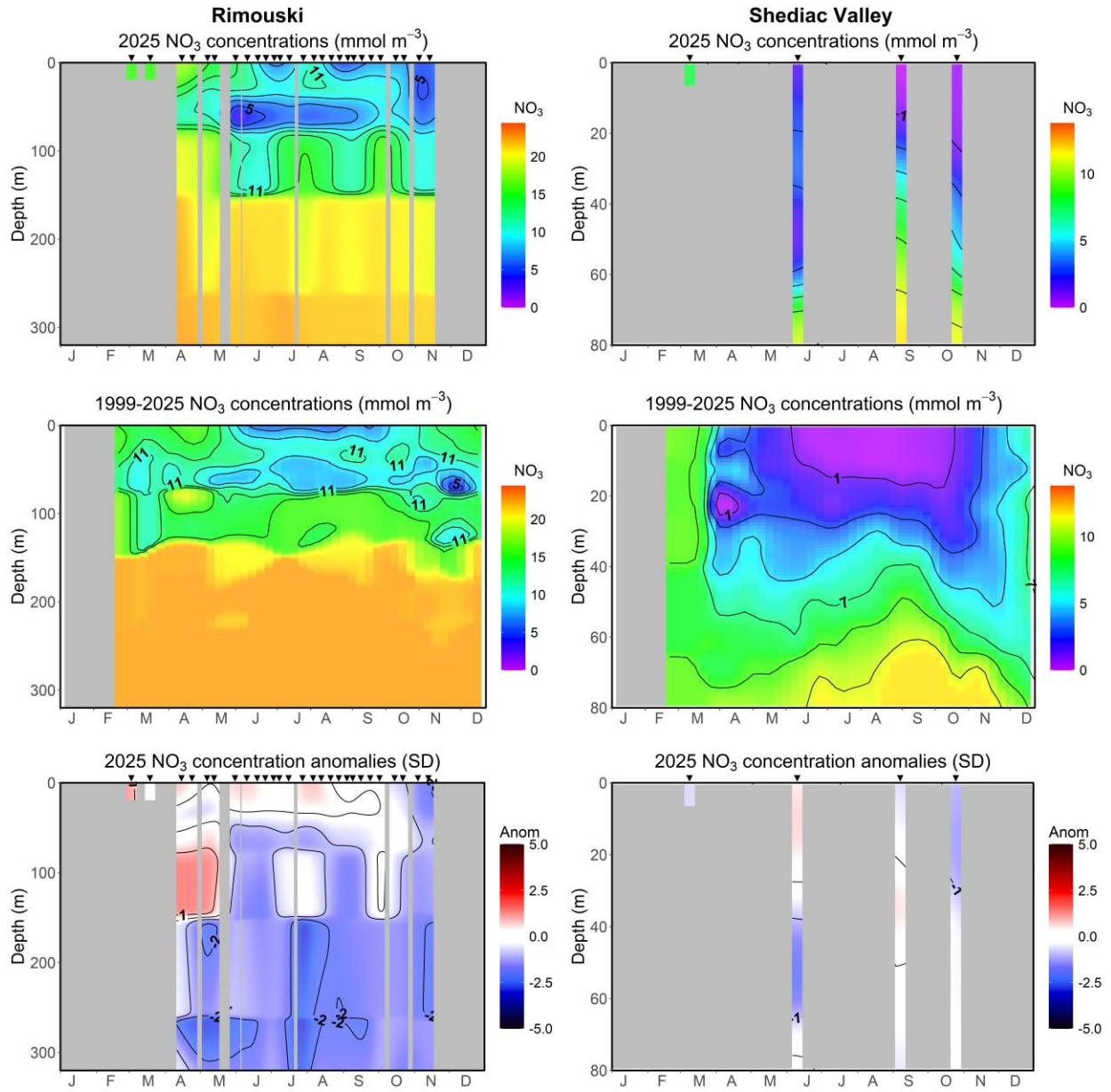


Figure 14. Vertical profiles of nitrate concentrations (mmol m⁻³) at Rimouski and Shediac Valley stations in 2025 (upper panels), and for the 1999–2025 climatology (middle panels). Bottom panels show the vertical profiles of nitrate standardized anomalies (SD). Blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels. Black triangles indicate the timing of the station occupation.

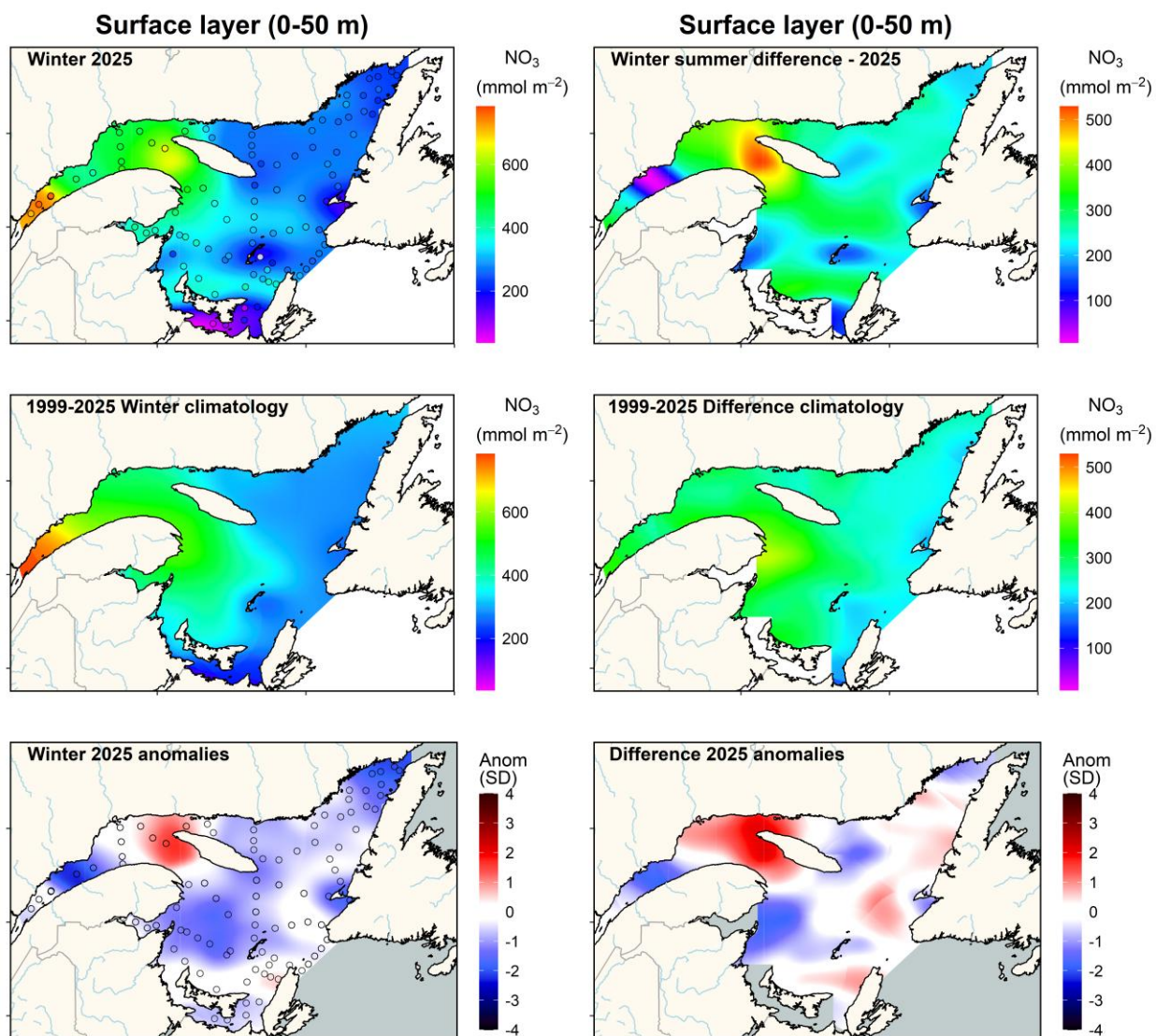


Figure 15. Nitrate inventories (mmol m⁻²) in the surface layer (0–50 m) of the Estuary and Gulf of St. Lawrence during early March 2025 (upper left panel). Difference in nitrate inventories (mmol m⁻²) in the surface layer of the Estuary and Gulf of St. Lawrence between winter and early summer (upper right panel). The climatology (1999–2025; middle panels), and standardized anomalies (SD; lower panels) are shown. Blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels. Open circles show station locations in 2025.

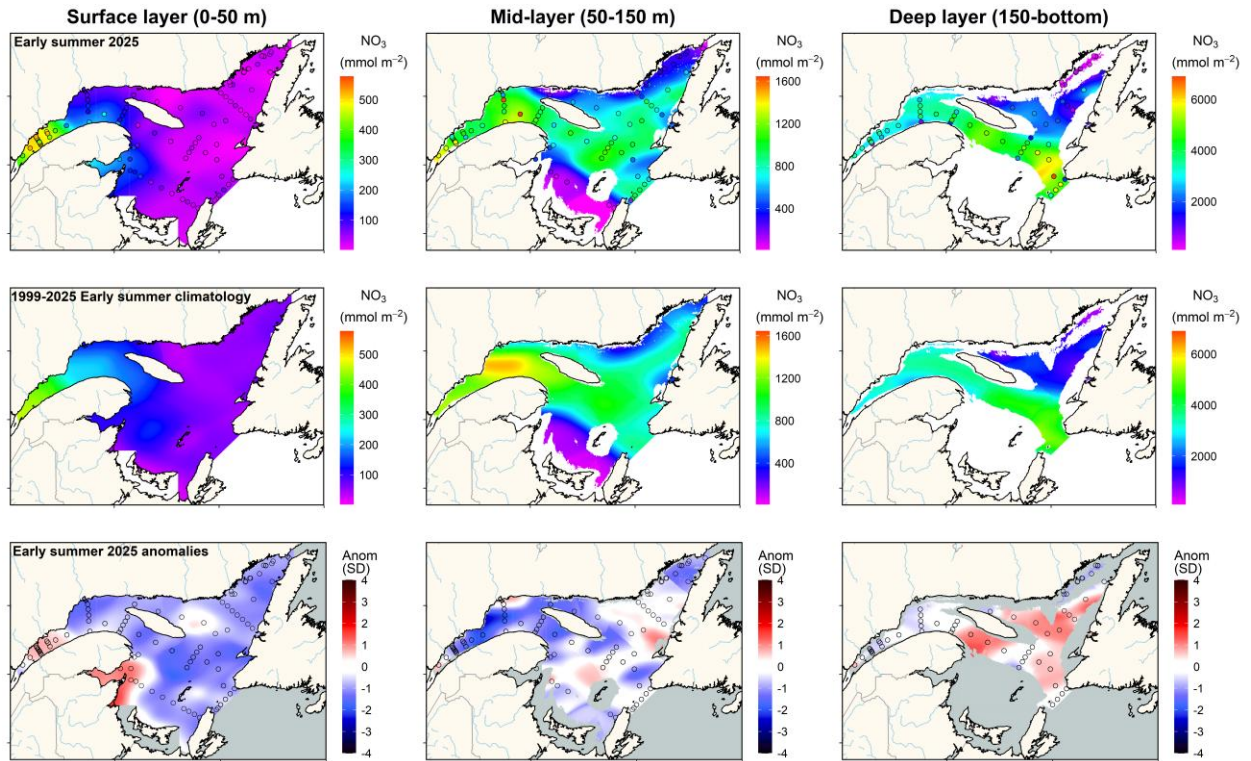


Figure 16. Nitrate inventories (mmol m^{-2}) in the surface (left panels), mid (middle panels), and deep (right panels) layers of the Estuary and Gulf of St. Lawrence during early summer 2025 (upper panels). The climatology (1999–2025; middle panels), and standardized anomalies (SD; lower panels) are shown for each layer. Blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels. Open circles show station locations in 2025.

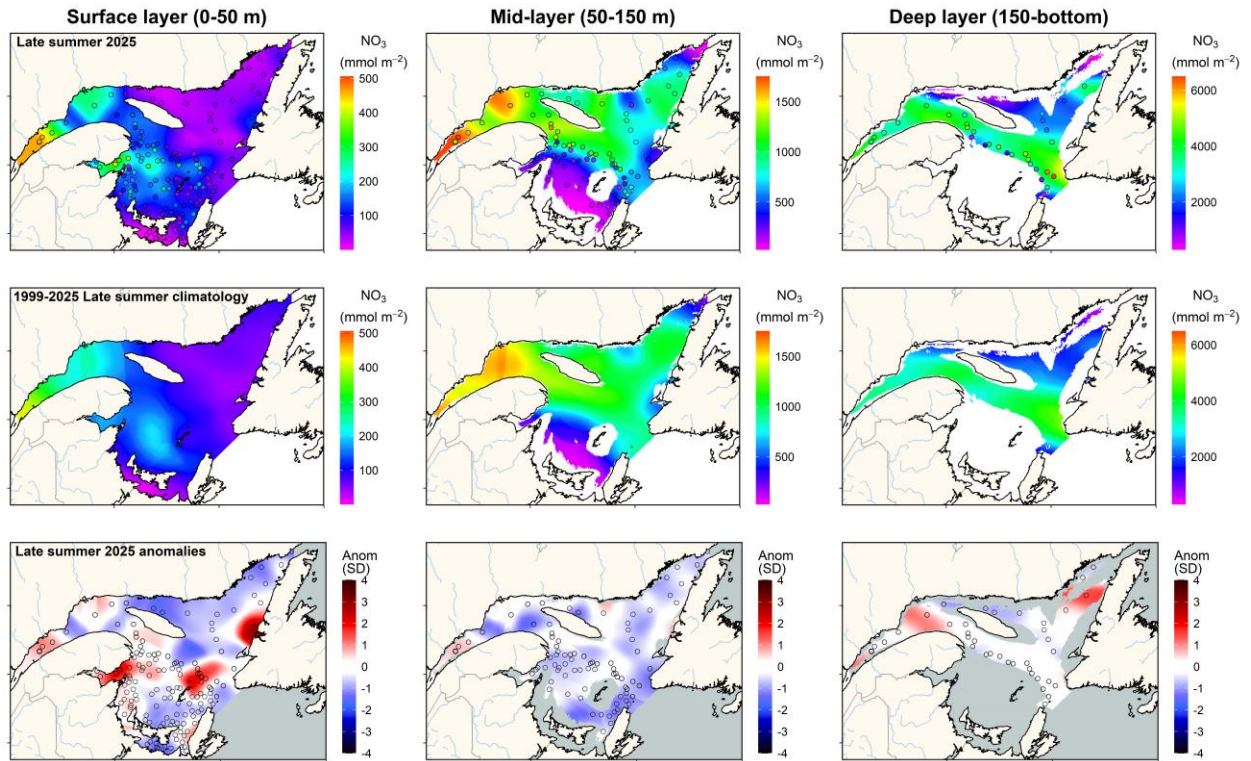


Figure 17. Nitrate inventories (mmol m^{-2}) in the surface (left panels), mid (middle panels), and deep (right panels) layers of the Estuary and Gulf of St. Lawrence during late summer 2025 (upper panels). The climatology (1999–2025; middle panels), and standardized anomalies (SD; lower panels) are shown for each layer. Blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels. Open circles show station locations in 2025.

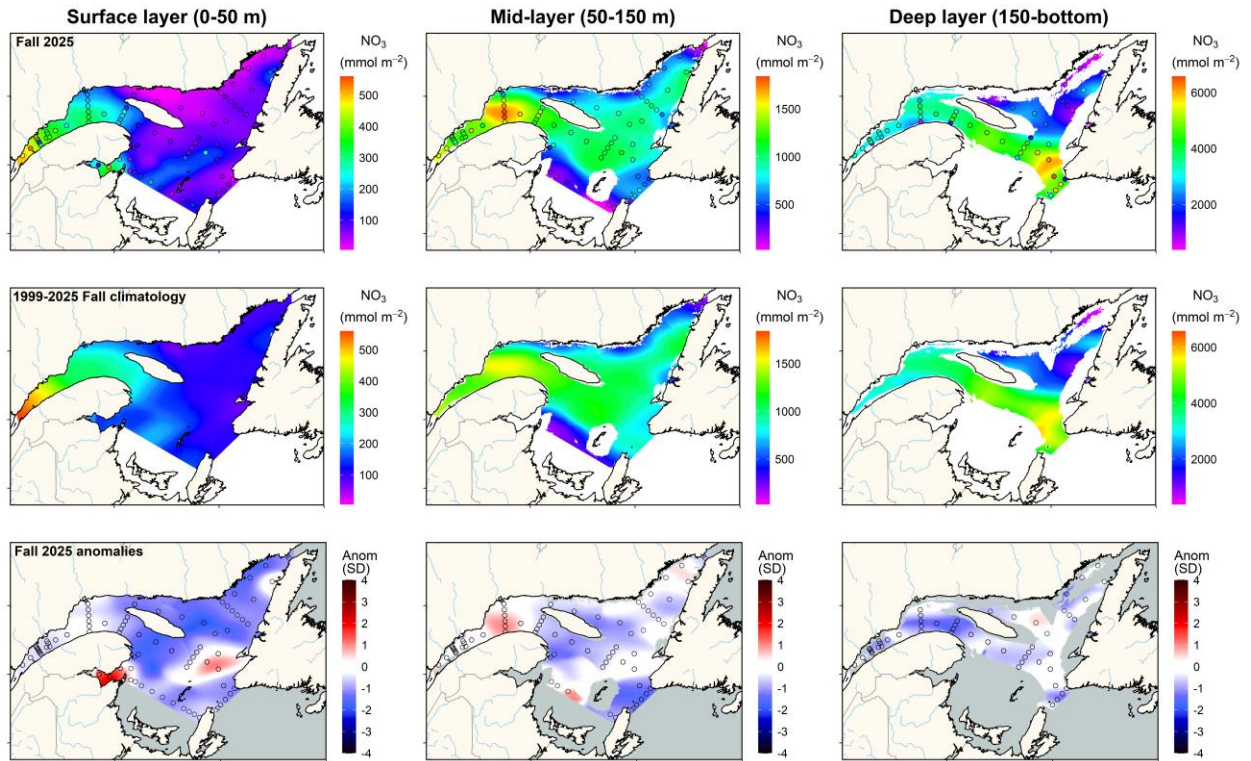


Figure 18. Nitrate inventories (mmol m^{-2}) in the surface (left panels), mid (middle panels), and deep (right panels) layers of the Estuary and Gulf of St. Lawrence during fall 2025 (upper panels). The climatology (1999–2025; middle panels), and standardized anomalies (SD; lower panels) are shown for each layer. Blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels. Open circles show station locations in 2025.

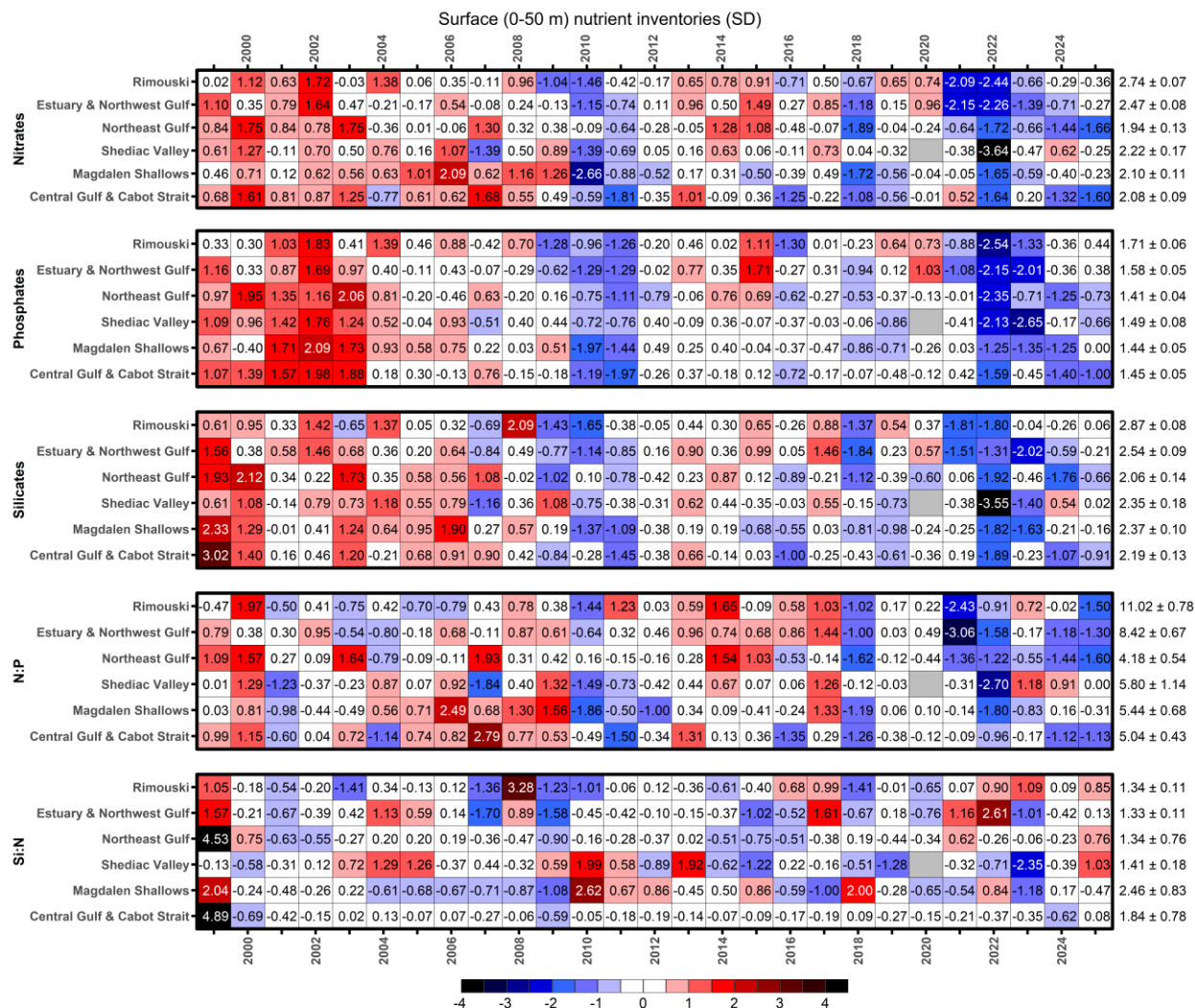


Figure 19. Time series of standardized annual anomalies (SD) for nutrient inventories and ratios in the surface layer (0–50 m) for high-frequency monitoring stations and Gulf regions. The numbers on the right are the 1999–2025 climatological means and standard deviations in units of $\log_{10}(\text{mmol m}^{-2})$ for nutrient inventories; nutrient ratios are dimensionless and have not been log-transformed. Blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels.

