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Oceanographic conditions in the Estuary and the Gulf of St. Lawrence during 2004: zooplankton

Conditions océanographiques dans l'estuaire et le golfe du St-Laurent en 2004 : zooplancton

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ABSTRACT

Zooplankton biomass, abundance, and species composition in the Québec Region (Lower St. Lawrence Estuary and Gulf of St. Lawrence) during 2004 are reviewed and related to conditions during the preceding years and over the longer term where applicable. In addition, this report gives an overview of the interannual variability of the mesozooplankton biomass and the macrozooplankton species composition, abundance, and biomass in the Lower Estuary (LE) and the northwest Gulf of St. Lawrence (NWGSL) as measured in fall of each year between 1994 and 2004.

Even with only four zooplankton samples collected in February, March, June and November 2004, at both Québec fixed stations in 2004, we can see that the zooplankton biomass follow the same temporal variations pattern then during the 5 previous years (1999-2003). Furthermore, the zooplankton biomass observed in February, March, June and November were comparable to the one observed previously (1999 – 2003) at the same period of the year except in June and November in the Anticosti gyre were the zooplankton biomass was ca 2 times lower than normal. Hierarchical community analysis revealed that copepods continue to numerically dominate the zooplankton year-round at both Québec fixed station in 2004. The depth-integrated abundance of the different *Calanus finmarchicus* stages reveled that the reproductive success of *C. finmarchicus* seems to have been lower in 2004 than during the previous years at both fixed stations. The overall abundance and biomass of zooplankton observed in 2004 along all sections in spring and fall were comparable to observations made since 2000.

The mean mesozooplankton biomass observed in November 2004 in the LE and the NWGSL was 1.3 times lower than in 2003 and corresponded to the second lowest value observed since the last 10 years in the study area. On the other hand, the mean macrozooplankton biomass observed in 2004 was 1.2 times higher than in 2003. The most notable feature observed in the LE and the NW GSL was that 2004 had the lowest mean biomass of euphausiids in the last decade and that for the first time the mean biomass of the hyperiid amphipod *T. libellula* was higher than the mean biomass of euphausiids. Finally, the mean abundance of both the chaetognaths and the jellyfish observed in 2004 corresponded to the highest value of the time series and were up 8.5 and 10.5 times higher than the average value of the last ten years respectively.

Résumé

L'information présentée dans ce rapport décrit l'état du zooplancton dans le Saint-Laurent en 2004. Ces résultats proviennent de l'analyse des données de deux stations fixes situées dans la gyre d'Anticosti (GA) et le courant de Gaspé (CG) et de sept sections réparties dans l'ensemble de l'estuaire maritime (EM) et du golfe du Saint-Laurent (GSL). Des informations additionnelles provenant d'une grille de 48 stations échantillonnées depuis 1994 dans l'estuaire maritime et le golfe du Saint-Laurent sont aussi présentées. Nous mettons l'accent sur les conditions en 2004, que nous comparons ensuite aux observations recueillies depuis 1999 dans le cadre du programme de la zone Atlantique (PMZA) et aux observations sur le macrozooplancton recueillies de 1994 à 2004.

L'année 2004 a été particulière en ce qui concerne la fréquence d'échantillonnage des 2 stations fixes de la région du Québec qui n'ont été échantillonnées qu'à 4 reprises au cours de l'année soit: en février, mars, juin et novembre 2004. Malgré cette faible fréquence d'échantillonnage, nous avons observé que le patron de variation saisonnière de la biomasse de zooplancton est demeuré le même que celui observé au cours des 5 dernières années. De plus, les biomasses de zooplancton observés en février, mars, juin et novembre 2004 étaient comparables aux biomasses de zooplancton mesurées précédemment aux mêmes dates, excepté en juin et novembre dans la gyre d'Anticosti, où les biomasses étaient 2 fois plus faibles que la normale. Les copépodes continuent à dominer numériquement la communauté de zooplancton pendant toute l'année aux deux stations fixes. Cependant, l'analyse de l'abondance des différents stades de développement de *Calanus finmarchicus* suggère que la production de cette espèce aurait été plus faible en 2004 qu'au cours des années précédentes, aux deux stations fixes. Finalement, la biomasse et l'abondance du zooplancton observée au printemps et à l'automne 2004 le long des six sections correspondaient aux observations faites en 2003, 2002, 2001 et 2000 dans l'ensemble des régions.