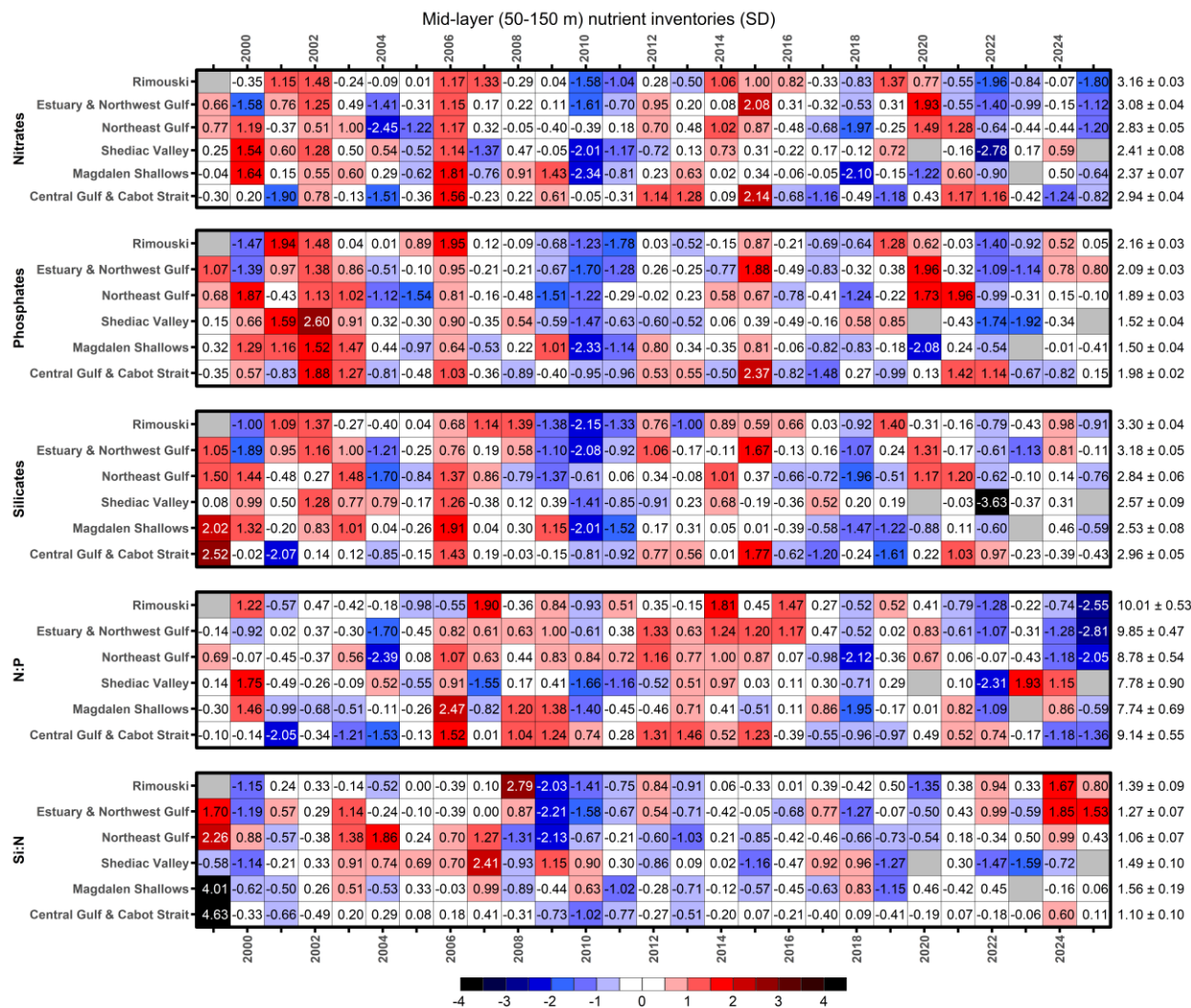


Figure 20. Time series of standardized annual anomalies (SD) for nutrient inventories and ratios in the mid-layer (50–150 m) for high-frequency monitoring stations and Gulf regions. The numbers on the right are the 1999–2025 climatological means and standard deviations in units of $\log_{10}(\text{mmol m}^{-2})$ for nutrient inventories; nutrient ratios are dimensionless and have not been log-transformed. Blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels.

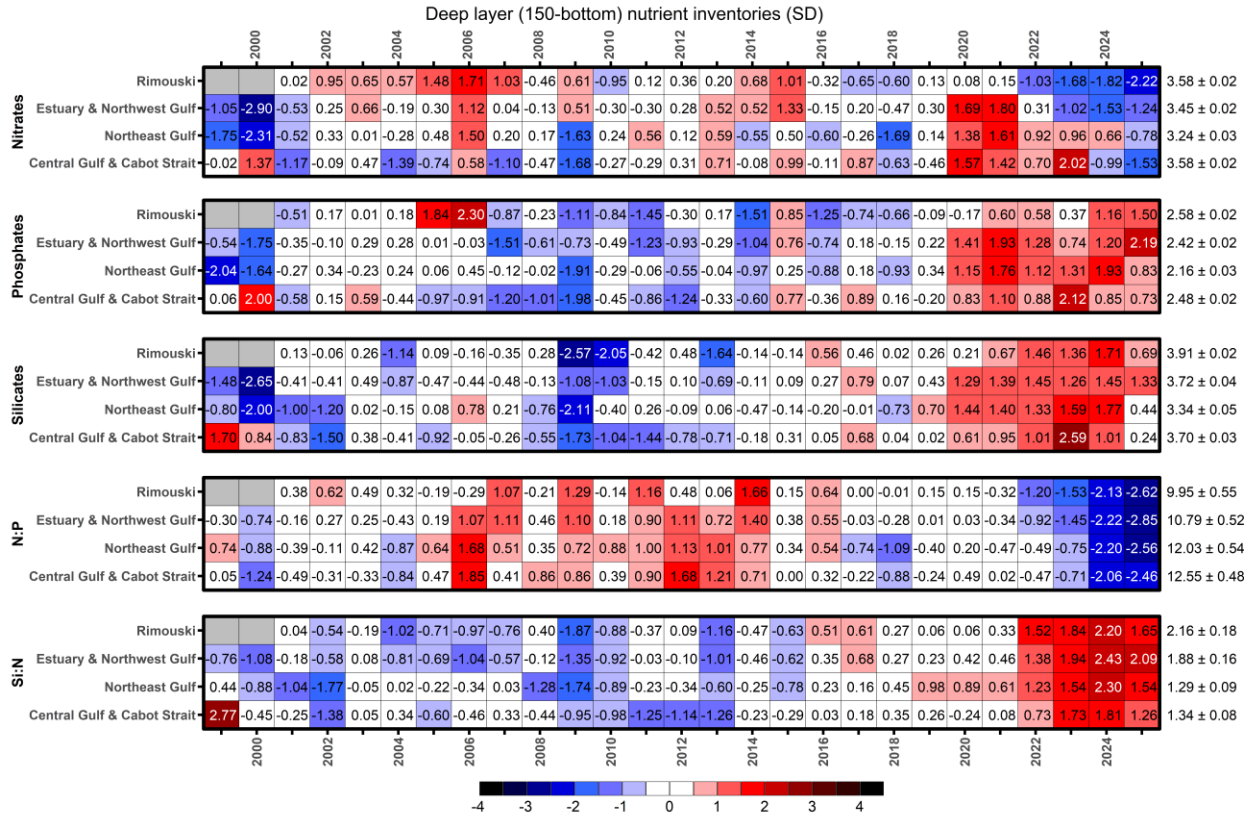


Figure 21. Time series of standardized annual anomalies (SD) for nutrient inventories and ratios in the deep layer (150–bottom) for high-frequency monitoring stations and Gulf regions. The numbers on the right are the 1999–2025 climatological means and standard deviations in units of $\log_{10}(\text{mmol m}^{-2})$ for nutrient inventories; nutrient ratios are dimensionless and have not been log-transformed. Blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels.

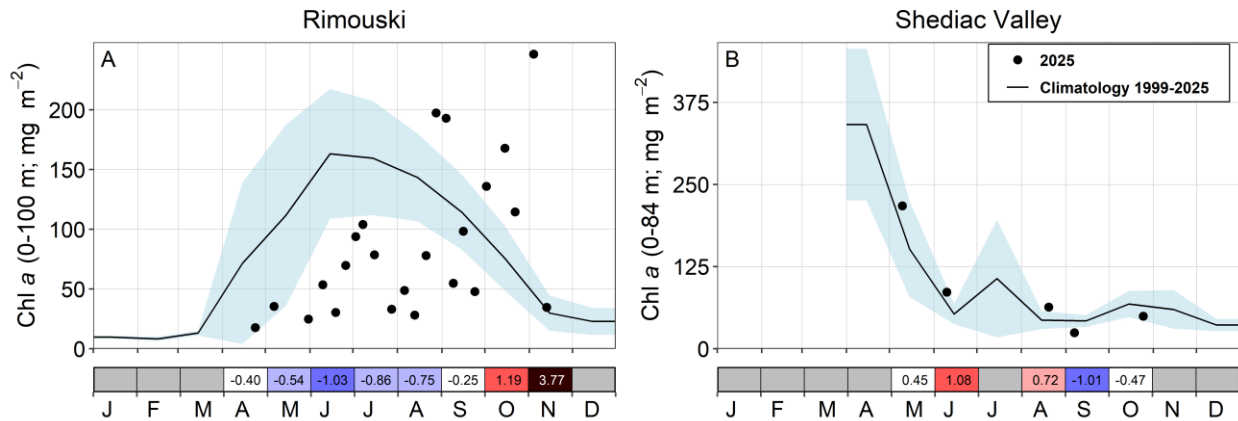


Figure 22. Chlorophyll *a* inventories (0–100 m for Rimouski and 0–84 m for Shediac Valley) in 2025 (black circles) with monthly mean conditions (± 0.5 SD) for the 1999–2025 climatology (black line with blue shading) at Rimouski and Shediac Valley stations. The scorecards show monthly chlorophyll *a* inventory standardized anomalies (SD), where blue indicates below-normal values, red indicates above-normal values, and white indicates normal values.

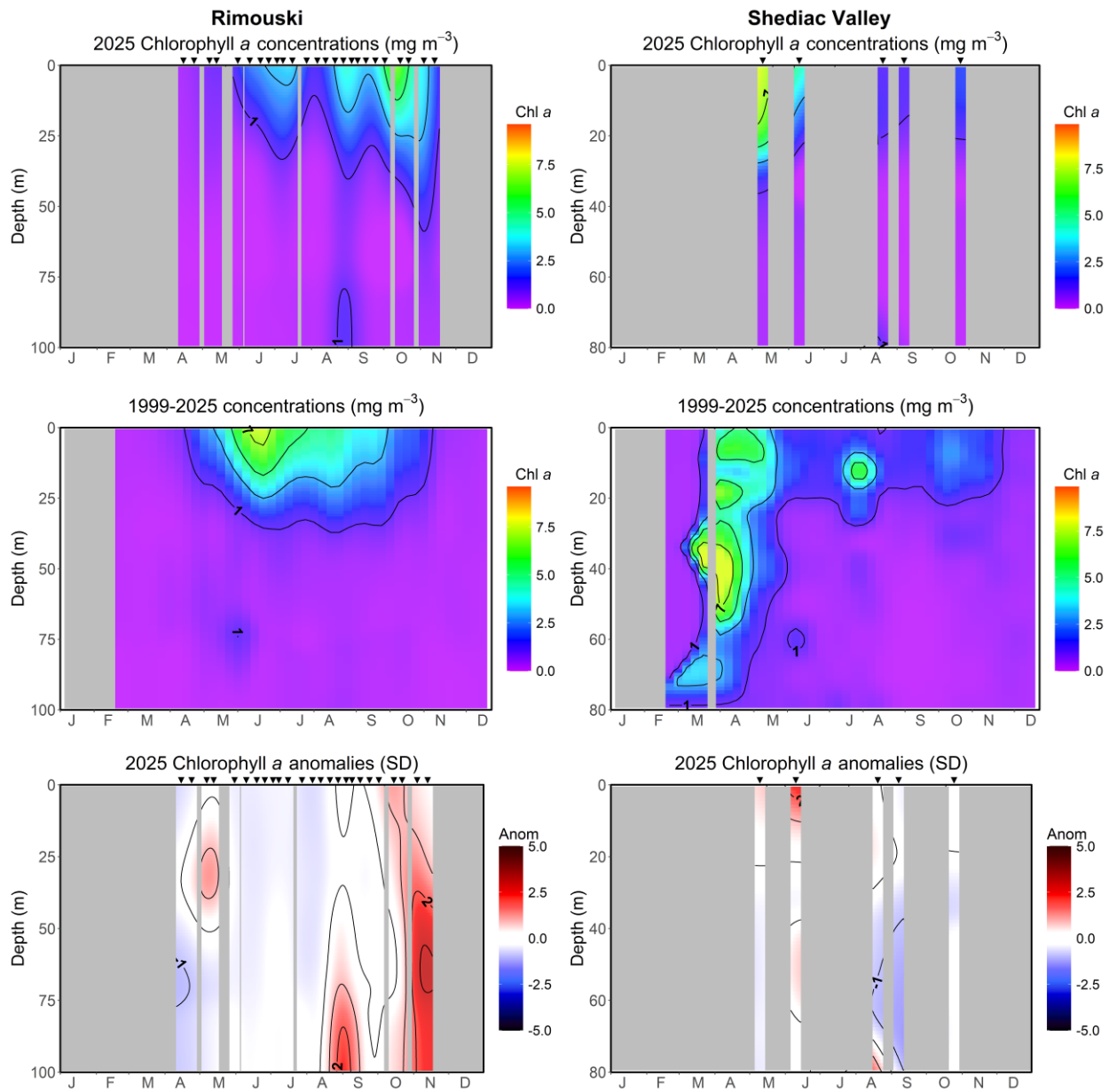


Figure 23. Vertical profiles of chlorophyll *a* concentrations (mg m^{-3}) at Rimouski and Shediac Valley stations in 2025 (upper panels), and for the 1999–2025 climatology (middle panels). Bottom panels show the vertical profiles of chlorophyll *a* standardized anomalies (SD). Blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels. Black triangles indicate the timing of the station occupation.

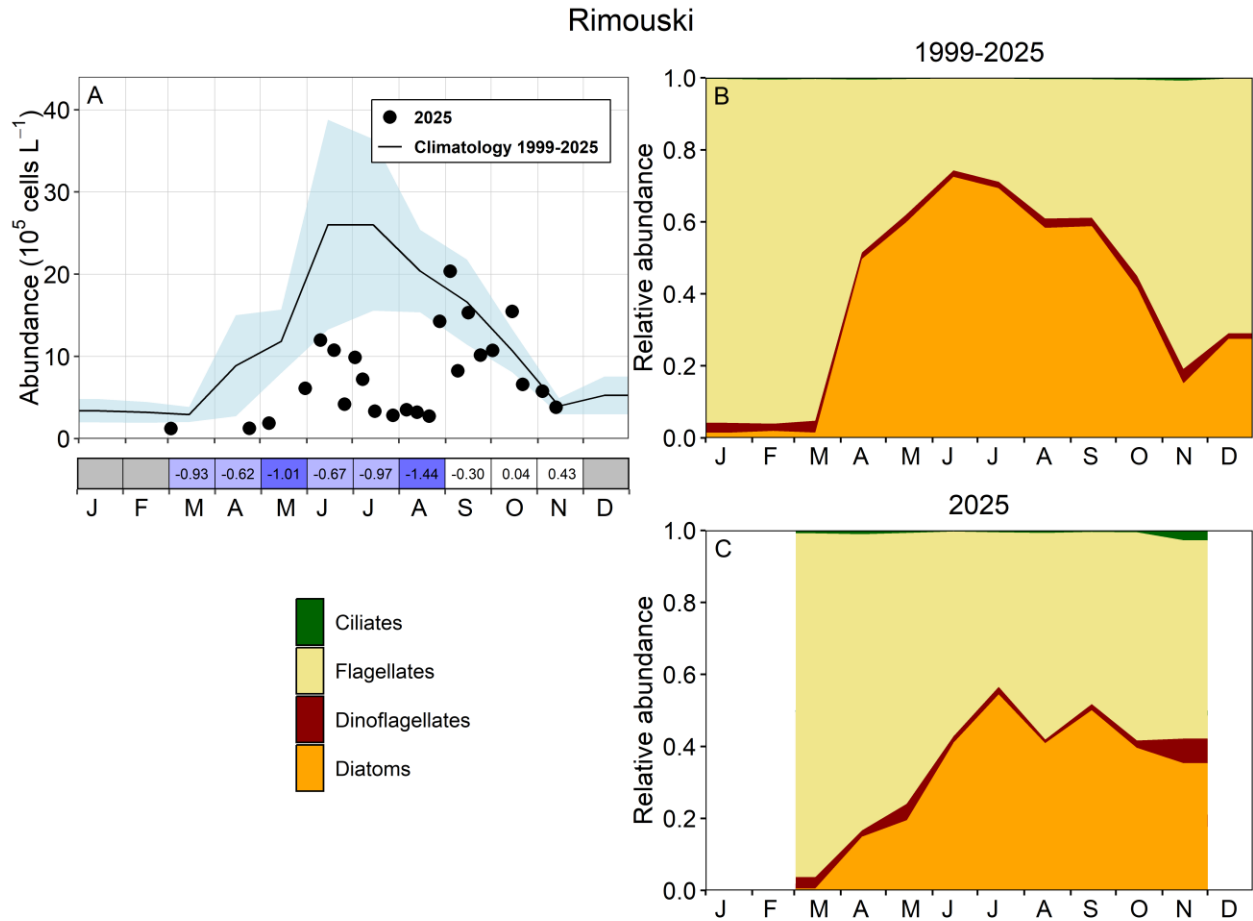


Figure 24. Phytoplankton abundance (A), and community composition at Rimouski station for the 1999–2025 climatology (B), and for 2025 (C). Blue shading on panel (A) represents ± 0.5 SD of the monthly mean phytoplankton abundance for the climatology. While ciliate abundances were included in the graphics, they are barely visible because they usually represent $<1\%$ of phytoplankton cells each month for the climatology. The scorecards show monthly phytoplankton abundance standardized anomalies (SD), where blue indicates below-normal values, red indicates above-normal values, and white indicates normal values.

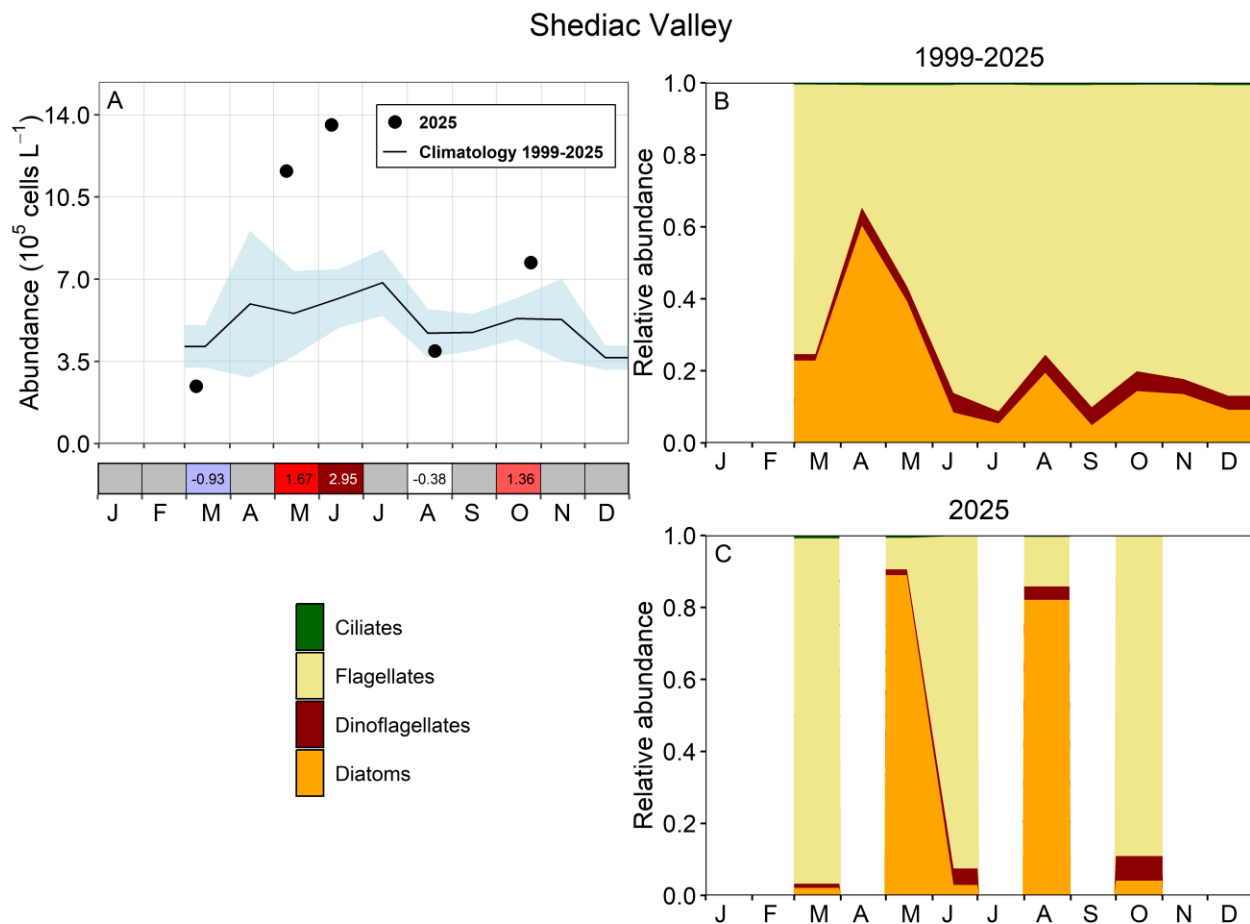


Figure 25. Phytoplankton abundance (A), and community composition at Shediac Valley station for the 1999–2025 climatology (B), and for 2025 (C). Blue shading on panel (A) represents ± 0.5 SD of the monthly mean phytoplankton abundance for the climatology. While ciliate abundances were included in the graphics, they are barely visible because they usually represent $<1\%$ of phytoplankton cells each month for the climatology. The scorecards show monthly phytoplankton abundance standardized anomalies (SD), where blue indicates below-normal values, red indicates above-normal values, and white indicates normal values.

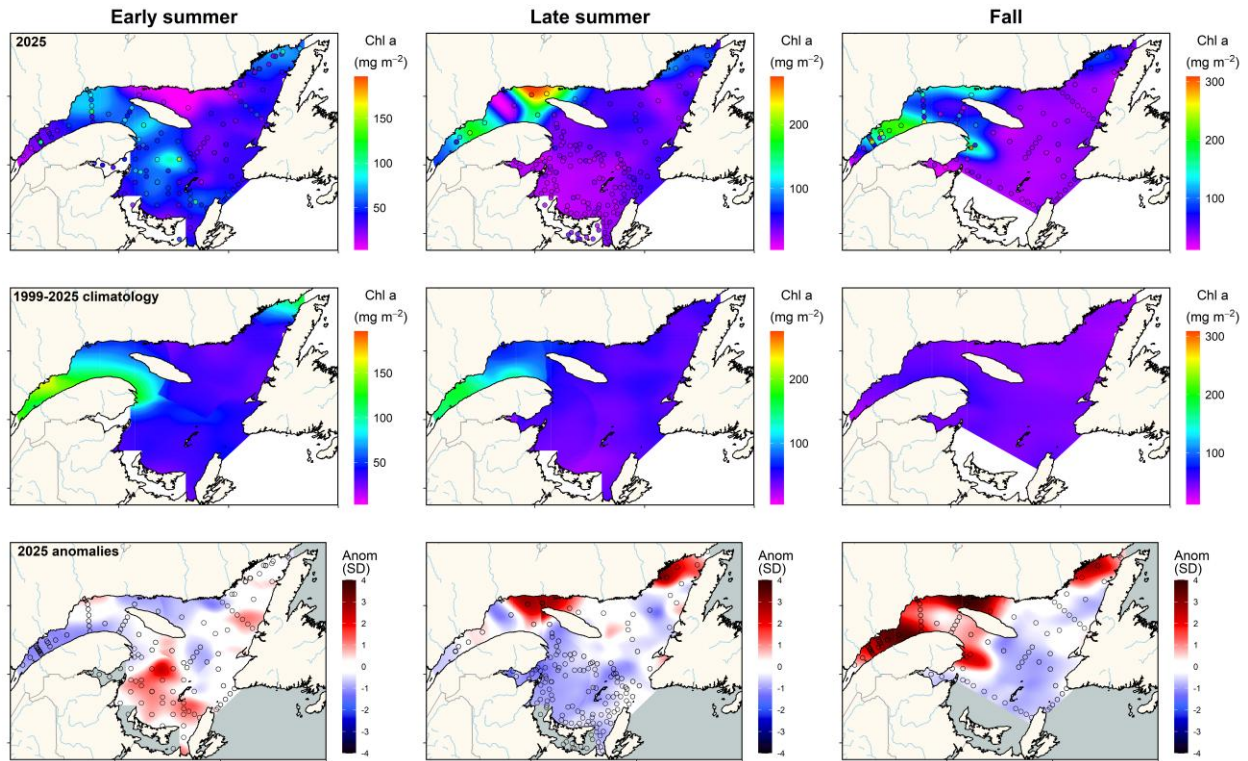


Figure 26. Vertically integrated (0–100 m) chlorophyll a inventory (mg m^{-2}) in the Estuary and Gulf of St. Lawrence during early summer (left panels), late summer (middle panels), and fall (right panels) 2025. The climatology (1999–2025; middle panels) and standardized anomalies (SD; lower panels) are shown for each season. Blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels. Open circles show station locations in 2025.

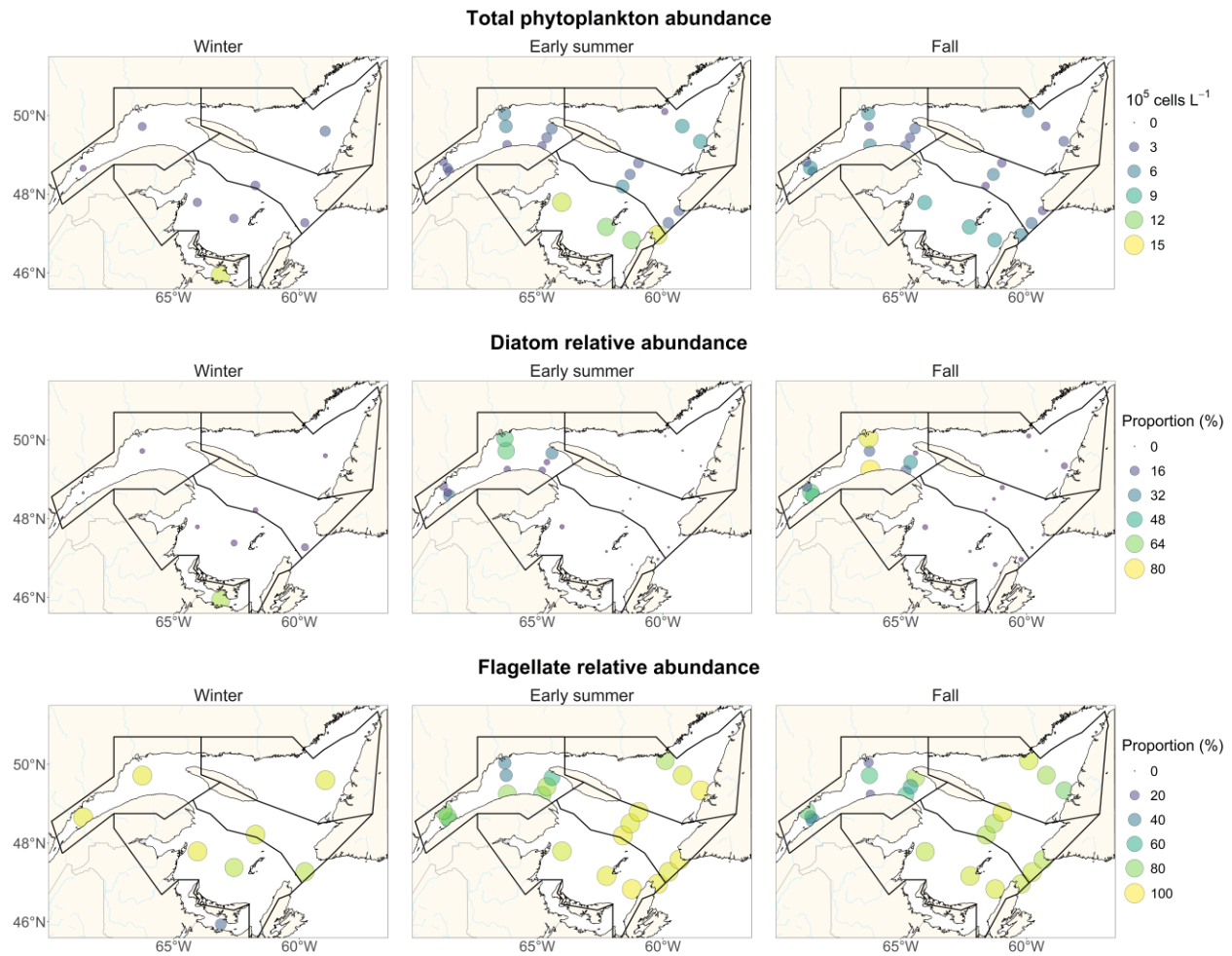


Figure 27. Total phytoplankton abundance (10⁵ cells L⁻¹; top panels) and proportion (%) of diatoms (mid-panels) and flagellates (bottom panels) in the upper 100 m of the Estuary and Gulf of St. Lawrence during winter, early summer and fall 2025.

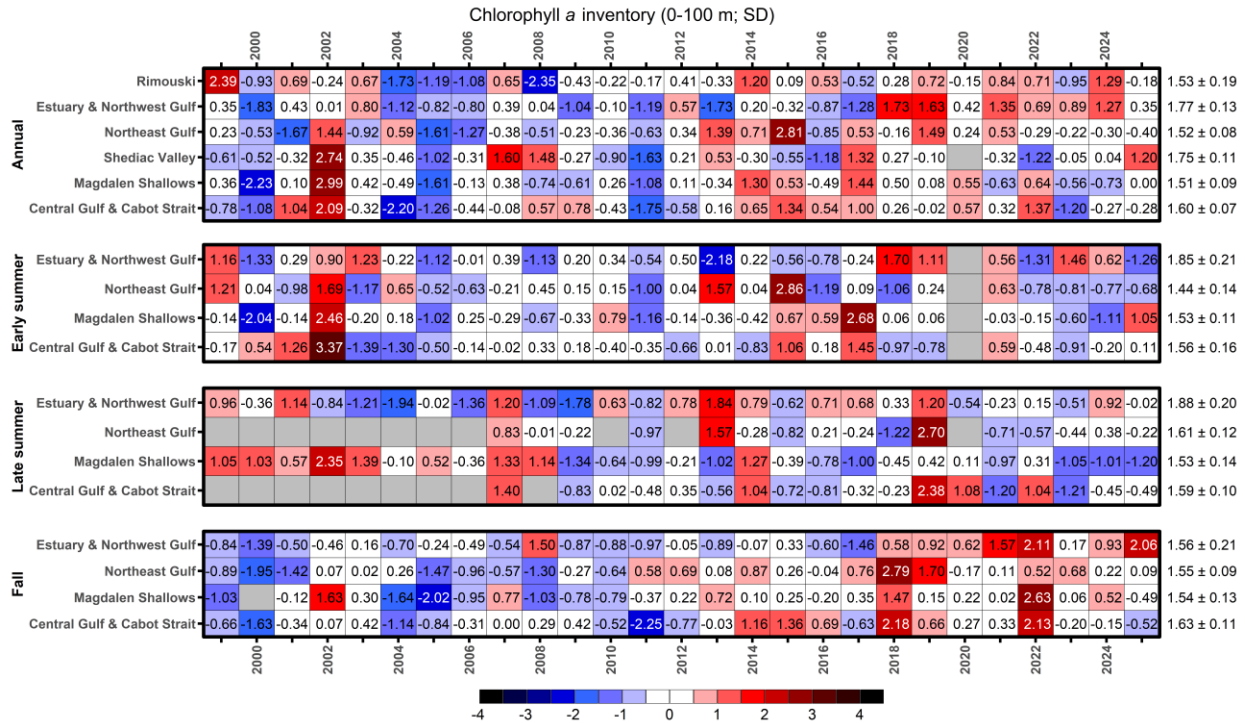


Figure 28. Time series of standardized annual and seasonal anomalies (SD) for chlorophyll *a* inventories (0–100 m) for high-frequency monitoring stations and Gulf regions. The numbers on the right are the 1999–2025 climatological means and standard deviations in units of $\log_{10}(\text{mg m}^{-2})$. Blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels. Gray cells indicate missing data.

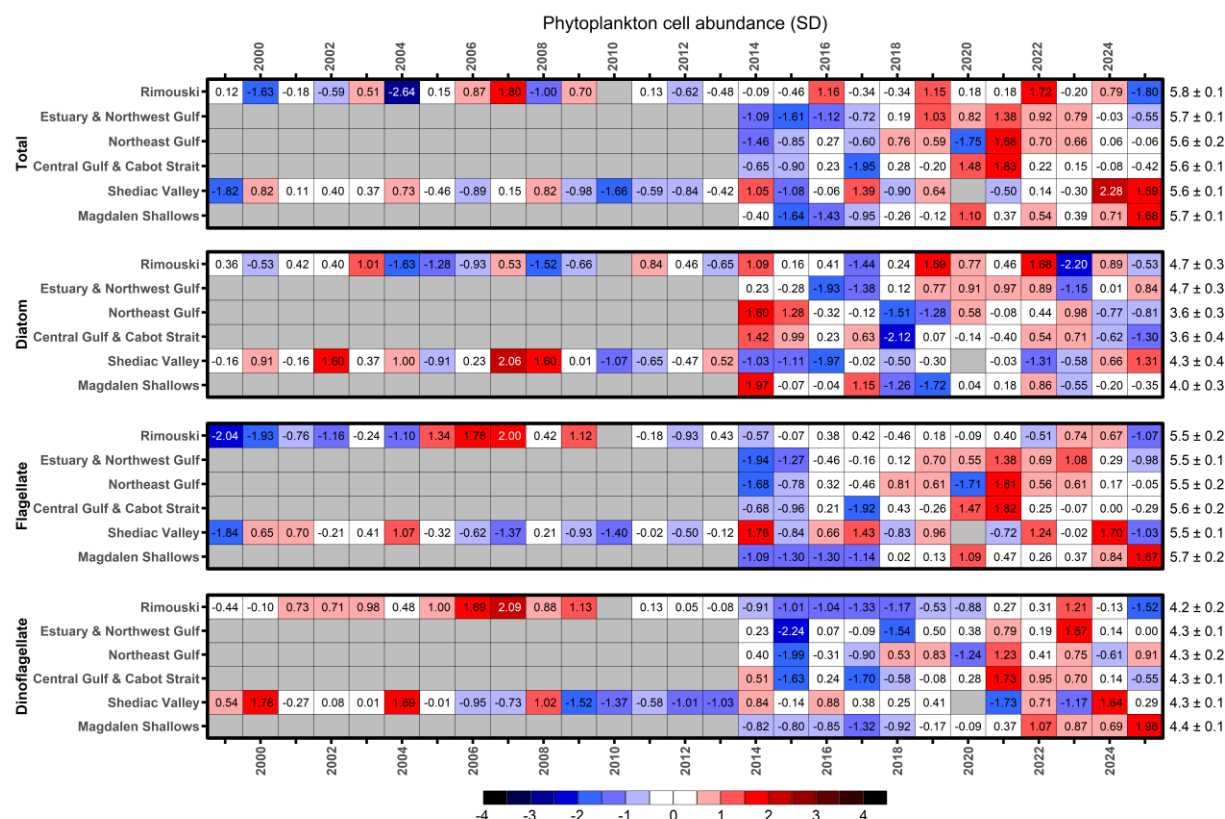


Figure 29. Time series of standardized annual anomalies (SD) for total phytoplankton abundance and the abundance of the main phytoplankton taxonomic groups at high-frequency monitoring stations and in Gulf regions. The numbers on the right are the 1999–2025 climatological means and standard deviations in units of $\log_{10}(\text{cells L}^{-1} + 1)$. Blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels. Gray cells indicate missing data.

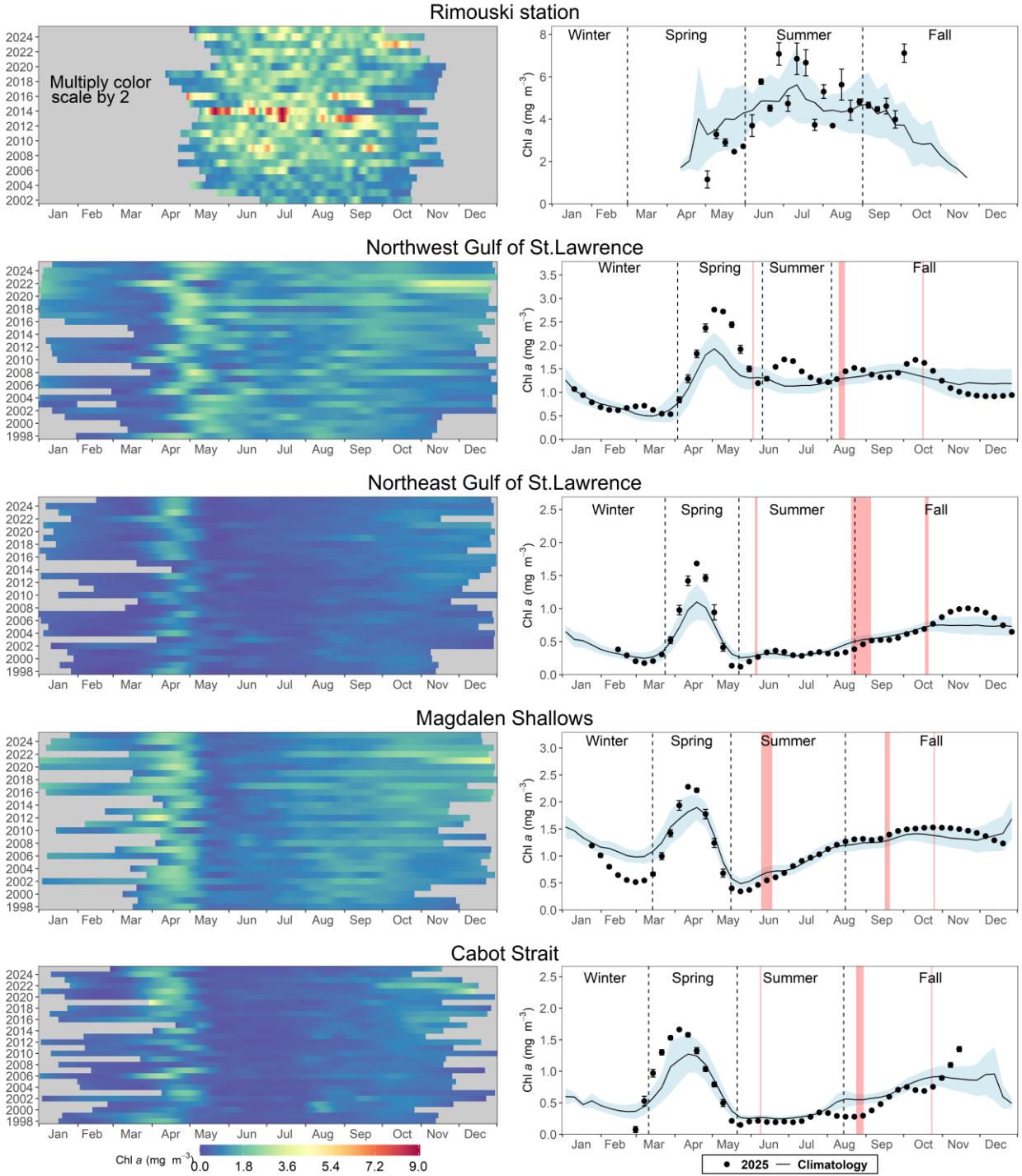


Figure 30 Left panels: LOESS-smoothed time series of daily surface chlorophyll *a* concentrations derived from data recorded by a fluorescence sensor fixed on the oceanographic buoy at Rimouski station (1st row panels), and from OC-CCI ocean-colour data in the ocean colour polygons (see Figure 4 for polygon locations). Right panels: comparison of weekly mean (± 0.5 SD) of LOESS-smoothed surface chlorophyll *a* estimates in 2025 (black circles) with average (± 0.5 SD) conditions from the 1999–2025 climatology (2002–2025 for Rimouski station; solid line with blue shading) for the same ocean-colour polygons. Red shadings indicate sampling times of the main surveys. Vertical dashed lines represent the season boundaries used to compute chl *a* seasonal average.

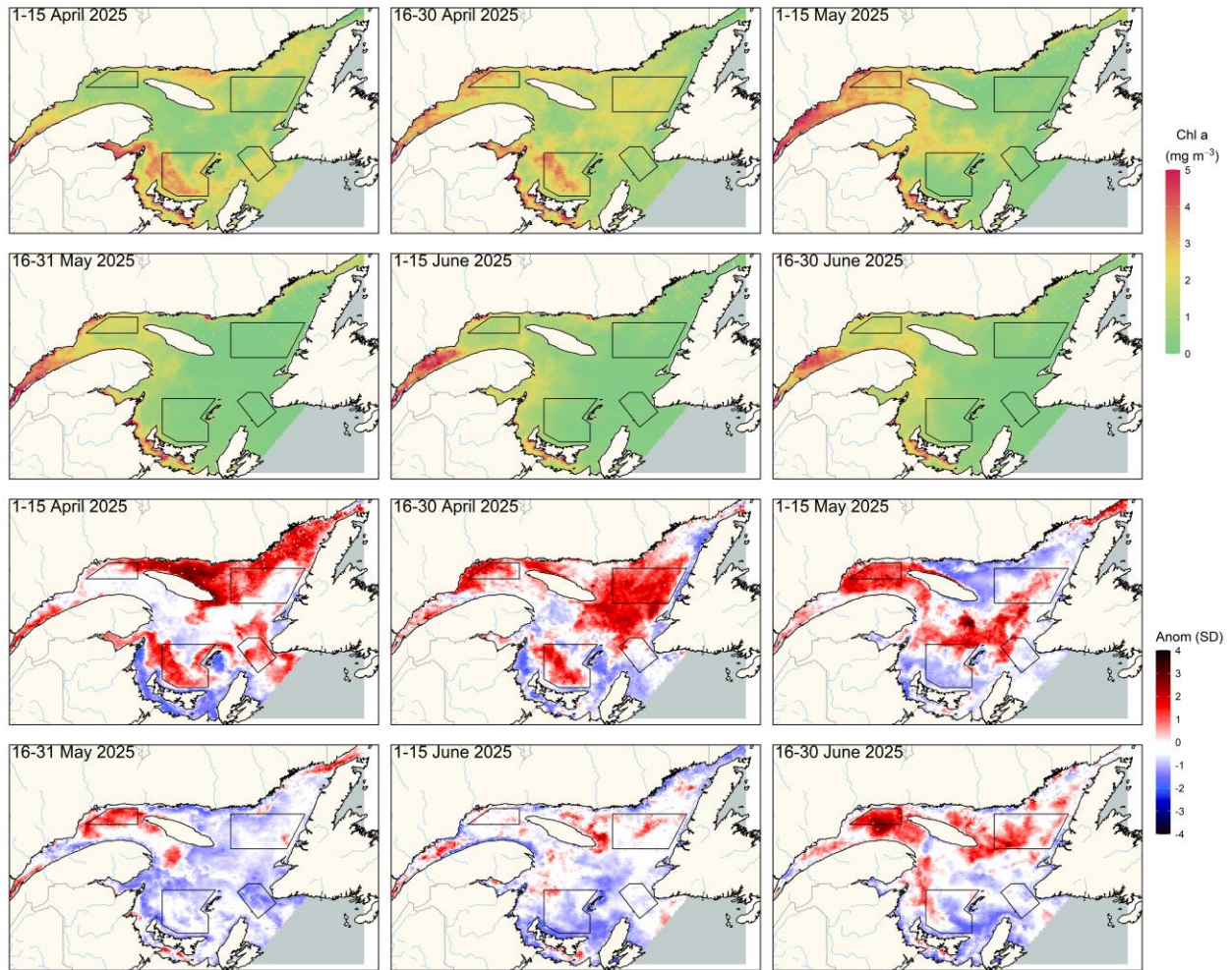


Figure 31. OC-CCI composite images of surface chlorophyll *a* (upper panels) and chlorophyll *a* standardized anomaly (SD) based on the 1999–2025 climatology (lower panels) in the Gulf of St. Lawrence during spring/early summer 2025. Grey colour indicates the absence of data. Blue colours indicate below-normal levels (negative anomalies), reds are above-normal levels (positive anomalies), and white represents normal levels. Ocean colour polygons shown for reference (see Figure 4).