La biomasse de mésozooplancton observée en novembre 2004 dans l'estuaire maritime et le nord-ouest du GSL était 1.3 fois plus faible qu'en 2003 et correspond à la seconde plus faible valeur observé au cours des 10 dernières années dans ces deux régions. Par ailleurs, la biomasse moyenne de macrozooplancton était 1.2 fois plus élevé qu'en 2003. Le résultat le plus marquant que nous avons obtenu a été que l'année 2004 correspond à la plus faible biomasse d'euphausiacés (krill) observé au cours des 10 dernières années et que pour la première fois depuis 1994, la biomasse moyenne de l'amphipode pélagique *Themisto libellula* était plus élevé que celle des euphausiacés (krill). Finalement, nous avons observé une importante augmentation de l'abondance moyenne des chaetognathes *Sagitta elegans* ainsi que du zooplancton gélatineux (*Aglantha digitale*, *Obelia* sp. et *Boreo* sp.); l'abondance moyenne de ces 2 groupes d'organismes était respectivement 8.5 et 10.5 fois plus élevées en 2004 qu'au cours des 10 dernières années.

INTRODUCTION

The Atlantic Zonal Monitoring Program (AZMP) was implemented in 1998 (Therriault et al. 1998) with the aim of (1) increasing DFO's capacity to understand, describe, and forecast the state of the marine ecosystem and (2) quantifying changes in the ocean's physical, chemical, and biological properties and the predator/prey relationships of marine resources. A critical element in the AZMP observational program is an annual assessment of the distribution and variability of nutrients and the plankton they support.

The description of the distribution in time and space of nutrients dissolved in seawater (nitrate, silicate, phosphate) provides important information on the water-mass movements and on the locations, timing, and magnitude of biological production cycles. A description of phytoplankton and zooplankton distribution provides important information on the organisms forming the base of the marine food web. An understanding of the plankton production cycles is an essential part of an ecosystem approach to fisheries management.

The AZMP derives its information on the state of the marine ecosystem from data collected at a network of sampling locations (e.g., fixed point stations, sections, groundfish surveys) in each region (Québec, Maritimes/Gulf, Newfoundland) sampled at frequencies of bi-weekly to once annually. Furthermore, we have a zooplankton biomass survey in the Québec Region, which has been carried out in the Lower Estuary and the northwest Gulf of St. Lawrence in fall since 1994. The sampling design provides basic information on the natural variability in the physical, chemical, and biological properties of the northwest Atlantic continental shelf and the Gulf of St. Lawrence (GSL). The annual zooplankton biomass survey and the AZMP sections provide detailed geographic information but are limited in their seasonal coverage. Critically placed fixed stations complement the geographically-based sampling by providing more detailed information on temporal (seasonal) changes in ecosystem properties.

The purpose of this document is to provide an overview of the temporal variability in 2004 of the zooplankton biomass, abundance, and species composition at two fixed stations and six sections of the AZMP as well as an overview of the interannual variability of the macrozooplankton species composition, abundance, and biomass in the Lower St. Lawrence Estuary (LSLE) and the northwest Gulf of St. Lawrence (NWGSL) from 1994 to 2004.