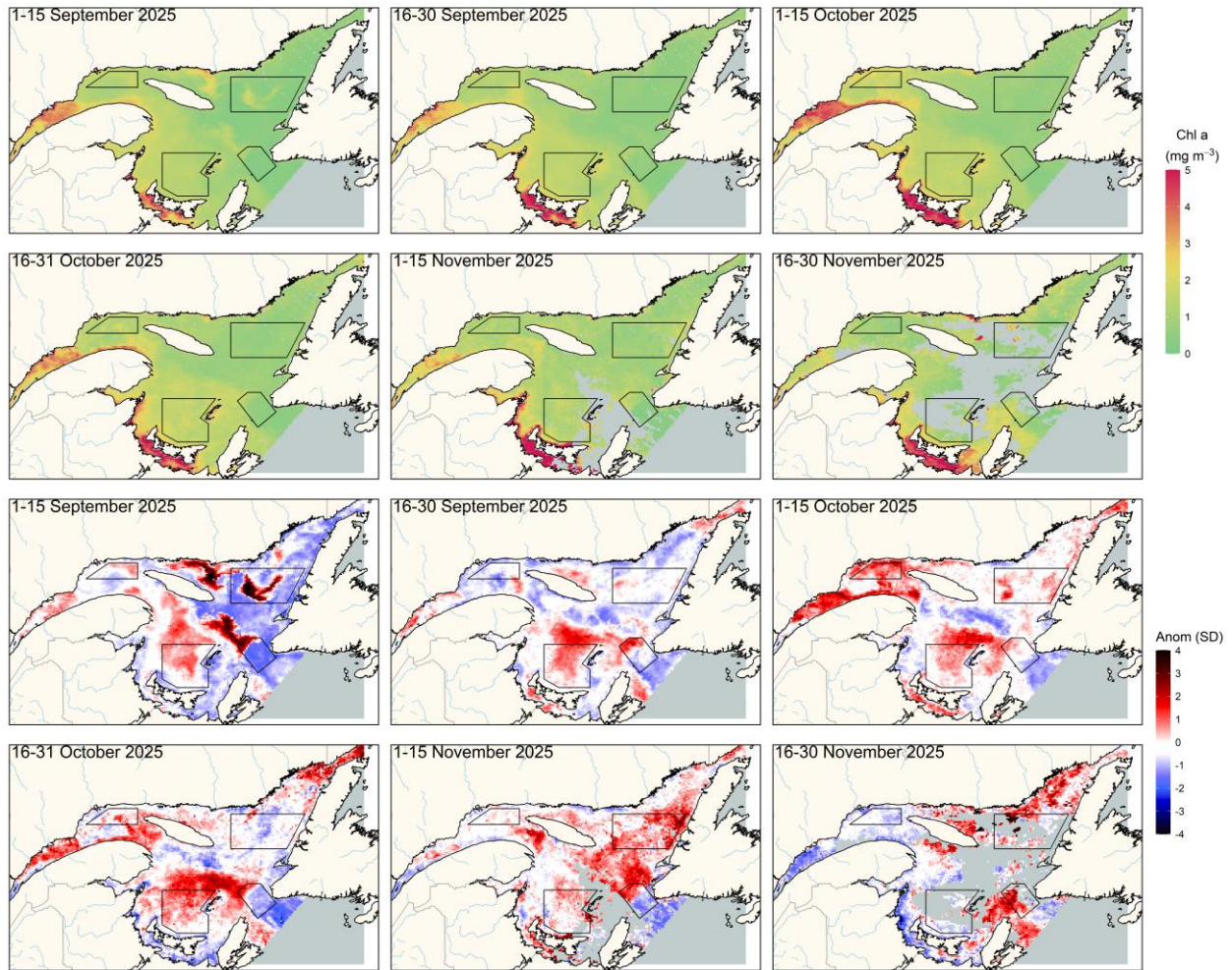


Figure 32. OC-CCI composite images of surface chlorophyll *a* (upper panels) and chlorophyll *a* standardized anomaly (SD) based on the 1999–2025 climatology (lower panels) in the Gulf of St. Lawrence during fall 2025. Grey colour indicates the absence of data. Blue colours indicate below-normal levels (negative anomalies), reds are above-normal levels (positive anomalies), and white represents normal levels. Ocean colour polygons shown for reference (see Figure 4).

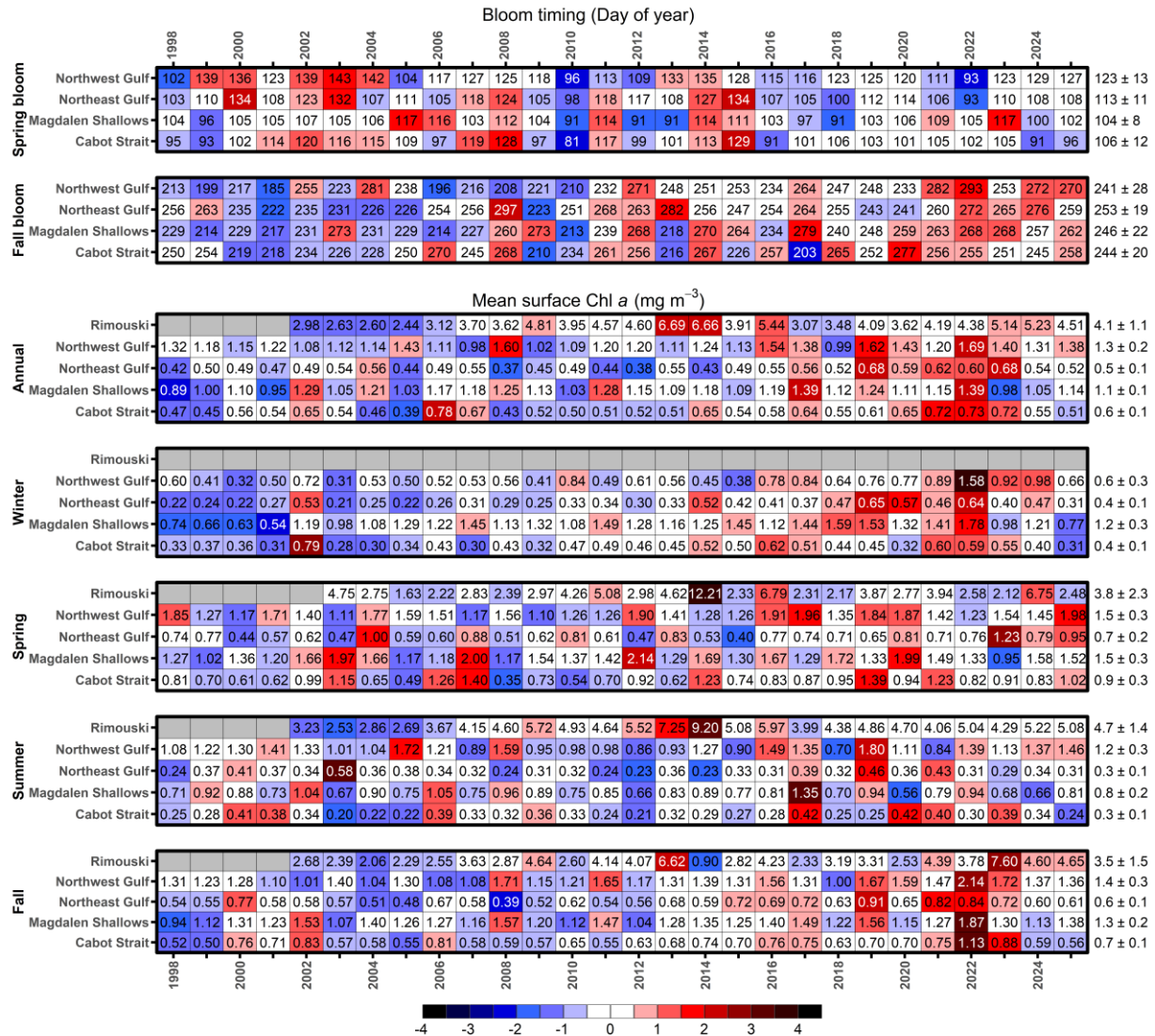


Figure 33. Time series of spring and fall bloom timings (upper section), and annual/seasonal mean surface chlorophyll a (lower section; mg m⁻³) estimated from satellite ocean colour data (OC-CCI) in the Gulf of St. Lawrence ocean-colour polygons (see Figure 4), and from the oceanographic buoy surface sensor at Rimouski station. The bloom timing indices are the spring bloom peak timing (day of the year), and the fall bloom start (day of the year). Variable means and standard deviations for the 1999–2025 climatology are shown to the right of the scorecard. The scorecard is colour-coded according to the annual standardized anomalies (SD). Blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels.

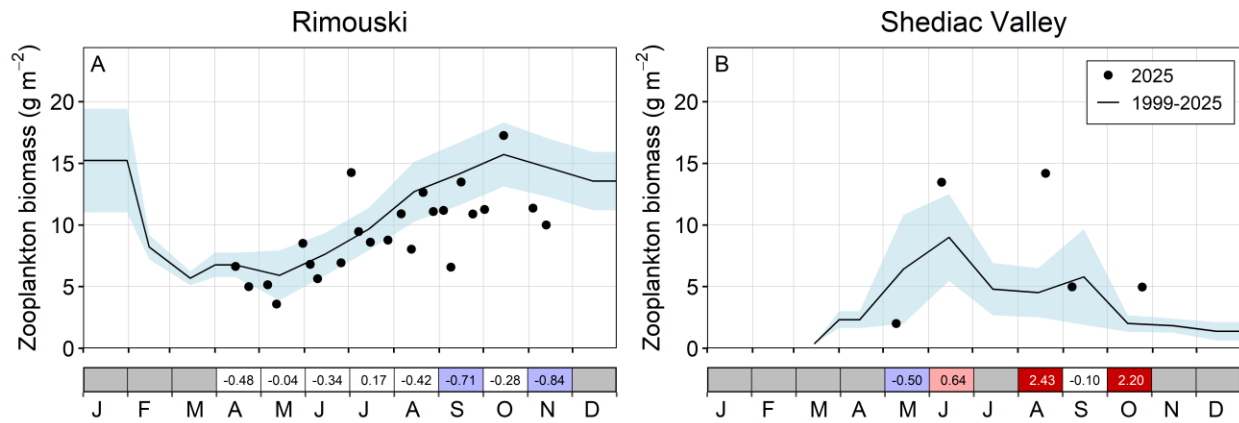


Figure 34. Comparison of mezooplankton biomass (dry weight) in 2025 (circles) with the monthly climatology from (A) Rimouski (2005–2025) and (B) Shediac Valley (1999–2025) stations (black line with blue shading). Blue shading represents ± 0.5 SD of the monthly means. The scorecards show monthly biomass standardized anomalies (SD), where blue indicates below-normal values, red indicates above-normal values, and white indicates normal values.

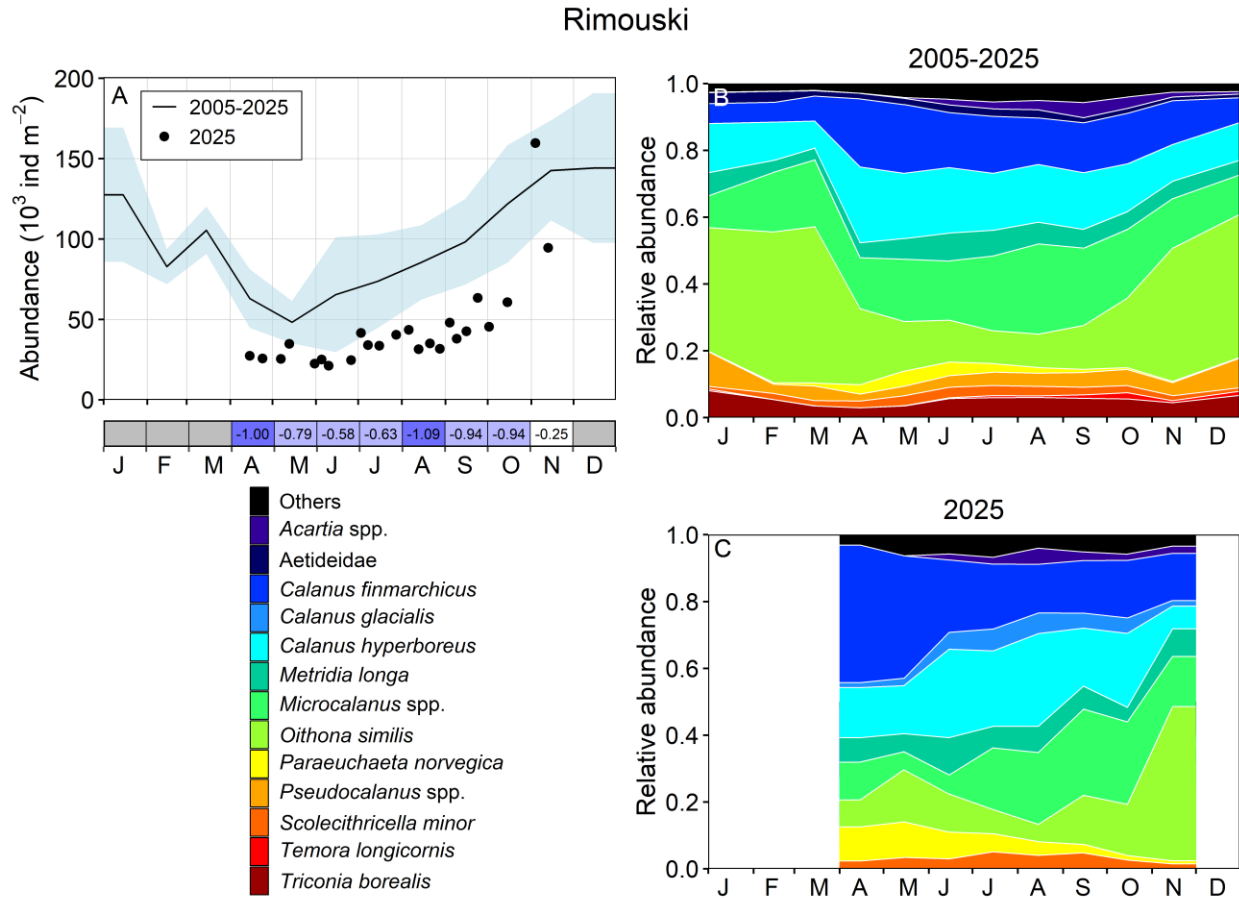


Figure 35. Seasonal variability of dominant copepods at Rimouski station. Climatology of copepod (copepodite stages only) abundance (10^3 individuals m^{-2} ; black line with blue shading indicating ± 0.5 SD), and in 2025 (circles) (A); climatology of the relative abundance of the identified copepod taxa representing 95% of total copepod abundance during the 2005–2025 period (B), and in 2025 (C). The scorecards show monthly copepod abundance standardized anomalies (SD), where blue indicates below-normal values, red indicates above-normal values, and white indicates normal values.

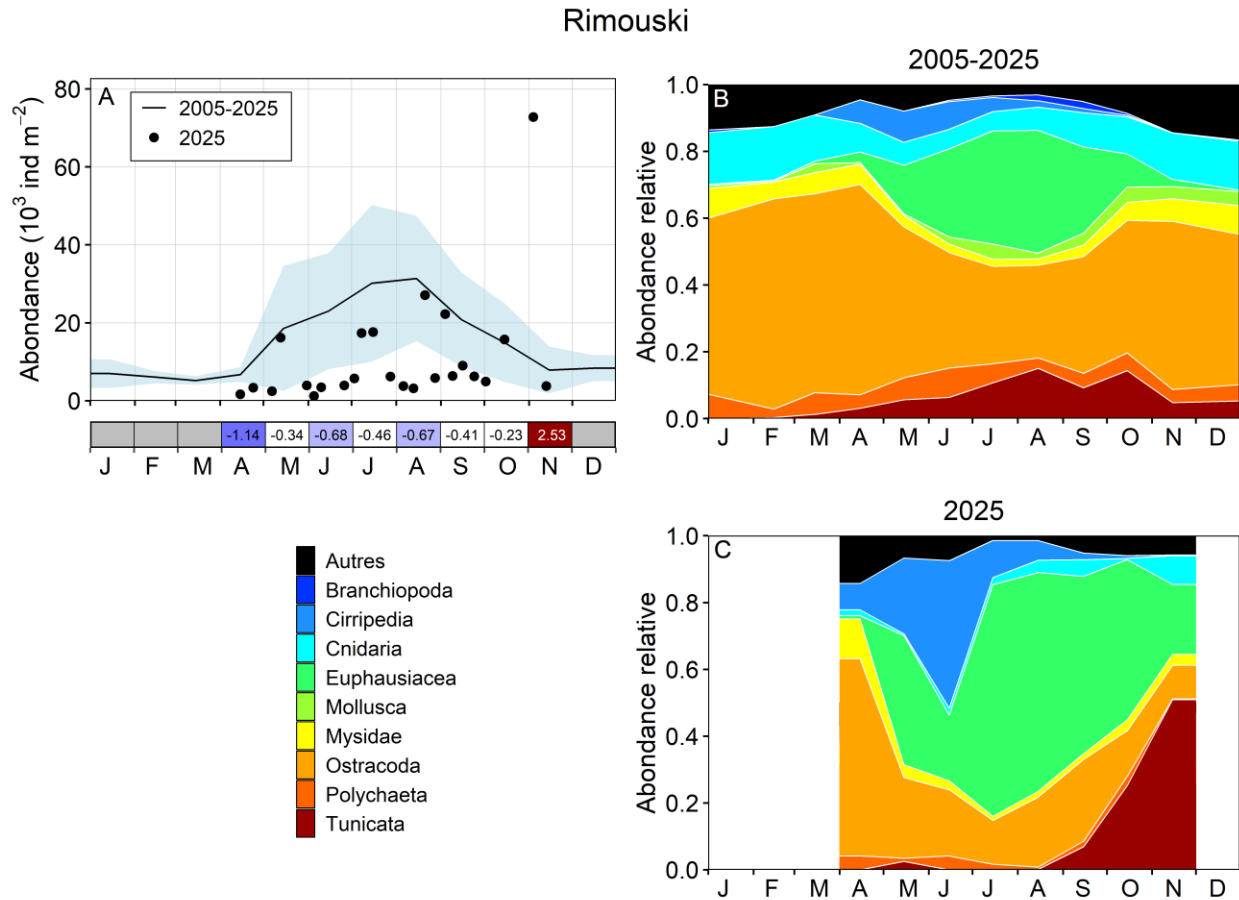


Figure 36. Seasonal variability of dominant non-copepod taxa at Rimouski station. Climatology of non-copepod abundance (10^3 individuals m^{-2} ; black line with blue shading indicating ± 0.5 SD), and in 2025 (circles) (A); climatology of the relative abundance of the identified non-copepod taxa representing 95% of total non-copepod abundance during the 2005–2025 period (B), and in 2025 (C). The scorecards show monthly non-copepod abundance standardized anomalies (SD), where blue indicates below-normal values, red indicates above-normal values, and white indicates normal values.

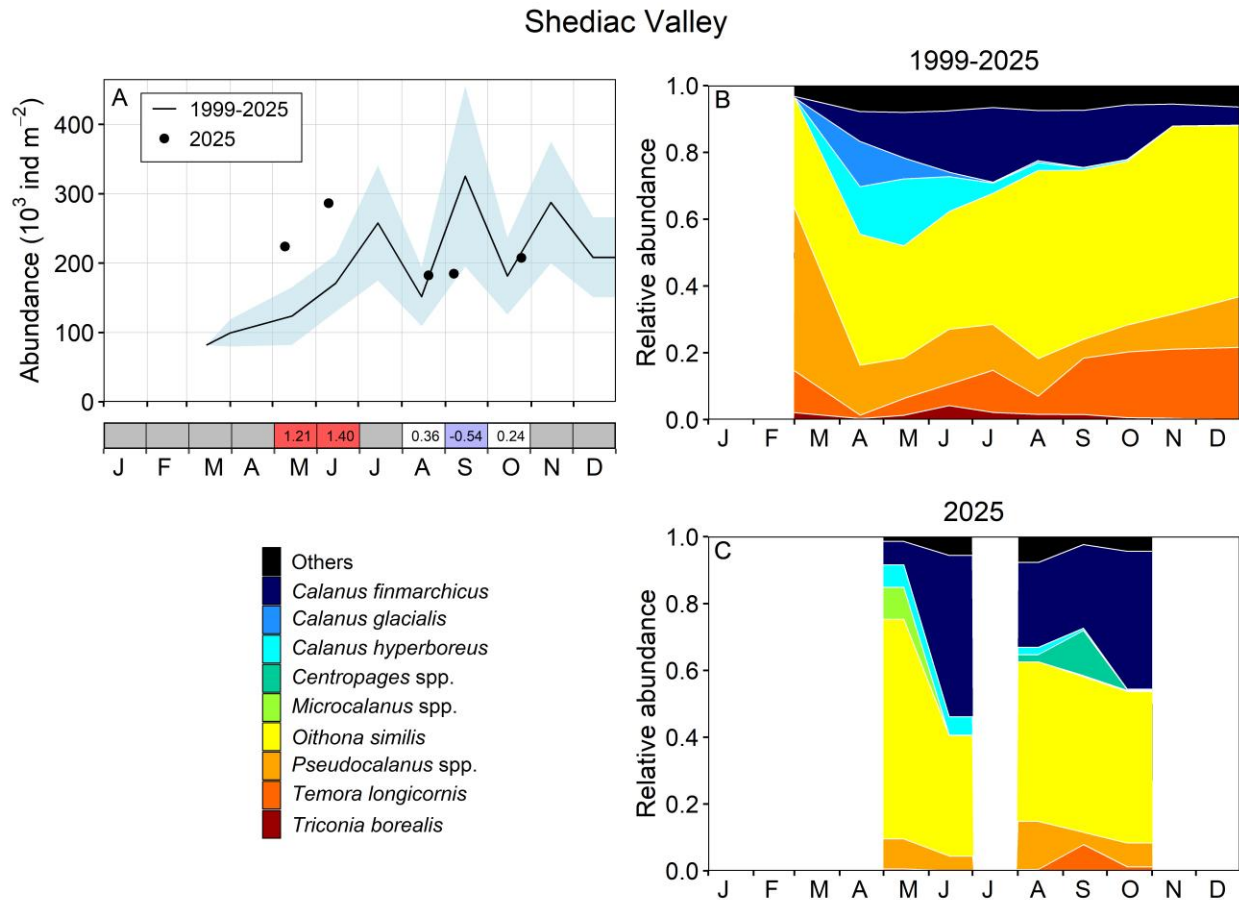


Figure 37. Seasonal variability of dominant copepods at Shediac Valley station. Climatology of copepod (copepodite stages only) abundance (10^3 individuals m^{-2} ; black line with blue shading indicating ± 0.5 SD), and in 2025 (circles) (A); climatology of the relative abundance of the identified copepod taxa representing 95% of total copepod abundance during the 1999–2025 period (B), and in 2025 (C). The scorecards show monthly copepod abundance standardized anomalies (SD), where blue indicates below-normal values, red indicates above-normal values, and white indicates normal values.

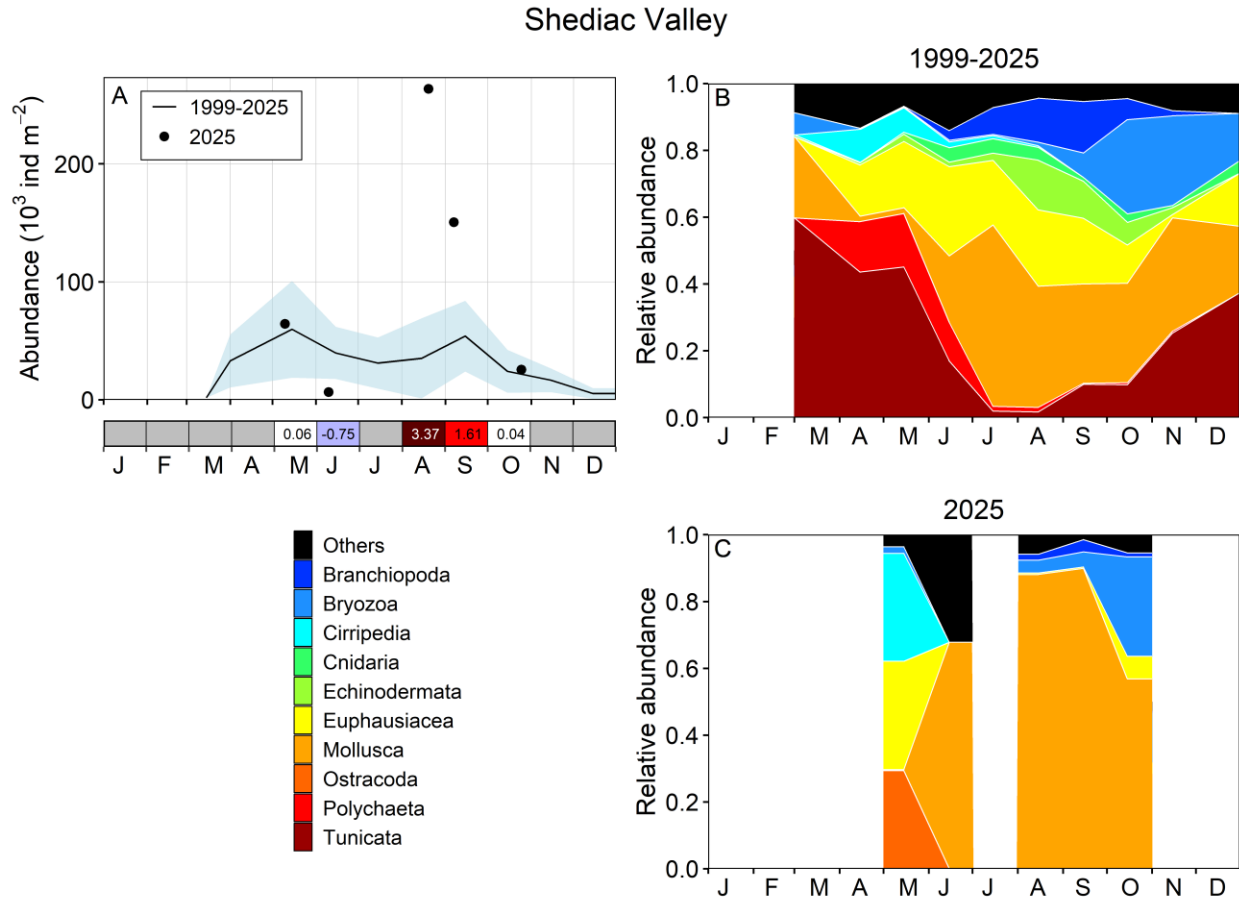


Figure 38. Seasonal variability of dominant non-copepod taxa at Shediac Valley station. Climatology of non-copepod abundance (10³ individuals m⁻²; black line with blue shading indicating ± 0.5 SD), and in 2025 (circles) (A); climatology of the relative abundance of the identified non-copepod taxa representing 95% of total non-copepod abundance during the 1999–2025 period (B), and in 2025 (C). The scorecards show monthly non-copepod abundance standardized anomalies (SD), where blue indicates below-normal values, red indicates above-normal values, and white indicates normal values.

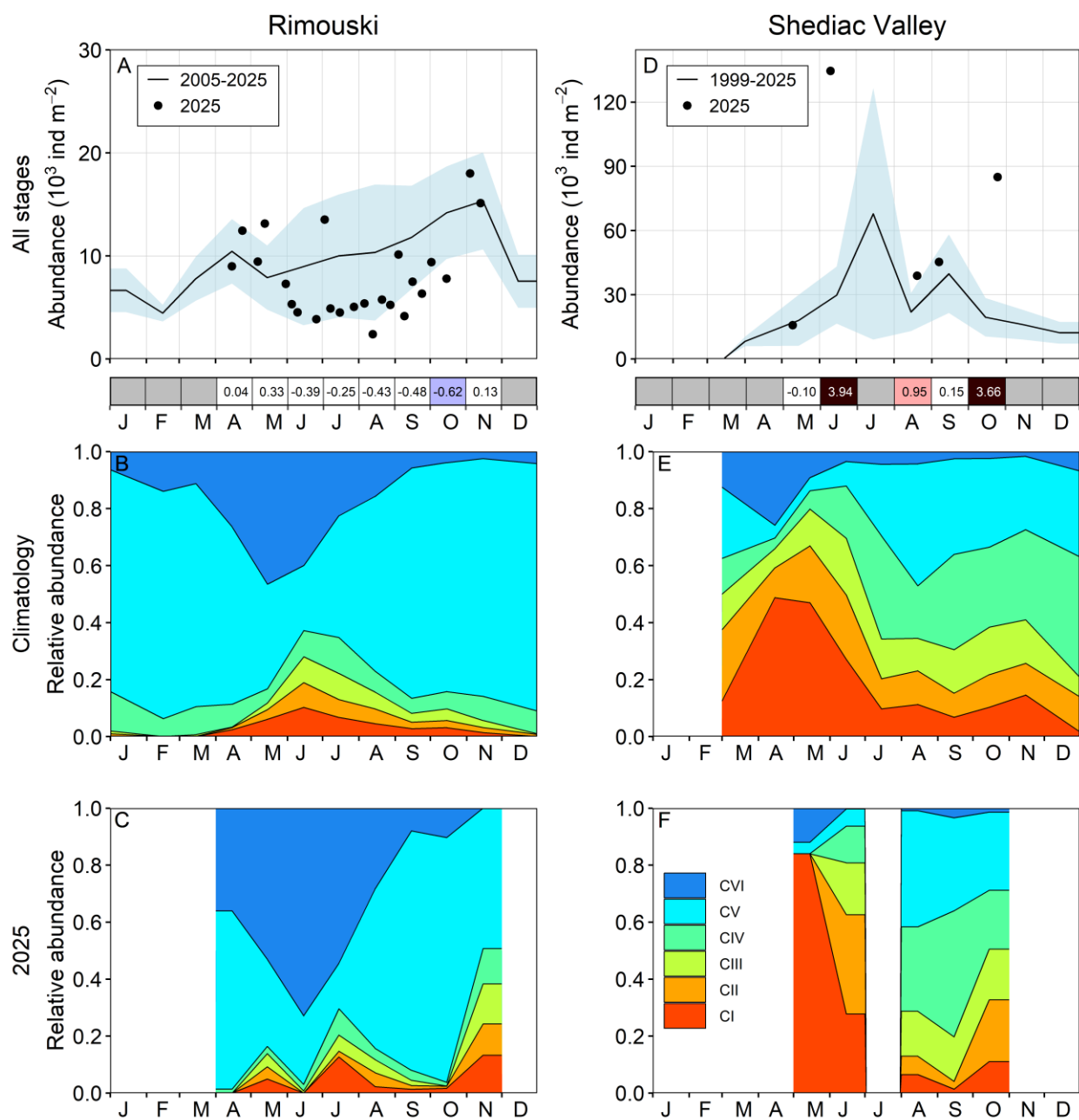


Figure 39. Seasonal variability in *Calanus finmarchicus* copepodite abundance (10^3 individuals m^{-2}) and stage composition at Rimouski (A–C) and Shediac Valley (D–F) stations. The scorecards show monthly abundance standardized anomalies (SD), where blue indicates below-normal values, red indicates above-normal values, and white indicates normal values. Climatology of *C. finmarchicus* abundance (black line with blue shading indicating ± 0.5 SD) with data from 2025 (circles) (A, D). Climatology of individual copepodite stages (B, E), and data for 2025 (C, F).

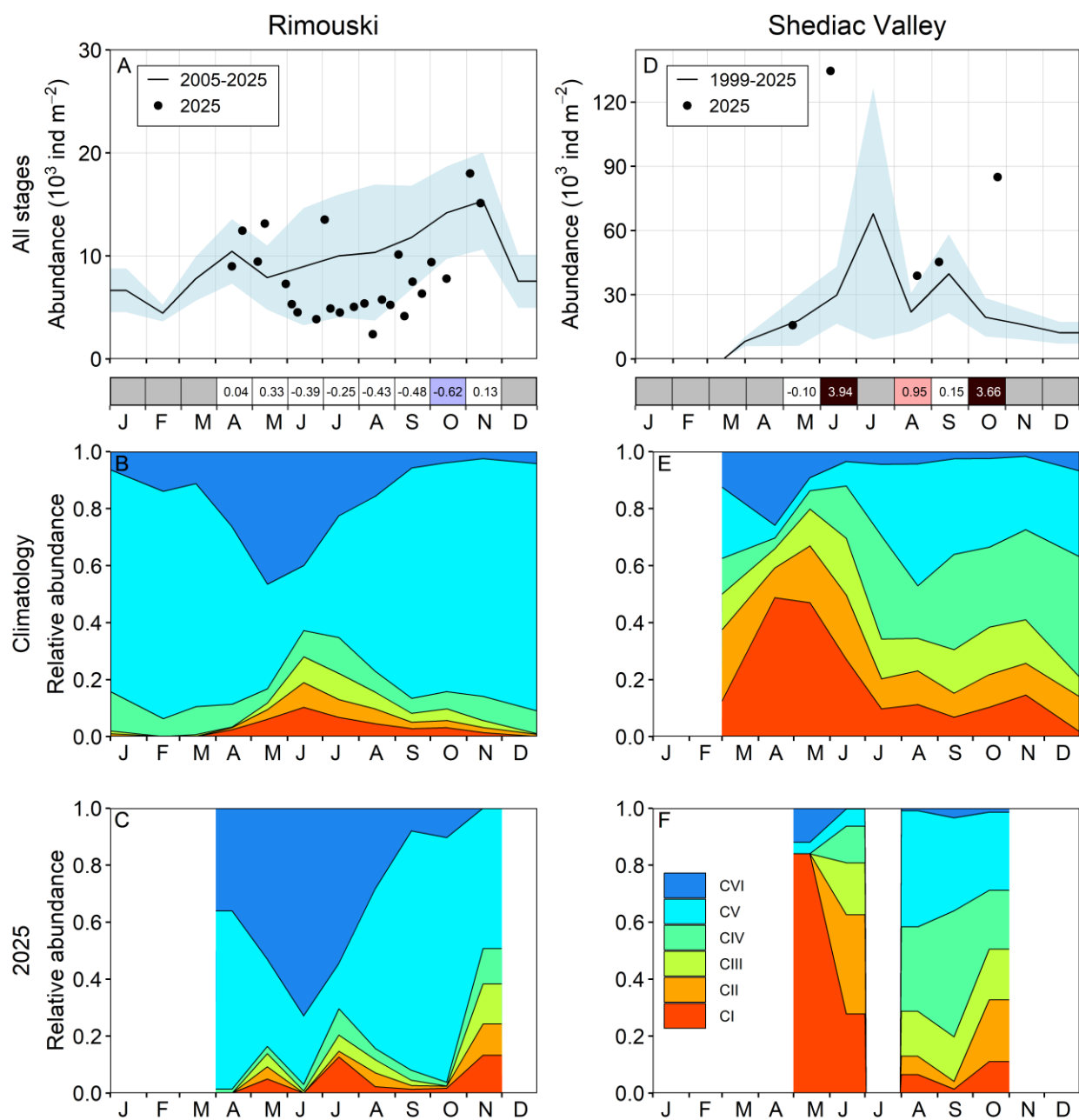


Figure 40. Seasonal variability in *Calanus hyperboreus* copepodite abundance (10^3 individuals m^{-2}) and stage composition at Rimouski (A–C) and Shediac Valley (D–F) stations. The scorecards show monthly abundance standardized anomalies (SD), where blue indicates below-normal values, red indicates above-normal values, and white indicates normal values. Climatology of *C. hyperboreus* abundance (black line with blue shading indicating ± 0.5 SD) with data from 2025 (circles) (A, D). Climatology of individual copepodite stages (B, E), and data for 2025 (C, F).

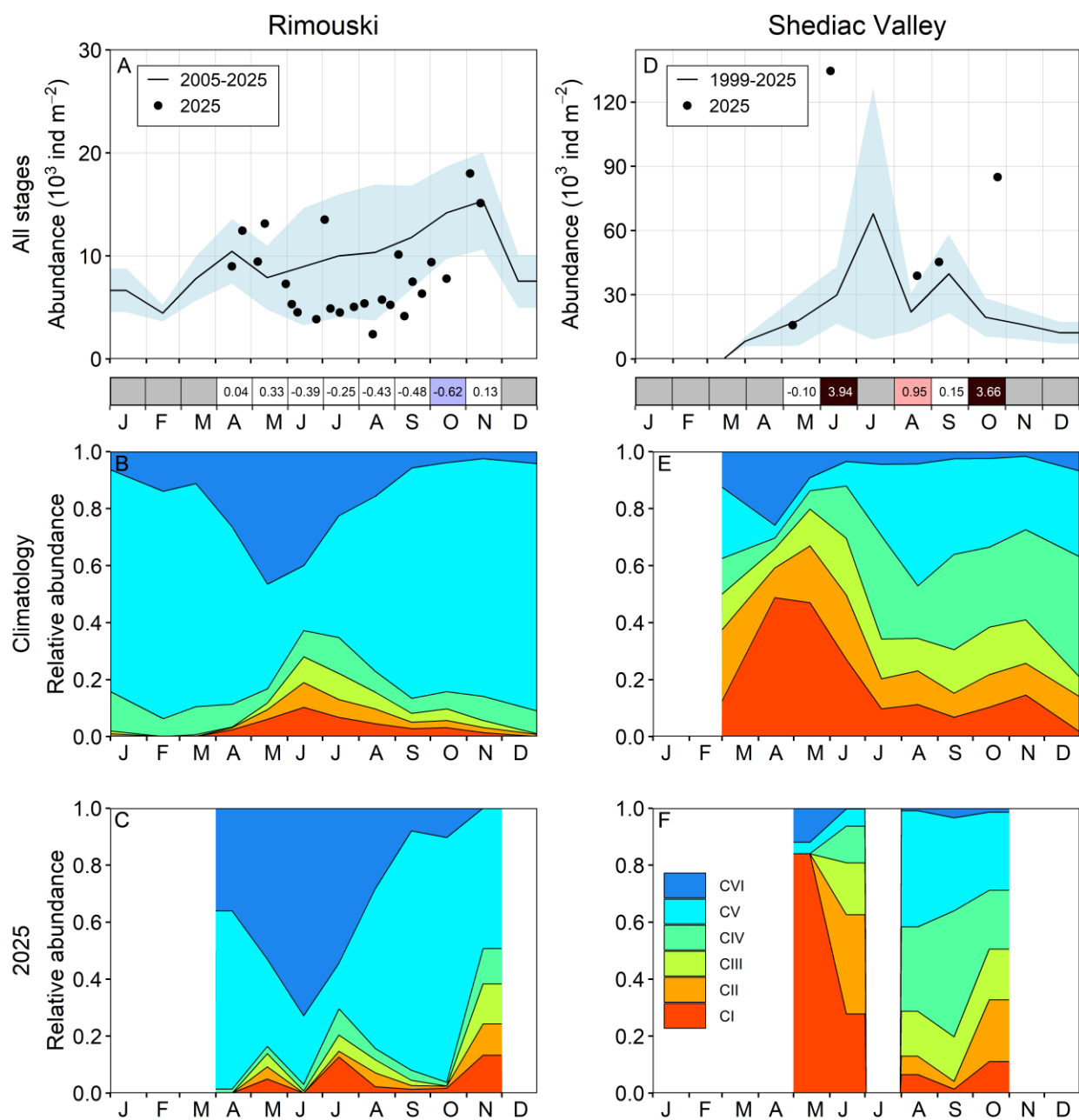


Figure 41. Seasonal variability in *Pseudocalanus* spp. copepodite abundance (10^3 individuals m^{-2}) and stage composition at Rimouski (A–C) and Shediac Valley (D) stations. The scorecards show monthly abundance standardized anomalies (SD), where blue indicates below-normal values, red indicates above-normal values, and white indicates normal values. Climatology of *Pseudocalanus* spp. abundance (black line with blue shading indicating ± 0.5 SD) with data from 2025 (circles) (A). Climatology of individual copepodite stages (B), and data for 2025 (C). Stage information is not available for Shediac Valley.

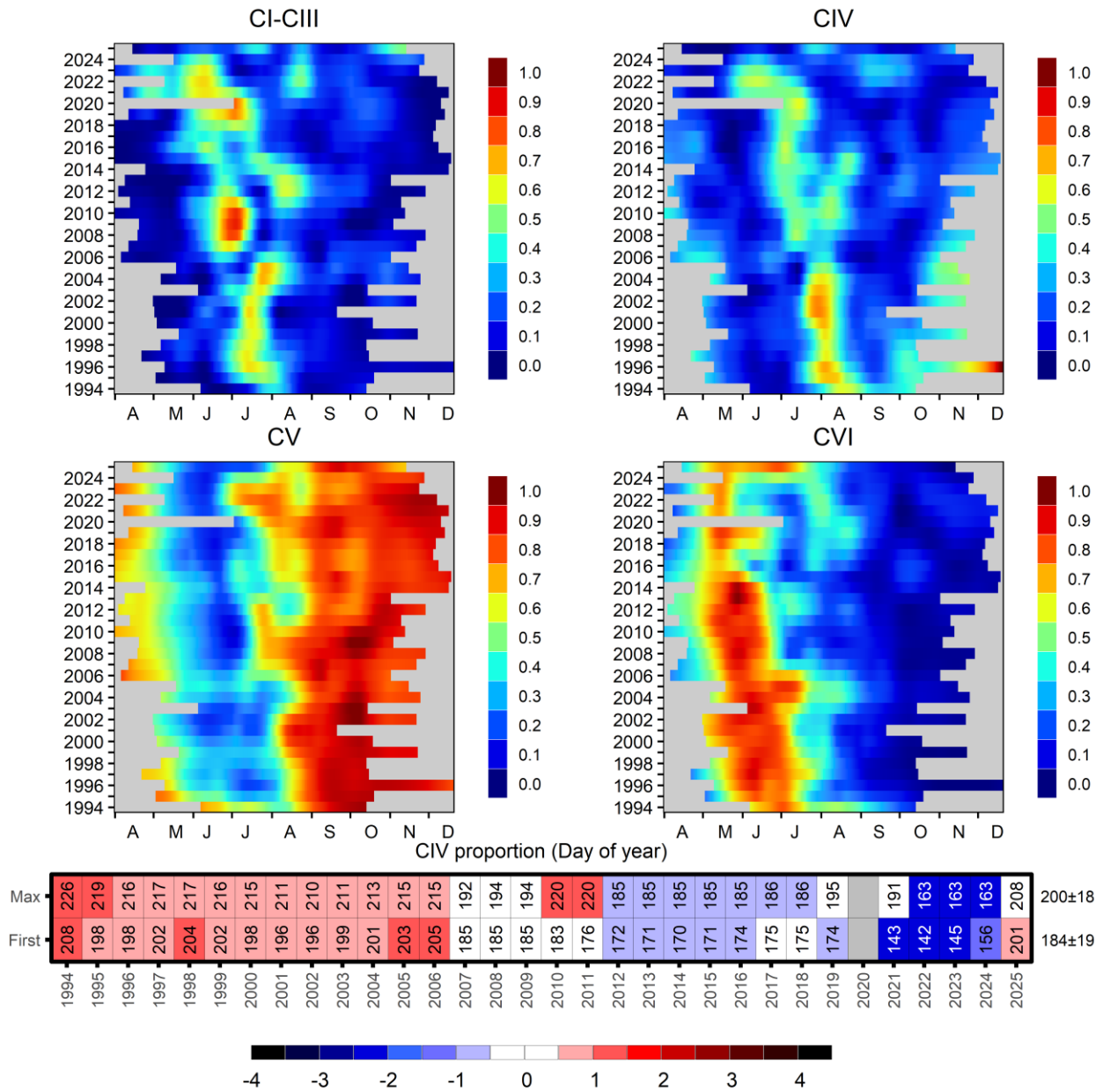


Figure 42. Time series of the seasonal cycle of relative proportion for *Calanus finmarchicus* copepodite stages at Rimouski station. Proportions are normalized by their annual maximum, and smoothed using a LOESS regression. Bottom scorecard shows the time series (climatology 1994–2025) associated with the day of maximum CIV proportion (Max), and the first day when the normalized proportion of CIV copepodite stage was higher than 35% (First). Means and standard deviations (in units of days) for the 1994–2025 climatology are shown to the right of the scorecard. The scorecard is colour-coded according to the annual standardized anomalies (SD). Blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels. Gray cells indicate unavailable data.