SPATIAL AND TEMPORAL VARIABILITY OF ZOOPLANKTON SPECIES COMPOSITION, ABUNDANCE, AND BIOMASS AT TWO FIXED STATIONS AND SEVEN SECTIONS OF THE AZMP IN 2004

Material and Methods

The sampling dates of two fixed stations (Anticosti Gyre and Gaspé Current) and along seven sections (St. Lawrence Estuary, Sept-Îles, Anticosti, Center Gulf of St. Lawrence, Cabot Strait, Bonne Bay, Îles-de-la-Madeleine) are given in Figure 1. In 2004, zooplankton samples were collected during only 4 visits to the fixed stations (29 February, 14 March, 8 June and 12 November 2004) and two visits to the sections (8-16 June and 3-16 November 2004). Collections and standard measurements of zooplankton biomass and abundance are based on protocols outlined by the steering committee of the AZMP (Mitchell 2002).

We analyzed the monthly variations of a series of indices describing the state of the zooplankton community at each station in 2004. The indices are 1) the depth-integrated biomass of both the macrozooplankton and the mesozooplankton, 2) the depth-integrated zooplankton abundance and community structure, 3) the depth-integrated copepod abundance and community structure, and 4) the depth-integrated abundance of the stage composition of *Calanus finmarchicus* copepodites.

Results and Discussion

Fixed stations. Even with only four zooplankton samples collected in February, March, June and November 2004, at both fixed stations, we can see that the zooplankton biomass follow the same temporal variations pattern then during the 5 previous years (1999-2003) (Fig. 2). Furthermore, the zooplankton biomass observed in February, March, June and November were comparable to the one observed previously (1999 – 2003) at the same period of the year except in June and November in the Anticosti gyre were the zooplankton biomass was ca 2 times lower than normal (Fig.2). The mean biomass for 2004 was 3.0 times higher in the AG (88.8 g ww · m^{-2}) than in the GC (27.2 g ww · m^{-2}) (not shown). The higher biomass at the AG station was largely due to the higher abundance of *Calanus hyperboreus*. This difference in the abundance of *C. hyperboreus* at the two fixed stations is probably due to the fact that the AG station is deeper (320 m) than the GC station (175 m). *C. hyperboreus* spends a large part of the year in diapause at depths greater than 200 m (Plourde et al. 2003).

The total abundance of zooplankton in 2004 varied between 45,728 and 204,692 individuals · m^{-2} in the GC and between 85,305 and 270,414 individuals · m^{-2} in the AG (Fig. 3). Hierarchical community analysis revealed that copepods continue to numerically dominate the zooplankton year-round at both Québec fixed stations in 2004 (Fig. 3). There was no apparent change in copepod community structure in 2004 at either station (Fig 4). Finally, the depth-integrated abundance of the different *Calanus finmarchicus* stages reveled that the reproductive success of *C. finmarchicus* seems to have been lower in 2004 than during the previous years at both fixed stations (Fig 5).

Sections. The total zooplankton biomass varied between 0.9 and 212 g ww · m^{-2} along the seven sections sampled in June, and November 2004 in the LSLE and the GSL (Fig. 6). The biomass increased with the depth along all sections for the two sampling periods. Highest biomass was found along sections located over the Laurentian Channel (St. Lawrence Estuary, Sept-Îles, Anticosti, Gulf center and Cabot Strait) and the lowest were in the northern (Bonne Bay) and the southern (Îles-de-la-Madeleine) regions. Zooplankton biomass was similar in late spring (June) and fall (November) along all sections except at stations 4 and 5 along the Cabot Strait section where zooplankton biomass was ca 2 times higher in fall than in late spring (Fig. 6). The seasonal averages zooplankton biomass observed in late spring and fall 2004 along all sections was comparable to observations made in 2000, 2001, 2002, and 2003 (Fig. 7).

The overall abundance of zooplankton integrated over the water column varied between 5,296 and 610,137 ind. · m^{-2} along all sections in June and November (Fig. 8). Total abundances of zooplankton were higher in fall (November) than in late spring (June) along all sections except along the Cabot Strait sections and on the east side of the Bonne Bay and the Îles-de-la-Madeleine sections (fig. 8). The seasonal averages zooplankton abundance in late spring and fall 2004 along all sections was comparable to 2000, 2001, 2002, and 2003 (Fig. 9). Finally, there were no marked variations in the seasonal averages abundance of *C. finmarchicus* along any section sampled in late spring and fall 2000, 2001, 2002, 2003, and 2004 except in fall 2003 along the Sept-îles and Anticosti transects, where the abundance of *C. finmarchicus* was respectively 2.5 and 1.5 times higher than normal (Fig. 10).