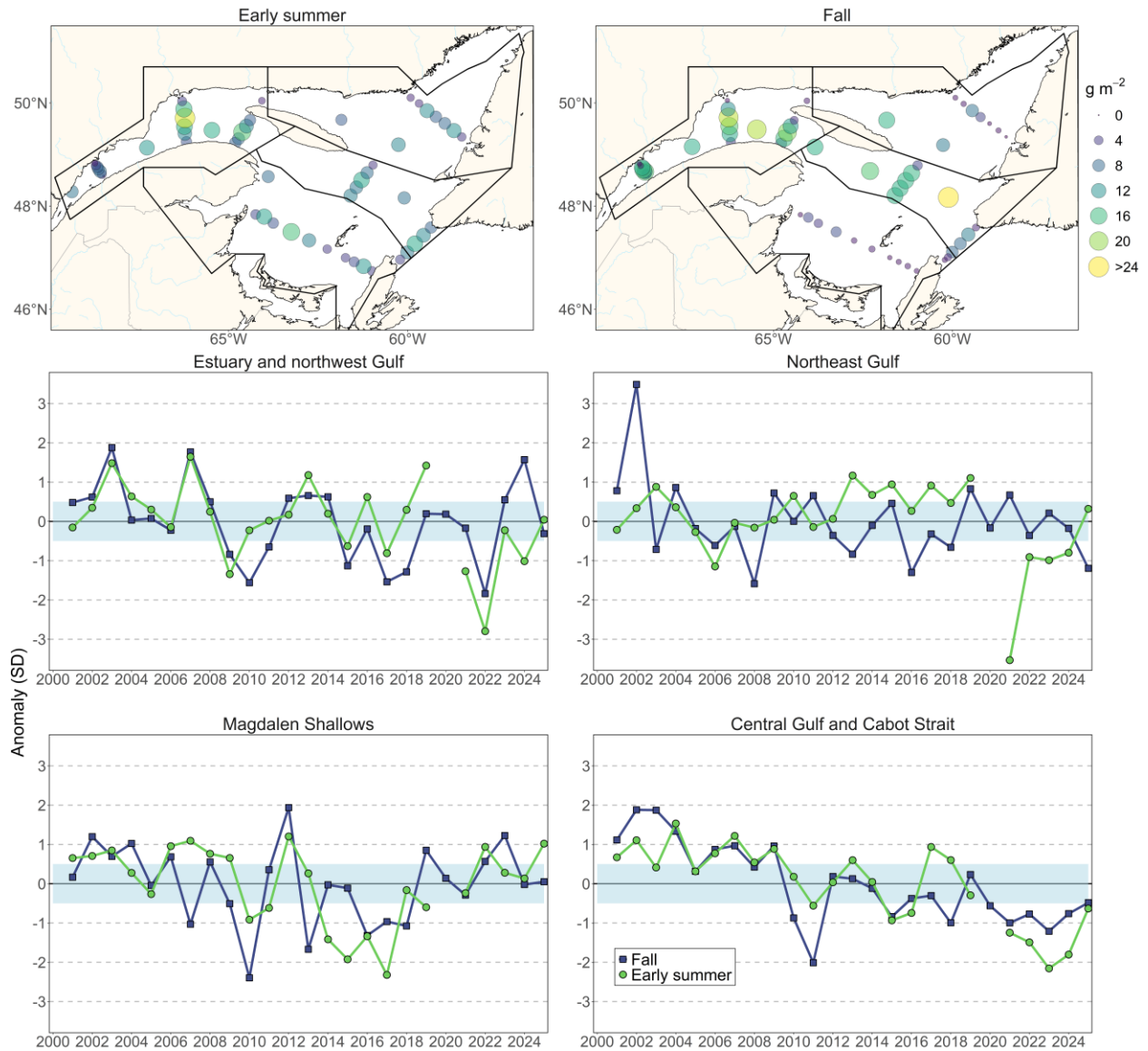


Figure 43. Zooplankton biomass (dry weight; g m^{-2}) spatial distribution during early summer and fall 2025 (upper panels), and regional seasonal time series of mezooplankton biomass standardized anomalies (SD; middle and bottom panels). The blue band represents near-normal levels (± 0.5 SD). Only stations located on the sections are used to calculate seasonal anomalies.

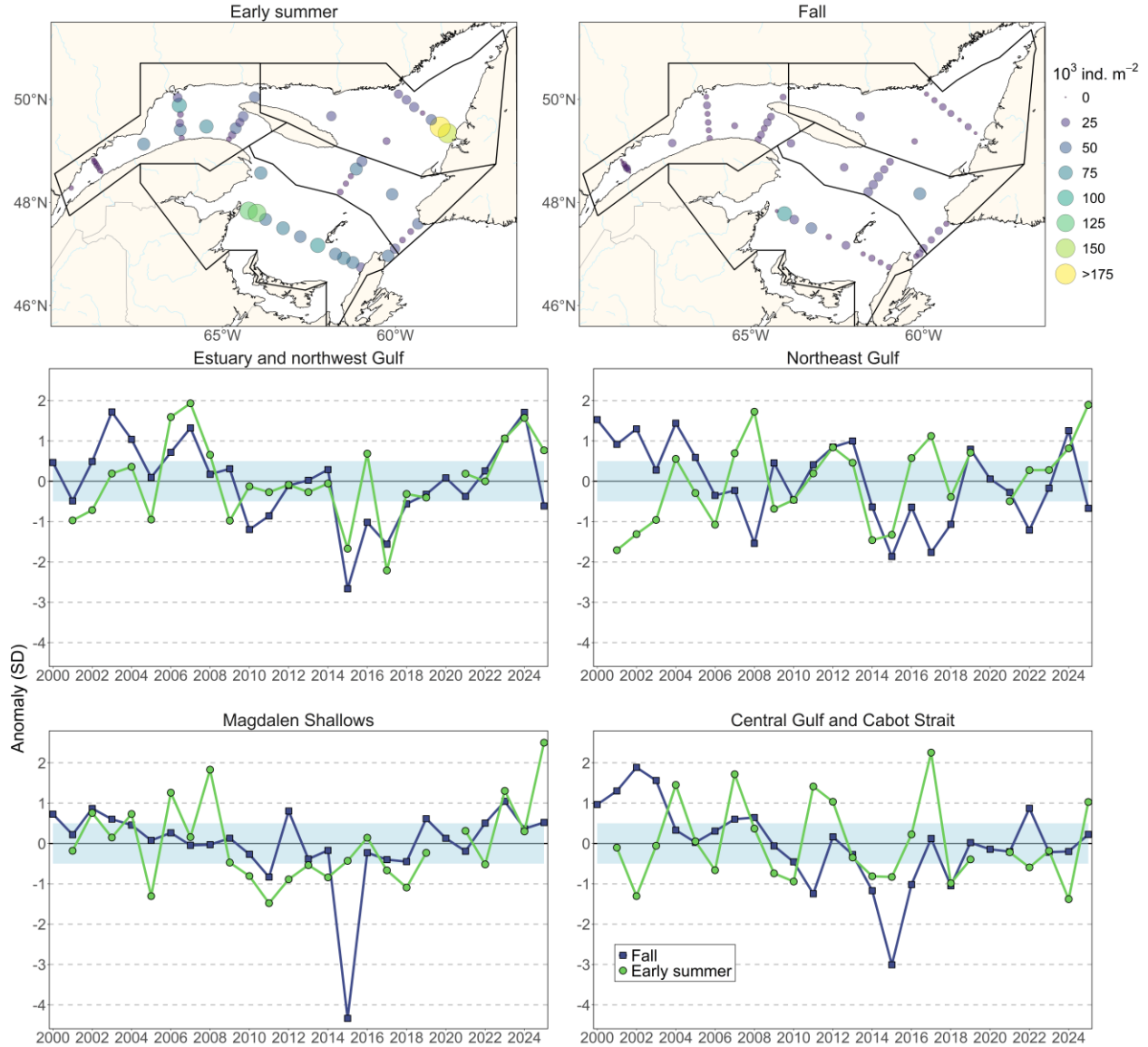


Figure 44. *Calanus finmarchicus* copepodite abundance (10³ individuals m⁻²) spatial distribution during early summer and fall 2025 (upper panels), and regional seasonal time series of total *C. finmarchicus* abundance standardized anomalies (SD; middle and bottom panels). The blue band represents near-normal levels (± 0.5 SD). Only stations located on the sections are used to calculate seasonal anomalies.

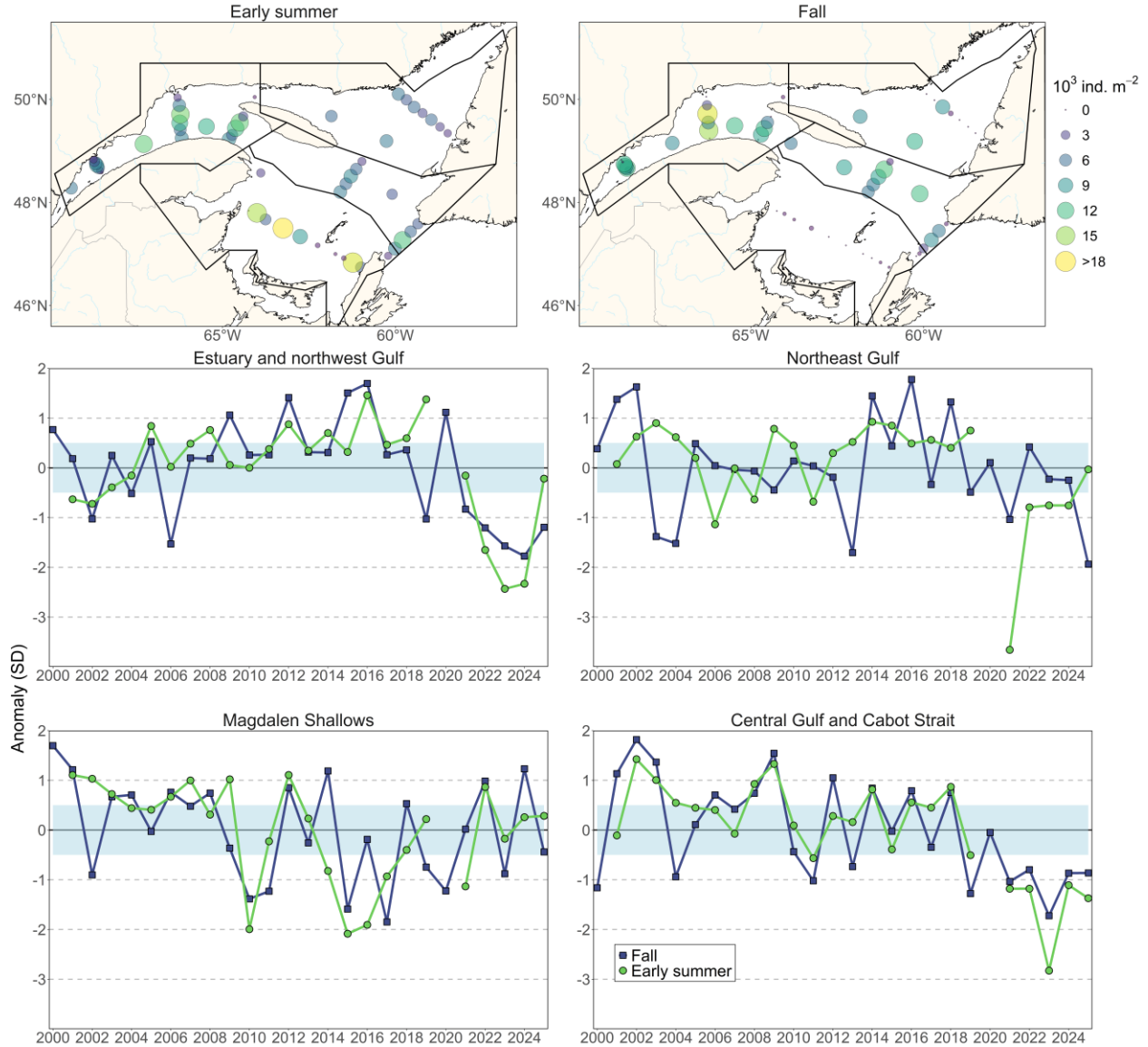


Figure 45. *Calanus hyperboreus* abundance (10^3 individuals m^{-2}) spatial distribution during early summer and fall 2025 (upper panels), and regional seasonal time series of total *C. hyperboreus* abundance standardized anomalies (SD; middle and bottom panels). The blue band represents near-normal levels ($\pm 0.5 \text{ SD}$). Only stations located on the sections are used to calculate seasonal anomalies.

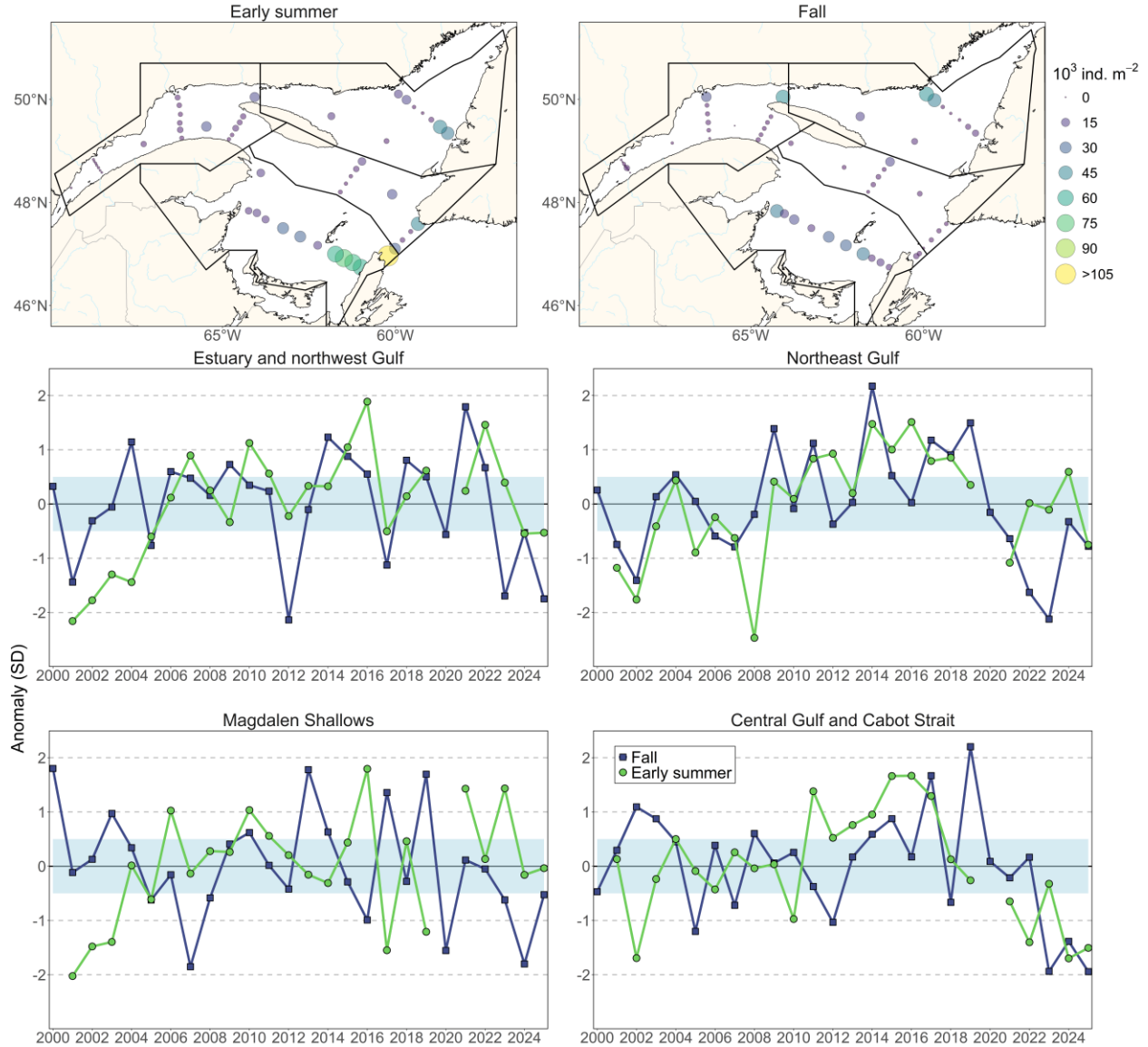
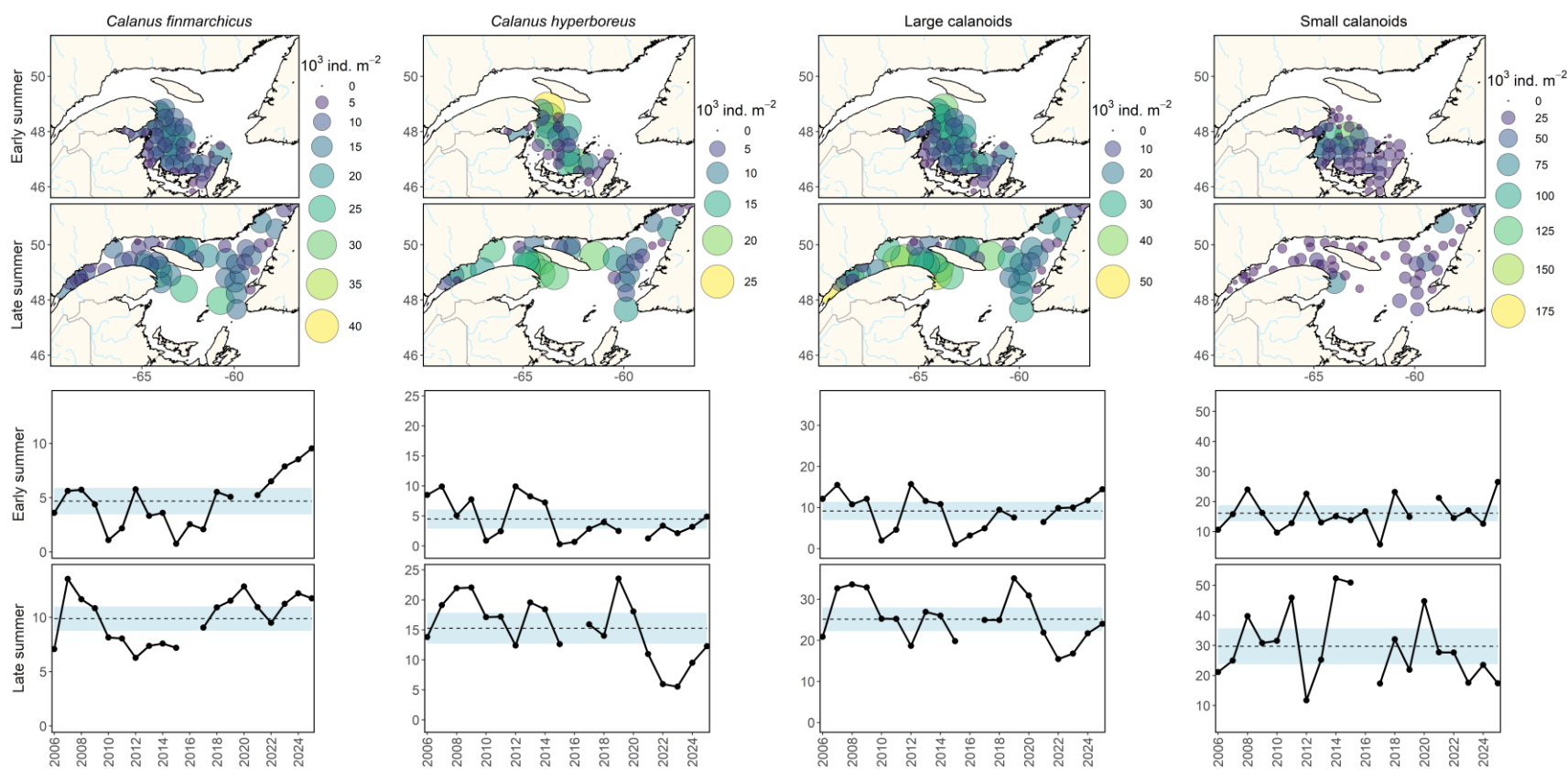


Figure 46. *Pseudocalanus* spp. abundance (10³ individuals m⁻²) spatial distribution during early summer and fall 2025 (upper panels), and regional seasonal time series of total *Pseudocalanus* spp. abundance standardized anomalies (SD; middle and bottom panels). The blue band represents near-normal levels (± 0.5 SD). Only stations located on the sections are used to calculate seasonal anomalies.



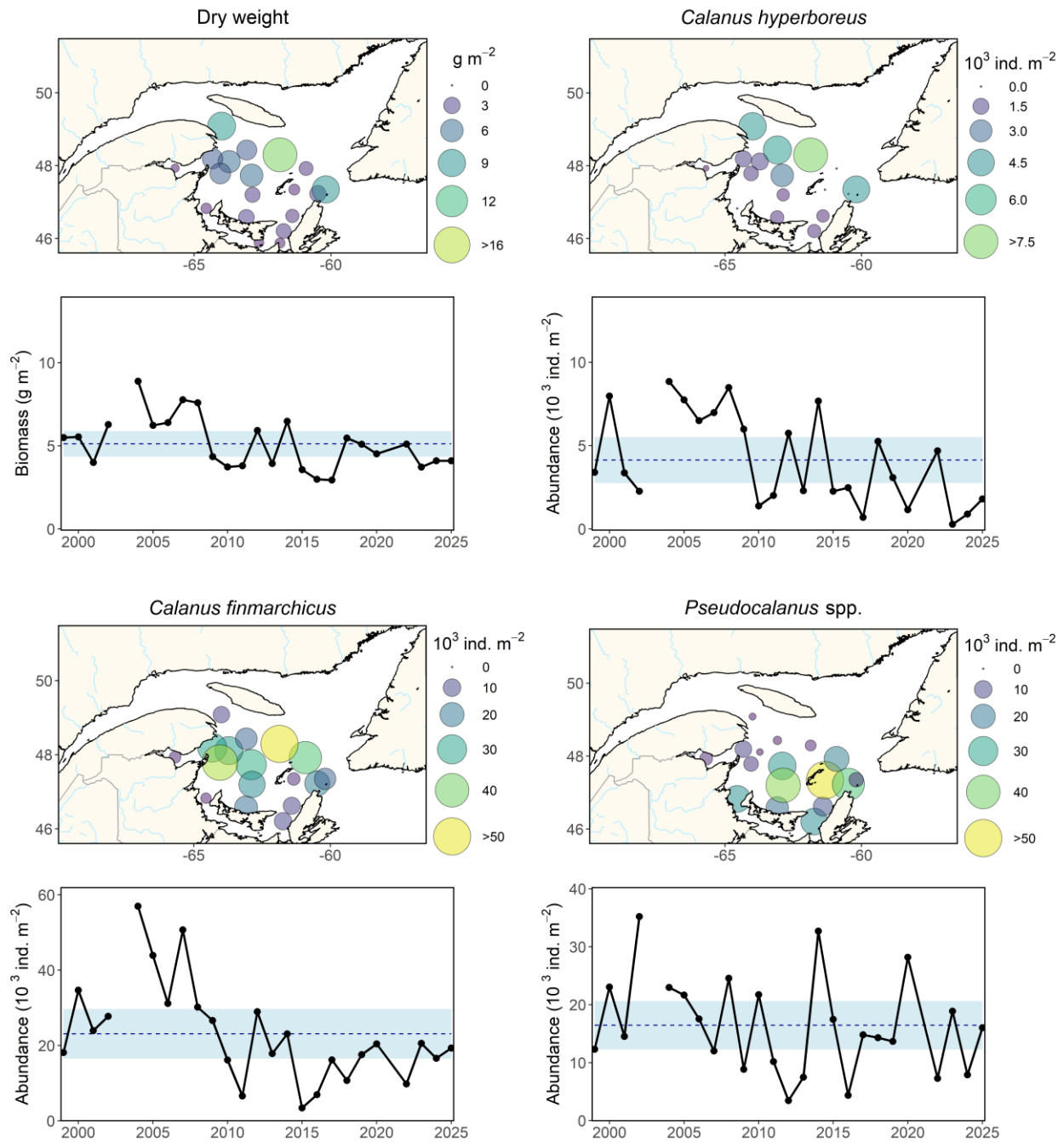


Figure 48. Biomass (g m^{-2}) and abundances ($10^3 \text{ individuals m}^{-2}$) of main zooplankton taxa at each sampling station during late summer ecosystemic survey on the Magdalen Shallows in September 2025. The seasonal time series of mean biomass (g m^{-2}) and total abundances for these taxa are also shown ($10^3 \text{ individuals m}^{-2}$; bottom panels). Dashed lines represent the climatology (2000–2025) averages (blue shading represents ± 0.5 SD).