INTERANNUAL VARIATIONS IN THE MACROZOOPLANKTON SPECIES COMPOSITION, ABUNDANCE, AND BIOMASS IN THE LOWER ST. LAWRENCE ESTUARY AND THE NORTHWEST GULF OF ST. LAWRENCE FROM 1994 TO 2004

Material and Methods

The survey involves sampling with a 1 m^2 BIONESS plankton sampler equipped with 333-µm mesh nets at up to 44 stations along eight sections covering the LSLE and the NWGSL from Les Escoumins to Sept-Îles (Fig. 11). In 1994, only sections K through T were surveyed. Sections G and I, at the head of the Laurentian Channel, have been sampled in since 1995 whereas section U in the AG has only been sampled since 1997. The survey has taken place in September of each year, usually during a period of 10 days in the middle of the month except in 2004 where the survey was carried out in early November. At each station, the water column was sampled twice, each time with two nets (bottom-150 m and 150-0 m or bottom-0 for stations < 150 m depth). Approximately half the stations were sampled during the day and half at night. The total zooplankton wet weight and the wet weights of fish (Atlantic soft pout, *Melanostigma atlanticum*), pandalid shrimp, and gelatinous zooplankton were measured on board immediately after the tow. Since 1998, larger samples have been split on board with a Folsom plankton splitter to obtain a maximum volume of 125 ml. The catch was then preserved and the following categories (sorted manually) were analyzed for wet weight upon return to the laboratory:

- **Macrozooplankton**: mainly adult and juvenile euphausids (*Meganyctiphanes norvegica*, *Thysanoessa inermis*, and *T. raschii*). This category also includes mysids, which were commonly found in deep samples, and hyperiid amphipods.

- **Mesozooplankton**: predominantly copepods, but also other mesozooplankton, including chaetognaths and benthic invertebrate larvae. This category excludes gelatinous zooplankton, decapods, and macrozooplankton (as defined above).

Two replicates per station per year were then analyzed to determine the species composition and the macrozooplankton abundance (adult size > 1 cm). Wet weights and species abundances for each tow were divided by volume filtered (m^3) as measured by a General Oceanics flow meter installed in the mouth of the BIONESS. Integrated biomass (g ww · m^{-2}) and abundance (ind. · m^{-2}) for the water column was calculated by multiplying the standardized wet weight and abundance by the depth interval sampled by the net.

Results and Discussion

The mean mesozooplankton biomass observed in September 2004 in the LSLE and in the NWGSL corresponded to the second lowest value observed since the last 10 years in the study area (Fig. 12). The mean mesozooplankton biomass observed in 2004 was 1.3 times lower than in 2003. On the other hand, the mean macrozooplankton biomass was 1.2 times higher in 2004 than in 2003. The relative biomass of the four most important macrozooplankton groups in terms of biomass (euphausiids, mysids, hyperiid amphipods, and chaetognaths) varied over time. The relative biomass of euphausiids decreased from 87% to 55% between 1994 and 1998, slightly increased to ca. 65% between 1999 and 2003, and drastically decreased to 26% in 2004. The relative biomass of the mysid *Boreomysis artica* increased from 3% in 1994 to 29% in 2000 and decreased again to ca.16% in 2001, 2002, 2003, and 2004. On the other hand, the relative biomass of the hyperiid amphipods increased from 8% in 1994 to 20% in 1995, stayed around 20% from 1996 to 1998, significantly decreased from 23% to 1% between 1998 and 2000, and significantly increased again from 1% to ca. 20% in 2001, 2002, 30% in 2003, and 40% in 2004. Likewise, the relative biomass of the chaetognaths varied between 1 to 6% of the total macrozooplankton biomass from 1994 to 2003, and drastically increased to ca. 19% in 2004 (Fig. 12).