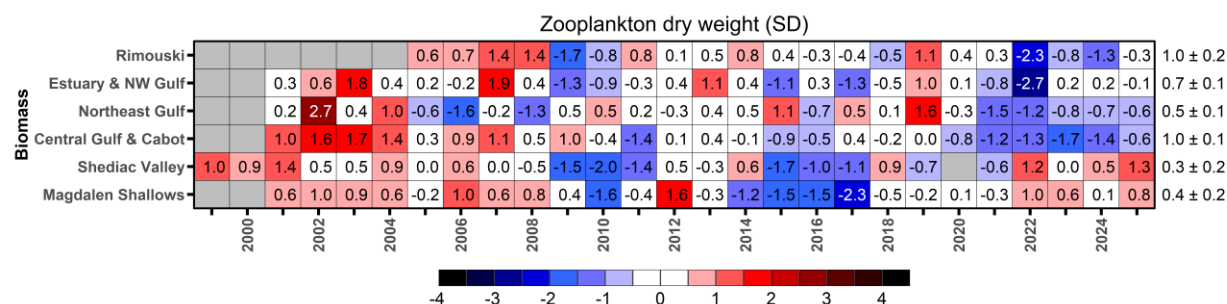


Figure 49. Time series of standardized annual anomalies of zooplankton biomass (dry weight) for the high-frequency monitoring stations and the regions of the Gulf of St. Lawrence. The numbers on the right are the 2001–2025 (2005–2025 for Rimouski; 1999–2025 for Shediac Valley) climatological means and standard deviations in units of $\log_{10}(\text{g m}^{-2})$. Blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels. Gray cells indicate unavailable data. Biomass at the Shediac Valley station in 1999 may be overestimated, as it includes macrozooplankton dry weight, which typically accounts for less than 10% of the total dry weight.

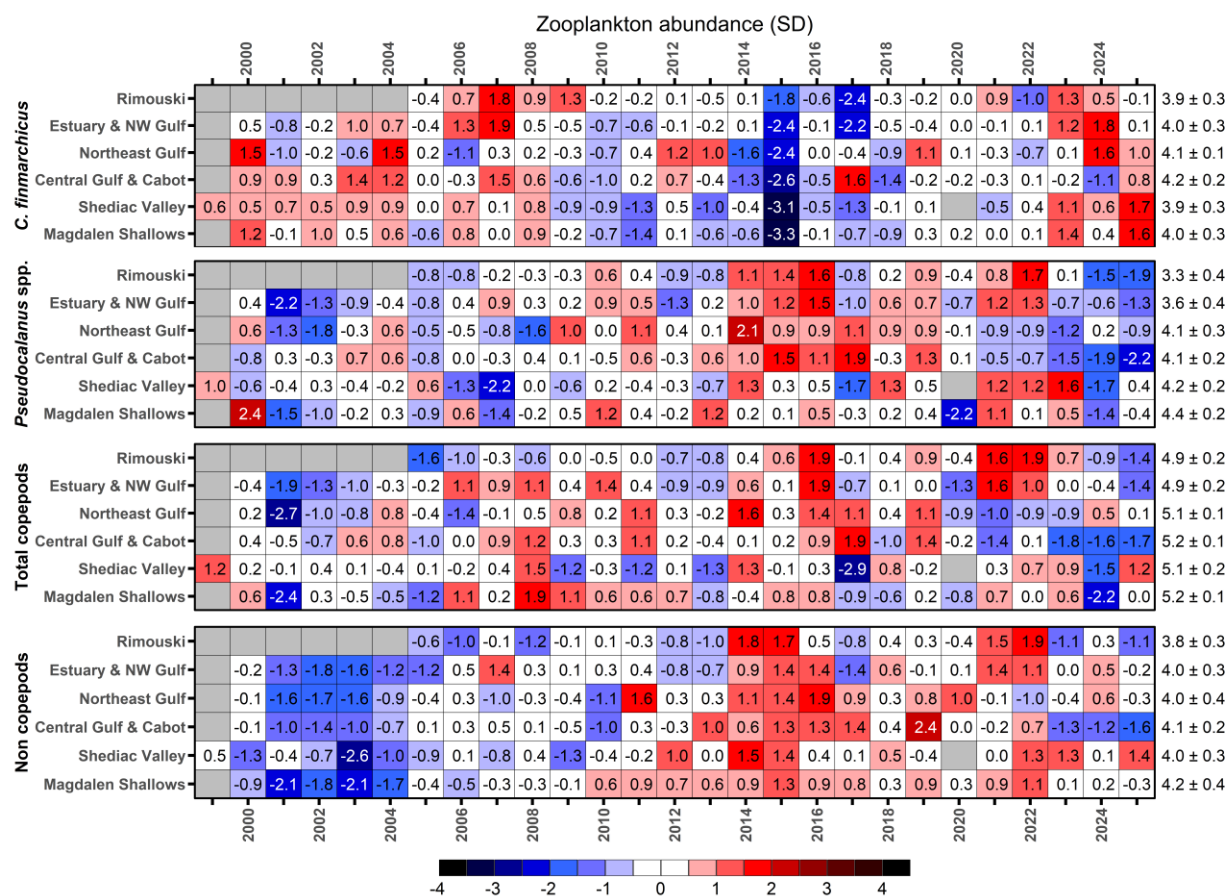


Figure 50. Time series of standardized annual anomalies for the abundance of four zooplankton categories for the high-frequency monitoring stations and regions of the Gulf of St. Lawrence. The numbers on the right are the 2000–2025 (2005–2025 for Rimouski; 1999–2025 for Shediac Valley) climatological means and standard deviations in units of $\log_{10}(\text{individuals m}^{-2} + 1)$. Blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels. Gray cells indicate unavailable data.

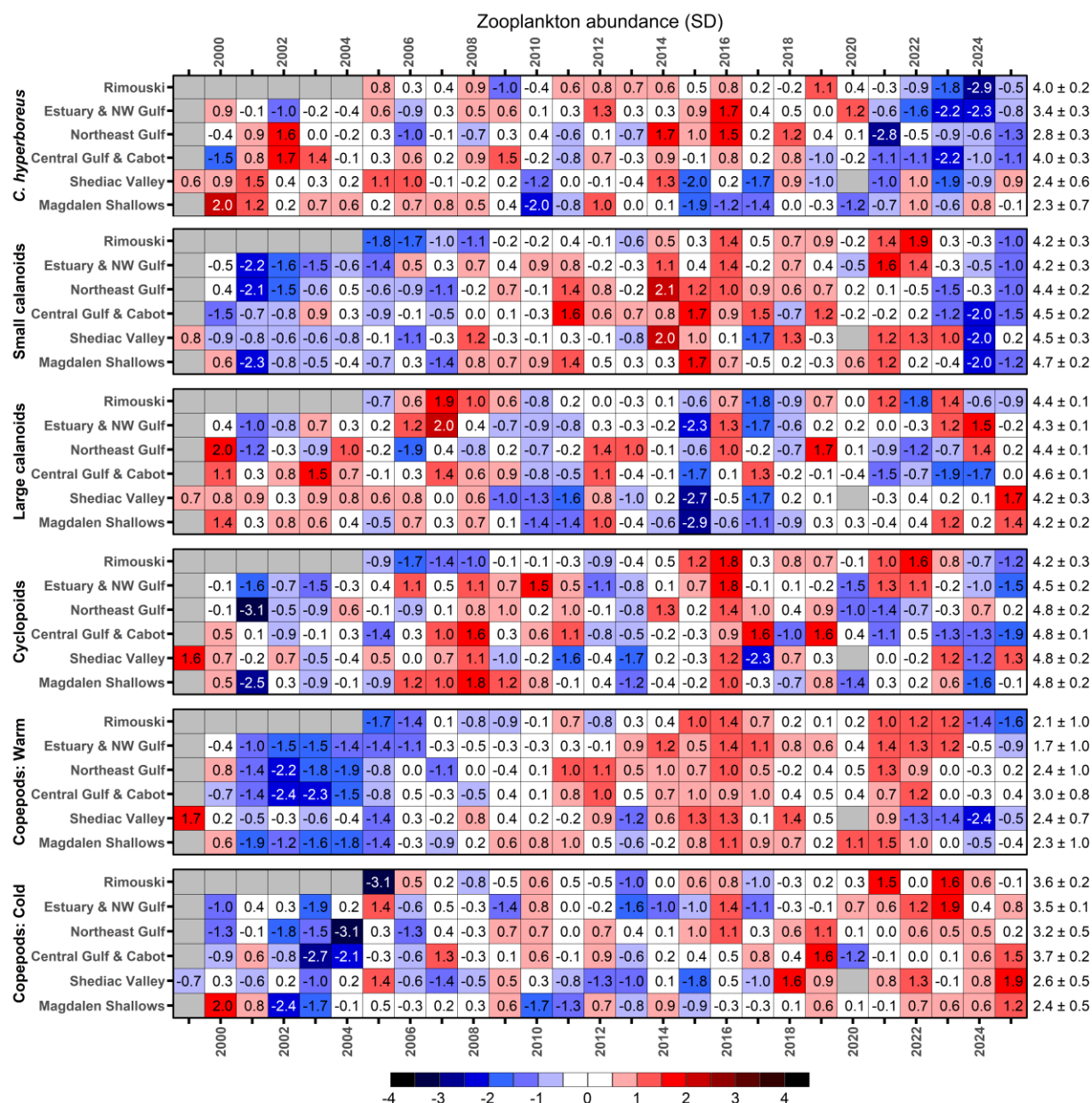


Figure 51. Time series of standardized annual anomalies for the abundance of six categories of zooplankton assemblages for the high-frequency monitoring stations and the regions of the Gulf of St. Lawrence. The numbers on the right are the 2000–2025 (2005–2025 for Rimouski; 1999–2025 for Shediac Valley) climatological means and standard deviations in units of $\log_{10}(\text{individuals m}^{-2} + 1)$. Blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels. Gray cells indicate unavailable data. A detailed list of species included in each copepod index is presented in Appendix 1.

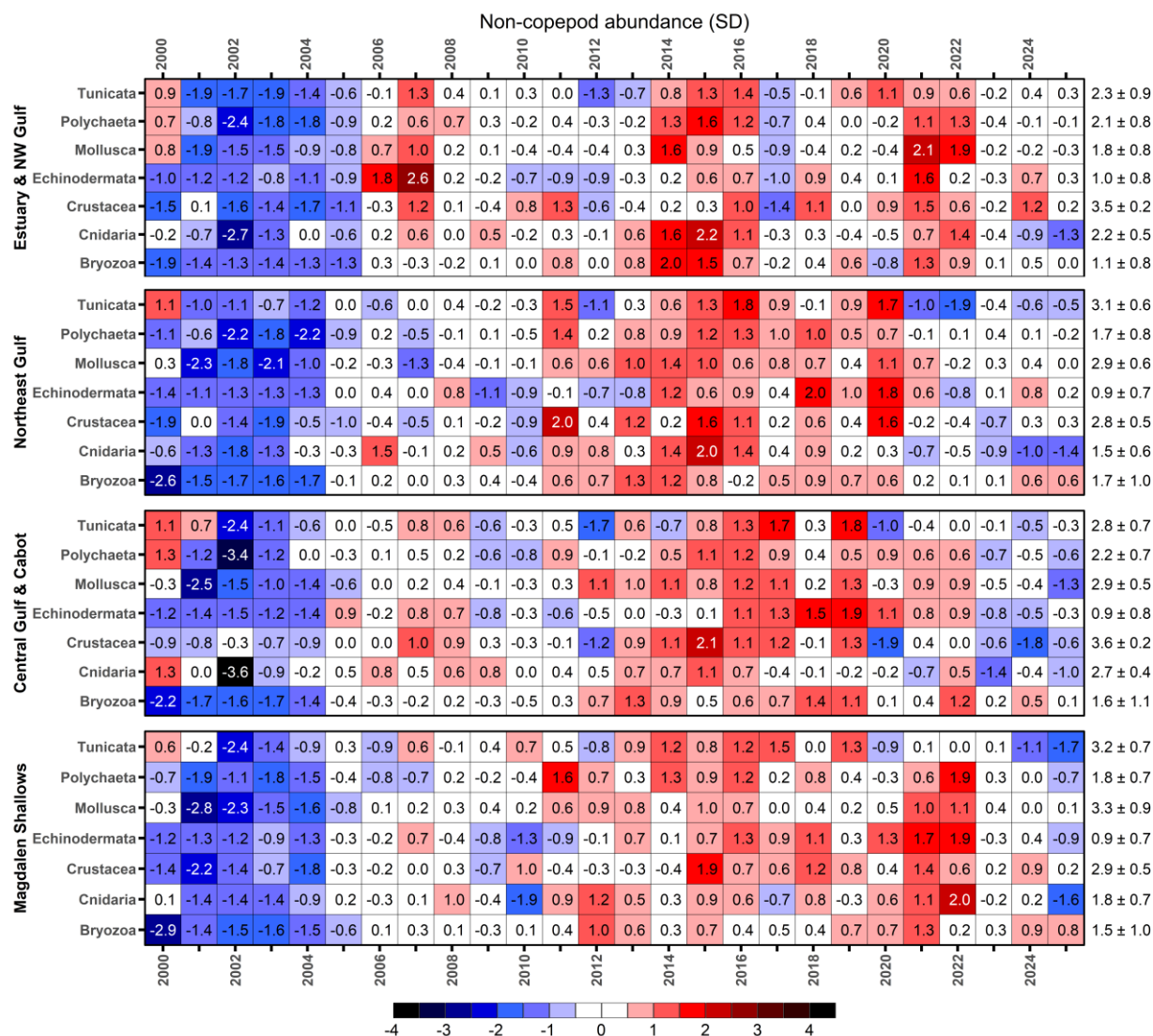


Figure 52. Time series of standardized annual anomalies for the abundance of main non-copepod zooplankton taxa for the regions of the Gulf of St. Lawrence. The numbers on the right are the 2000–2025 climatological means and standard deviations in units of $\log_{10}(\text{individuals m}^{-2} + 1)$. Blue colours indicate below-normal levels, reds are above-normal levels, and white represents normal levels.

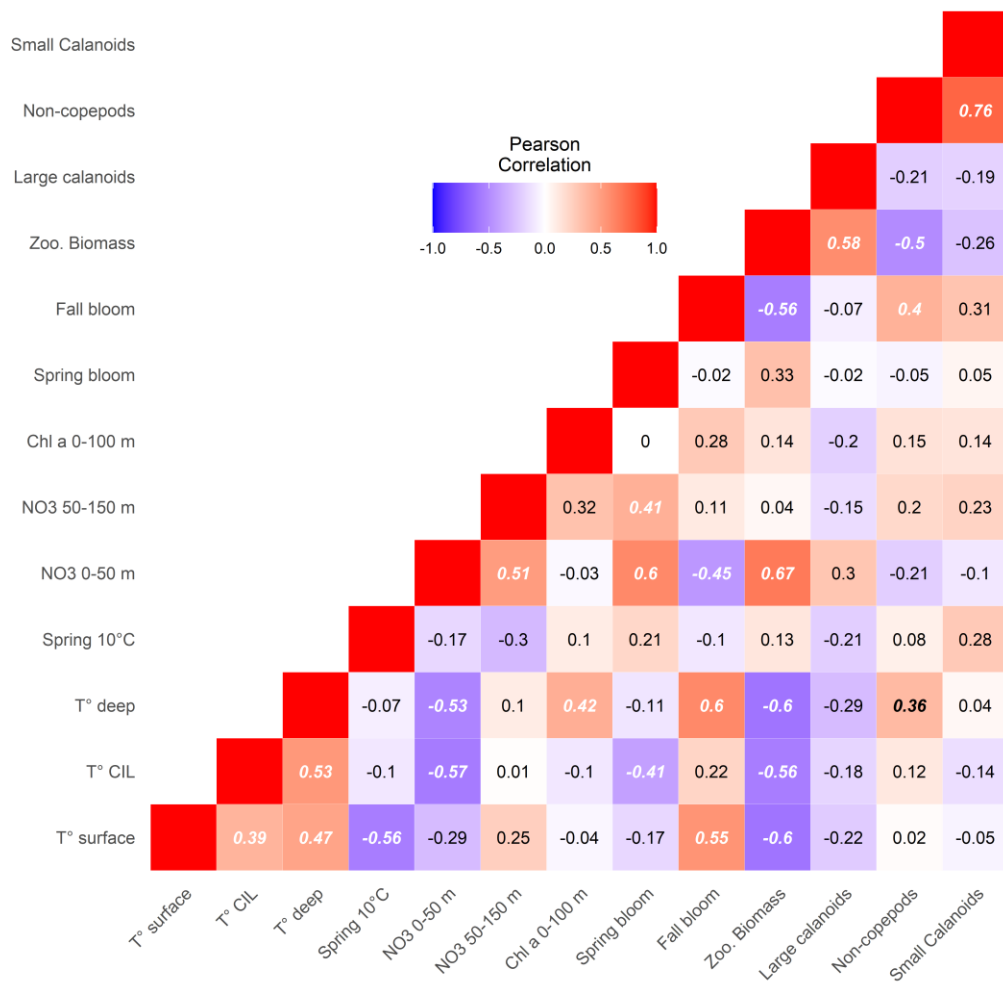


Figure 53. Correlation matrix of weighted averaged anomalies for key Gulf indices. Blue colours indicate negative correlations, and reds are positive correlations. Significant correlations are indicated in black bold italic ($p < 0.1$) or in white bold-italic ($p < 0.05$). CIL: cold intermediate layer. Spring 10 °C is an index of spring timing based on the date at which average Gulf temperature at the surface warms to 10 °C. Spring and fall blooms refer to their timing.

APPENDICES

Appendix 1: List of taxa associated with each copepod index.

Small calanoids	<i>Acartia</i> spp.
	<i>Aetideidae</i>
	<i>Centropages</i> spp.
	<i>Clausocalanus</i> spp.
	<i>Eurytemora</i> spp.
	<i>Microcalanus</i> spp.
	<i>Nannocalanus minor</i>
	<i>Paracalanus parvus</i>
	<i>Pseudocalanus</i> spp.
	<i>Scolecithricella</i> spp.
	<i>Spinocalanus</i> spp.
	<i>Temora</i> spp.
	<i>Tortanus</i> spp.
Large calanoids	<i>Anomalocera</i> spp.
	<i>Calanus finmarchicus</i>
	<i>Calanus glacialis</i>
	<i>Calanus hyperboreus</i>
	<i>Euchaeta</i> spp.
	<i>Metridia</i> spp.
	<i>Paraeuchaeta</i>
	<i>Pleuromamma borealis</i>
	<i>Pleuromamma robusta</i>
Warm copepods	<i>Centropages</i> spp.
	<i>Clausocalanus</i> spp.
	<i>Metridia lucens</i>
	<i>Nannocalanus minor</i>
	<i>Paracalanus</i> spp.
	<i>Pleuromamma borealis</i>
	<i>Pleuromamma robusta</i>
Cyclopoids	<i>Oithona</i> spp.
	<i>Oncaea</i> spp.
	<i>Triconia borealis</i>
	<i>Triconia conifer</i>
	<i>Triconia similis</i>
Cold copepods	<i>Metridia longa</i>
	<i>Calanus glacialis</i>

Appendix 2: Methodological details for the characterization of bloom and seasonal metrics

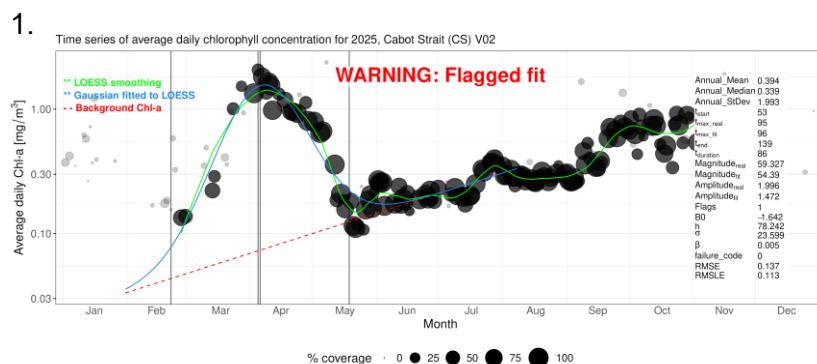
The timing of the spring phytoplankton bloom was derived by applying a LOESS function to the daily averages of $\log_{10}$ -transformed chl *a* concentration (weighted by percent coverage within the polygon, down to a minimum of 20%), and then by fitting a shifted Gaussian function to the smoothed data (Zhai et al. 2011). The start of the spring bloom corresponds to the day when chl *a* concentration reaches 20% of the maximum spring bloom amplitude, and the peak timing is the day at which fitted chl *a* concentration reaches its maximum. Initiation of the fall bloom was calculated by applying the threshold method described in Layton et al. (2022) on the LOESS-smoothed daily averages of the $\log_{10}$ -transformed chl *a* concentrations. Fall bloom start corresponds to the day when chl *a* concentration rises above the threshold of 5% over the annual median, and remains above it for at least 14 consecutive days.