Figure 13 shows the interannual variations in the total abundance and biomass of the various macrozooplankton species belonging to each of the groups previously discussed. From 1994 to 1996, the mean abundance of *Thysanoessa raschii* and *Meganyctiphanes norvegica* decreased from 250 to 40 ind. · m^{-2} and from 35 to 5 ind. · m^{-2} respectively. The mean abundance of *T. raschii* was stable at ca. 40 ind. · m^{-2} from 1996 to 1999 and increased to 50 ind. · m^{-2} in 2000. From 2000 to 2002, the mean abundance of *T. raschii* decreased from 46 to 25 ind. · m^{-2} and increased slightly to ca. 32 ind. · m^{-2} in 2003 and 2004. On the other hand, the mean abundance of *M. norvegica* increased from 5 to 22 ind. · m^{-2} from 1996 to 1997 and decreased again to 5 ind. · m^{-2} in 2000. From 2000 to 2001, the mean abundance of *M. norvegica* increased from 5 to 15 ind. · m^{-2} and decreased to 10 ind. · m^{-2} in 2002, 7 ind. · m^{-2} in 2003, and 3 ind. · m^{-2} in 2004. The same temporal pattern of variation was observed for the biomass of euphausiids except that the very low abundance of *M. norvegica* observed in 2004 (3 ind. · m^{-2}) mean that 2004 had the lowest mean biomass of euphausiids in the last decade.

The mean abundance of the hyperiid amphipod *Themisto abyssorum* decreased from 40 ind. · m^{-2} in 1994 to 3 ind. · m^{-2} in 1995, increased slightly in 1997 and 1998, and decreased again to reach 1 ind. · m^{-2} in 2003 and 3 ind. · m^{-2} in 2004. Likewise, the mean abundance of *T. libellula* decreased from 15 to 5 ind. · m^{-2} between 1995 and 1996, increased to 10 ind. · m^{-2} in 1998, and decreased to 0.17 ind. · m^{-2} in 2000. From 2000 to 2004, the mean abundance of *T. libellula* increased greatly from 0.17 to 16 ind. · m^{-2}. For the first time in the last decade, the mean biomass of the hyperiid amphipod *T. libellula* was higher to the mean biomass of euphausiids in the LSLE and the NW GSL (Fig. 13). We hypothesize that this significant increase in the mean abundance of *Themisto libellula* observed in 2001, 2002, 2003, and 2004 in the LSLE and the GSL is associated with the intrusion of cold Labrador Shelf water into the Gulf of St. Lawrence via the Strait of Belle Isle. This hypothesis is supported by the finding of a significant negative relationship (R^2 = 0.62) between the abundance of *T. libellula* and the percent of the Labrador Shelf water (Fig. 14).

In contrast with all other macrozooplankton species, the mean abundance of the mysid *Boreomysis arctica* was lowest in 1994, 1995, and 1996 (ca. 18 ind. · m^{-2}) and increased significantly in 1997, 1998, and 1999 to reach a value that was three times higher in 1999 than in 1996. Since 1999, the mean abundance of *B. artica* has been stable at ca. 60 ind. · m^{-2}. In 2002, the mean abundance of *B. arctica* decreased to near the level observed in 1994, 1995, and 1996 (ca. 20 ind. · m^{-2}), increased to 40 ind. · m^{-2} in 2003, and decreased again to 25 ind. · m^{-2} in 2004 (Fig. 13). Likewise, the mean abundance of the chaetognath *Sagitta elegans* decreased from 22 to 8 ind. · m^{-2} between 1994 and 1997, increased to 25 ind. · m^{-2} in 1998, and decreased again to ca. 10 ind. · m^{-2} in 1999 and 2000. From 2000 to 2002, the mean abundance of *S. elegans* increased significantly from 10 to 35 ind. · m^{-2}, decreased to 10 ind. · m^{-2} in 2003 and increased drastically to 141 ind. · m^{-2} in 2004 (Fig. 13). Finally, the mean abundance of gelatinous zooplankton (mostly cnidarians) followed the same pattern of temporal variations as the chaetognaths during the whole time series including the drastic increase from 23 to 148 ind. · m^{-2} from 2003 to 2004.

In conclusion, two major trends have characterized the interannual variations of the macrozooplankton community structure and abundance in the LSLE and the NWGSL during the last decade (1994-2003). First, the biomass of macrozooplankton in the LSLE has decreased from 32 g · m^{-2} in 1994 to 8.6 g · m^{-2} in 2003, a 70% percent drop in 10 years. Krill, which is essentially composed of the species *Meganyctiphanes norvergica* and *Thysanoessa raschii*, accounted for 80% of the macrozooplankton in 1994. However, these two species represented only 40% of the macrozooplankton in 2003. This decline in the abundance of krill has also been measured elsewhere: 1) in the southern Gulf of St. Lawrence since 1987 (M. Harvey analysis of zooplankton samples collected over an 20-year time interval extending from 1982 to 2003 (unpublished data); Hanson & Chouinard 2002, analysis of the cod stomach content over an 40-year time interval extending from 1959 to 2000), 2) in the Newfoundland and Labrador ecosystem (F. K. Mowbray and P. Lundrigan, Northwest Atlantic Fisheries Centre, capelin stomach content analysis over 20 years (unpublished data), and 3) on the Scotian Shelf (Harrison et al. 2003, analysis of the CPR data), suggesting that the decline in krill abundance is not restricted to the GSL but widespread over a large part of the Atlantic coast of Canada. Another major change is the presence of the cold-water Arctic hyperiid amphipod *Themisto libellula* in the GSL waters since the early 1990s. Indeed, both a review of the literature going back to the beginning of 1900s and a reanalysis of several zooplankton samples collected during the 1980s in different areas of the GSL (M. Harvey, unpublished data) have shown that *T. libellula* was virtually absent from the waters of the GSL before the early 1990s. Since the early 1990s, the abundance of this species in the LSLE and the GSL has increased in proportion to the amount of cold water penetrating into the GSL from the Labrador Shelf during winter. This does not mean that cold water from Labrador did not enter the St. Lawrence before the early 1990s: several studies have demonstrated just the opposite (see Petrie et al. 1988). Nevertheless, a recent study comparing the stomach contents of Arctic charr on the Labrador Shelf over an 18-year period from 1982 to 1999 showed that *T. libellula* was four times more abundant during the 1990s than during the 1980s (Dempson et al. 2002 and B. Dempsen, personal comm.). This suggests that *T. libellula* was more abundant in the Labrador Sea during the last decade than during the 1980s. This could be the result of a large-scale change in the circulation of the Arctic waters associated with the global warming (Morison et al. 2000).

Euphausiids represent keystone species of marine ecosystems, and a major constituent of the diet of a variety of species in the Northwest Atlantic, including several fish (e.g., Atlantic cod, Hanson and Chouinard 2002; capelin, Vesin et al. 1981; pollock, Steele 1963), invertebrates (e.g., squid, Nicol, S. and O'Dor, R.K. 1985) and marine mammals (e.g., blue whales and fin whales, Mitchell 1975; Kawamura 1980). Major changes were documented in the abundance and distribution of several species have been documented since the 1980s (e.g. Myers et al. 1997; Sears and Calambokidis 2002; Nielson et al. 2004). The affect of what appears to be a wide scale reduction in the abundance of euphausiids on the condition and survival of individuals of predator species and on the structure of the ecosystem remains unclear (Sherman and Skjoldal 2002; Pauly and Maclean 2003). The consequences of a reduction in euphausiids for specialist feeders such as blue whales might be dramatic. Further studies using such indicator species might be useful in elucidating the consequences of these decadal fluctuations in prey abundance. On the other hand, the arrival of a new carnivorous macrozooplankton species (*Themisto libellula*) feeding on copepods and/or fish larvae may affect the secondary production (mesozooplankton) as well as the survival and recruitment of fish larvae through direct predation, and through competition with the larvae for copepod prey (Madin et al. 1997).