Seasonal chl *a* averages were computed using season boundaries. These boundaries are unique to each polygon and are defined based on the climatological timing (start and end) of the spring and fall blooms. Winter extends from January 1st to the start of the spring bloom, summer extends from the end of the spring bloom to the start of the fall bloom, and fall extends from the end of the fall bloom to December 31st.

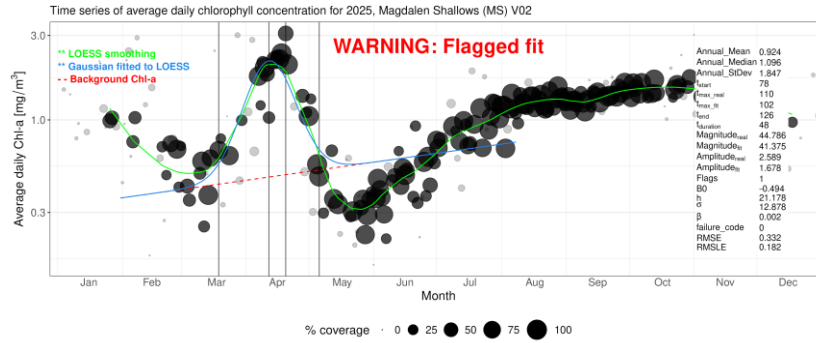
The figures below show the spring and fall bloom fits for 2025 in all Gulf ocean colour polygons, generated using the PhytoFit application v1.0.0 (Clay et al. 2021) with the parameters listed in the table below. These bloom fits are used to define spring (peak; plots 1–4) and fall (start; plots 5–8) timing of the bloom, as well as to define season boundaries. Different "flagged fit" warning may arise if the offset between observed and modelled parameters is too large or if parameters are on the boundary of the allowed range. These flags exist in the PhytoFit app to aid the user in detecting bad fits.

Reference:

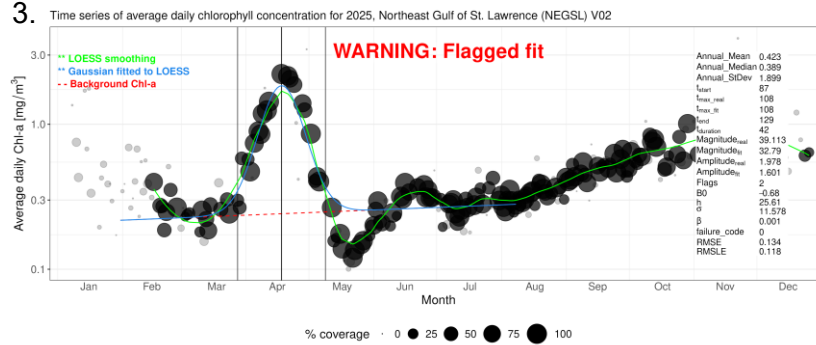
Clay, S., Layton, C., and Devred, E. 2021. BIO-RSG/PhytoFit: First release (Version v1.0.0). Zenodo. <https://doi.org/10.5281/zenodo.4770754>



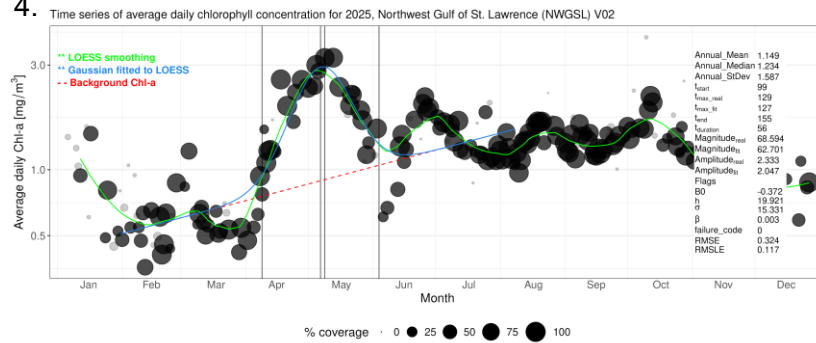
2.



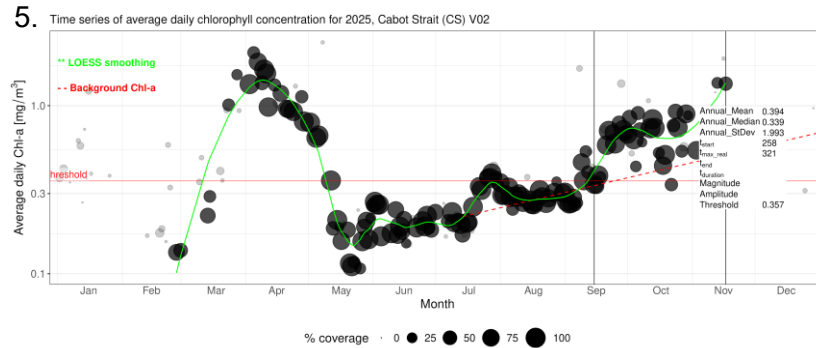
3.



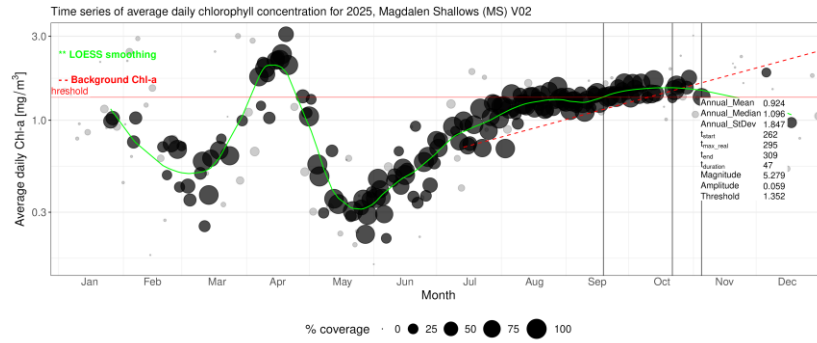
4.



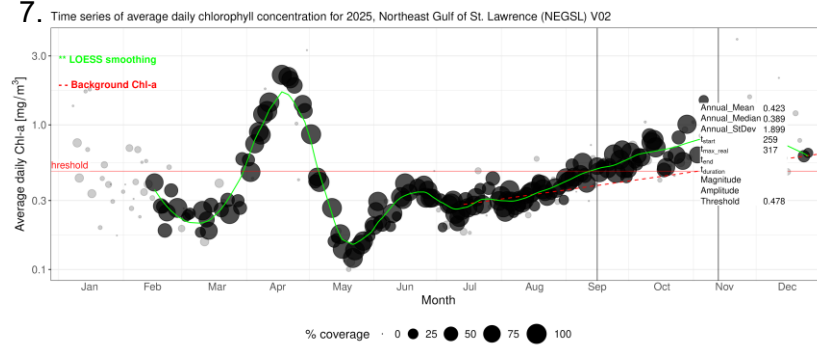
5.



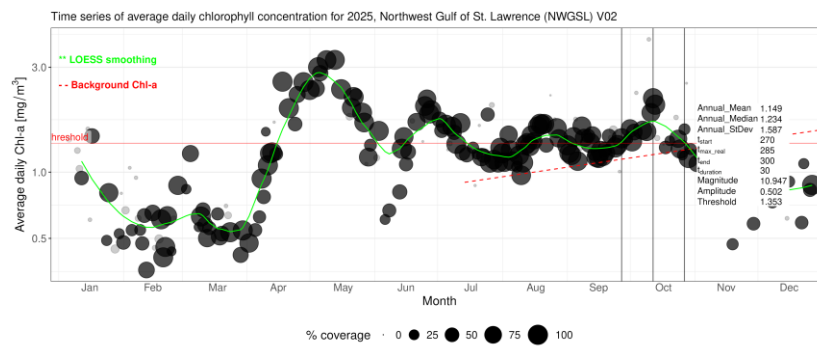
6.



7.



8.



Parameters	Spring	Fall
Settings_region	Gulf of Saint Lawrence 4km	Gulf of Saint Lawrence 4km
Settings_sat_alg	occciv6.0_chlpoly4	occciv6.0_chlpoly4
Settings_concentration_type	full	full
Settings_interval	daily	daily
Settings_log_chla	TRUE	TRUE
Settings_percent	20	20
Settings_outlier	sd3	sd3
Settings_dailystat	average	average
Settings_pixrange1	-	-
Settings_pixrange2	-	-
Settings_fitmethod	gauss	thresh
Settings_bloomShape	symmetric	asymmetric
Settings_smoothMethod	loess	loess
Settings_loessSpan	0.2	0.2
Settings_t_range	31, 220	195, 365
Settings_ti_limits	58, 150	196, 354
Settings_tm_limits	91,181	197, 364
Settings_ti_threshold_type	percent_thresh	-
Settings_ti_threshold_percent	20	-
Settings_threshcoef	-	1.05
Settings_tm	TRUE	-
Settings_beta	TRUE	-
Settings_use_weights	TRUE	FALSE
Settings_rm_bkrnd	TRUE	TRUE
Settings_flag1_lim1	0.75	0.75
Settings_flag1_lim2	1.25	1.25
Settings_flag2_lim1	0.85	0.85
Settings_flag2_lim2	1.15	1.15

Appendix 3: General linear model results for Rimouski and Shediac Valley stations. Significance of the year and month effects as well as the adjusted coefficients (R^2) of the regression for nutrients and chlorophyll a are presented.

Station	Index	Year (<i>p</i>)	Month (<i>p</i>)	R^2
Rimouski	Chlorophyll <i>a</i> (0–100 m)	<0.0001	<0.0001	0.42
	Nitrate (0–50 m)	<0.0001	<0.0001	0.37
	Nitrate (50–150 m)	<0.0001	<0.0001	0.28
	Nitrate (150–320 m)	<0.0001	<0.0001	0.53
Shediac Valley	Chlorophyll <i>a</i> (0–100 m)	0.003	<0.0001	0.29
	Nitrate (0–50 m)	<0.0001	<0.0001	0.49
	Nitrate (50–84 m)	<0.0001	<0.0001	0.45

Appendix 4: General linear model results for Rimouski and Shediac Valley stations. Significance of the year and month effects as well as the adjusted coefficients (R^2) of the regression for phytoplankton groups are presented.

Station	Index	Year (<i>p</i>)	Month (<i>p</i>)	R^2
Rimouski	Diatoms	<0.0001	<0.0001	0.34
	Dinoflagellates	<0.0001	<0.0001	0.49
	Flagellates	<0.0001	<0.0001	0.35
	Total	<0.0001	<0.0001	0.26
Shediac Valley	Diatoms	<0.0001	<0.0001	0.34
	Dinoflagellates	<0.0001	0.002	0.35
	Flagellates	<0.0001	<0.0001	0.36
	Total	0.002	0.1	0.18

Appendix 5: General linear model results for Gulf regions. Significance of the year, season, and station effects as well as the adjusted coefficients (R^2) squared of the regression for nutrients or chlorophyll a are presented. Btm: Bottom.

Region	Index	Year (<i>p</i>)	Season (<i>p</i>)	Station(<i>p</i>)	R^2
Estuary/ Northwest Gulf	Chlorophyll <i>a</i> (0–100 m)	<0.0001	<0.0001	<0.0001	0.33
	Nitrate (0–50 m)	<0.0001	<0.0001	<0.0001	0.59
	N:P (0–50 m)	<0.0001	<0.0001	<0.0001	0.65
	Si:N (0–50 m)	<0.0001	<0.0001	<0.0001	0.16
	Nitrate (50–150 m)	<0.0001	<0.0001	<0.0001	0.70
	N:P (50–150 m)	<0.0001	<0.0001	<0.0001	0.44
	Si:N (50–150 m)	<0.0001	<0.0001	<0.0001	0.33
	Nitrate (150-btm)	<0.0001	<0.0001	<0.0001	0.73
	N:P (150-btm)	<0.0001	<0.0001	<0.0001	0.73
	Si:N (150-btm)	<0.0001	<0.0001	<0.0001	0.78
Northeast Gulf	Chlorophyll <i>a</i> (0–100m)	<0.0001	<0.0001	0.01	0.24
	Nitrate (0–50m)	<0.0001	<0.0001	<0.0001	0.73
	N:P (0–50m)	<0.0001	<0.0001	<0.0001	0.85
	Si:N (0–50m)	<0.001	<0.001	1	0.02
	Nitrate (50–150m)	<0.0001	<0.0001	<0.0001	0.85
	N:P (50–150m)	<0.0001	<0.0001	<0.0001	0.70
	Si:N (50–150m)	<0.0001	<0.0001	<0.0001	0.23
	Nitrate (150-btm)	<0.0001	<0.0001	<0.0001	0.92
	N:P (150-btm)	<0.0001	<0.001	<0.0001	0.67
	Si:N (150-btm)	<0.0001	<0.0001	<0.0001	0.70
Central Gulf/Cabot Strait	Chlorophyll <i>a</i> (0–100m)	<0.0001	<0.0001	0.04	0.14
	Nitrate (0–50m)	<0.0001	<0.0001	<0.0001	0.70
	N:P (0–50m)	<0.0001	<0.0001	<0.0001	0.78
	Si:N (0–50m)	<0.0001	0.2	<0.0001	0.25
	Nitrate (50–150m)	<0.0001	<0.0001	<0.0001	0.52
	N:P (50–150m)	<0.0001	<0.0001	<0.0001	0.39
	Si:N (50–150m)	<0.0001	<0.0001	<0.0001	0.52
	Nitrate (150-btm)	<0.0001	<0.0001	<0.0001	0.93
	N:P (150-btm)	<0.0001	0.007	<0.0001	0.51
	Si:N (150-btm)	<0.0001	<0.0001	<0.0001	0.67
Magdalen Shallows	Chlorophyll <i>a</i> (0–100m)	<0.0001	<0.0001	<0.0001	0.33
	Nitrate (0–50m)	<0.0001	<0.0001	<0.0001	0.63
	N:P (0–50m)	<0.0001	<0.0001	<0.0001	0.66
	Si:N (0–50m)	<0.0001	<0.0001	<0.0001	0.17
	Nitrate (50–150m)	<0.0001	<0.0001	<0.0001	0.76
	N:P (50–150m)	<0.0001	<0.0001	<0.0001	0.55
	Si:N (50–150m)	<0.0001	0.1	<0.0001	0.33

Appendix 6: General linear model results for Rimouski and Shediac Valley stations. Significance of the year and month effects as well as the adjusted coefficients (R^2) of the regression for each zooplankton index are presented.

Station	Index	Year (<i>p</i>)	Month (<i>p</i>)	R^2
Rimouski	<i>Calanus finmarchicus</i>	<0.0001	<0.0001	0.51
	<i>Pseudocalanus</i> spp.	<0.0001	<0.0001	0.57
	Total copepods	<0.0001	<0.0001	0.61
	Non-copepods	<0.0001	<0.0001	0.43
	<i>Calanus hyperboreus</i>	<0.0001	<0.0001	0.62
	Small calanoids	<0.0001	<0.0001	0.70
	Large calanoids	<0.0001	<0.0001	0.36
	Cyclopoids	<0.0001	<0.0001	0.60
	Copepods: Warm	<0.0001	0.8	0.55
	Copepods: Cold	<0.0001	<0.0001	0.45
	Dry weight	<0.0001	<0.0001	0.7
	Bryozoa	<0.0001	<0.0001	0.23
	Cnidaria	<0.0001	<0.0001	0.61
	Crustacea	<0.0001	<0.0001	0.33
	Echinodermata	<0.0001	0.001	0.22
	Mollusca	<0.0001	<0.0001	0.36
	Polychaeta	<0.0001	<0.0001	0.42
	Tunicata	<0.0001	<0.0001	0.45
Shediac Valley	<i>Calanus finmarchicus</i>	<0.0001	<0.0001	0.33
	<i>Pseudocalanus</i> spp.	0.03	0.2	0.09
	Total copepods	0.1	<0.0001	0.17
	Non-copepods	<0.001	0.002	0.21
	<i>Calanus hyperboreus</i>	<0.0001	<0.0001	0.68
	Small calanoids	0.001	<0.001	0.20
	Large calanoids	<0.0001	<0.0001	0.35
	Cyclopoids	0.2	<0.0001	0.21
	Copepods: Warm	0.02	0.1	0.1
	Copepods: Cold	0.03	<0.0001	0.29
	Dry weight	<0.0001	<0.0001	0.35
	Bryozoa	<0.0001	<0.0001	0.45
	Cnidaria	<0.0001	<0.001	0.39
	Crustacea	0.004	<0.0001	0.33
	Echinodermata	0.06	<0.0001	0.18
	Mollusca	<0.001	<0.0001	0.34
	Polychaeta	<0.0001	<0.0001	0.48
	Tunicata	0.02	<0.0001	0.22

Appendix 7: General linear model results for Gulf regions. Significance of the year, season, and station effects as well as the adjusted coefficients (R^2) of the regression for each zooplankton index are presented.

Region	Index	Year (p)	Season (p)	Station(p)	R^2
Estuary/ Northwest Gulf	<i>Calanus finmarchicus</i>	<0.0001	0.008	<0.0001	0.64
	<i>Pseudocalanus</i> spp.	<0.0001	<0.0001	<0.0001	0.53
	Total copepods	<0.0001	<0.0001	<0.0001	0.72
	Non-copepods	<0.0001	<0.0001	<0.0001	0.53
	<i>Calanus hyperboreus</i>	<0.0001	<0.0001	<0.0001	0.61
	Small calanoids	<0.0001	<0.0001	<0.0001	0.64
	Large calanoids	<0.0001	<0.001	<0.0001	0.76
	Cyclopoids	<0.0001	<0.0001	<0.0001	0.68
	Copepods: Warm	<0.0001	<0.001	<0.0001	0.54
	Copepods: Cold	<0.0001	0.006	<0.0001	0.66
	Dry weight	<0.0001	0.004	<0.0001	0.79
	Bryozoa	<0.0001	<0.0001	<0.0001	0.44
	Cnidaria	<0.0001	0.008	<0.0001	0.71
	Crustacea	<0.0001	<0.0001	<0.0001	0.51
	Echinodermata	<0.0001	<0.001	<0.0001	0.36
	Mollusca	<0.0001	<0.0001	<0.0001	0.49
	Polychaeta	<0.0001	<0.0001	<0.0001	0.56
	Tunicata	<0.0001	<0.0001	<0.0001	0.42
Northeast Gulf	<i>Calanus finmarchicus</i>	<0.0001	<0.0001	0.02	0.22
	<i>Pseudocalanus</i> spp.	<0.0001	<0.0001	<0.0001	0.34
	Total copepods	<0.0001	<0.0001	<0.001	0.34
	Non copepods	<0.0001	0.001	<0.0001	0.43
	<i>Calanus hyperboreus</i>	<0.0001	<0.0001	<0.0001	0.59
	Small calanoids	<0.0001	0.6	<0.0001	0.41
	Large calanoids	0.02	<0.0001	<0.0001	0.43
	Cyclopoids	<0.0001	<0.0001	0.03	0.45
	Copepods: Warm	<0.0001	<0.0001	0.01	0.44
	Copepods: Cold	<0.0001	<0.0001	<0.0001	0.42
	Dry weight	<0.0001	<0.0001	<0.0001	0.65
	Bryozoa	<0.0001	<0.0001	0.9	0.61
	Cnidaria	<0.0001	0.9	<0.001	0.35
	Crustacea	<0.0001	<0.0001	<0.001	0.40
	Echinodermata	<0.0001	0.05	0.05	0.19
	Mollusca	<0.0001	0.8	<0.001	0.30
	Polychaeta	<0.0001	<0.0001	0.9	0.53
	Tunicata	<0.0001	<0.0001	<0.0001	0.36

Appendix 7 (continued): General linear model results for Gulf regions. Significance of the year, season, and station effects as well as the adjusted coefficients (R^2) of the regression for each zooplankton index are presented.

Region	Index	Year (p)	Season (p)	Station(p)	R ²
Central Gulf/ Cabot Strait	<i>Calanus finmarchicus</i>	<0.0001	<0.0001	<0.001	0.26
	<i>Pseudocalanus</i> spp.	<0.0001	<0.0001	<0.0001	0.38
	Total copepods	<0.0001	<0.0001	<0.001	0.25
	Non-copepods	<0.0001	<0.0001	<0.0001	0.48
	<i>Calanus hyperboreus</i>	<0.0001	<0.0001	<0.0001	0.54
	Small calanoids	<0.0001	0.5	<0.0001	0.39
	Large calanoids	<0.0001	0.9	<0.0001	0.36
	Cyclopoids	<0.0001	<0.0001	0.001	0.24
	Copepods: Warm	<0.0001	<0.0001	<0.0001	0.48
	Copepods: Cold	<0.0001	1	0.06	0.12
	Dry weight	<0.0001	0.3	<0.0001	0.64
	Bryozoa	<0.0001	<0.0001	0.4	0.48
	Cnidaria	<0.0001	<0.0001	<0.0001	0.46
	Crustacea	<0.0001	<0.0001	<0.0001	0.37
	Echinodermata	<0.0001	0.002	0.002	0.25
	Mollusca	<0.0001	0.006	0.003	0.18
	Polychaeta	<0.0001	<0.0001	<0.0001	0.58
	Tunicata	<0.0001	<0.0001	<0.001	0.42
Magdalen Shallows	<i>Calanus finmarchicus</i>	<0.0001	<0.001	<0.0001	0.33
	<i>Pseudocalanus</i> spp.	<0.0001	<0.0001	0.7	0.13
	Total copepods	<0.0001	<0.0001	<0.0001	0.21
	Non copepods	<0.0001	<0.0001	<0.0001	0.49
	<i>Calanus hyperboreus</i>	<0.0001	<0.0001	<0.0001	0.49
	Small calanoids	<0.0001	0.1	<0.001	0.19
	Large calanoids	<0.0001	<0.0001	<0.0001	0.49
	Cyclopoids	<0.0001	<0.0001	<0.0001	0.30
	Copepods: Warm	<0.0001	<0.0001	0.005	0.49
	Copepods: Cold	<0.0001	<0.0001	<0.0001	0.39
	Dry weight	<0.0001	<0.0001	<0.0001	0.43
	Bryozoa	<0.0001	<0.0001	0.6	0.65
	Cnidaria	<0.0001	0.06	<0.0001	0.32
	Crustacea	<0.0001	<0.0001	<0.0001	0.43
	Echinodermata	<0.0001	0.03	0.007	0.23
	Mollusca	<0.0001	0.08	<0.0001	0.57
	Polychaeta	<0.0001	<0.0001	0.005	0.63
	Tunicata	<0.0001	<0.0001	<0.0001	0.34

Appendix 8. Trend results from linear regression or Mann-Kendall test for Gulf annual mean anomalies.