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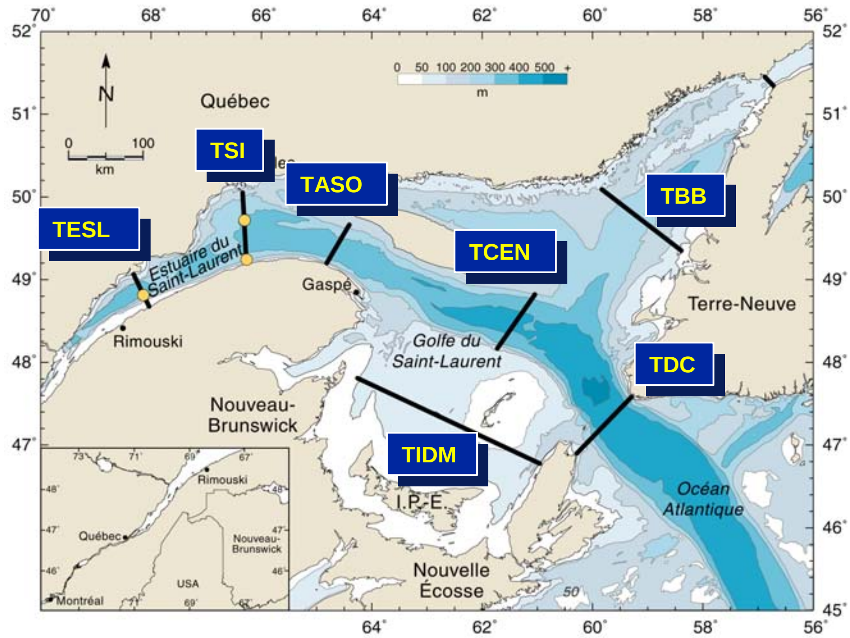

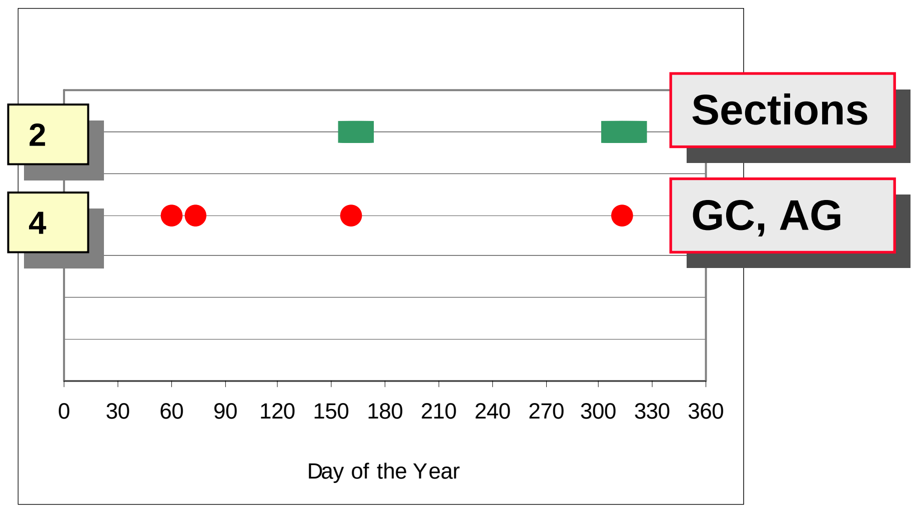

Figure 1. Dates of 2004 sampling at the Atlantic Zonal Monitoring Program (AZMP) sections (lines) and fixed stations (dots) (GC: Gaspé Current; AG: Anticosti Gyre; TESL: St. Lawrence Estuary; TSI: Sept-Îles; TASO: Anticosti; TCEN: Center Gulf of St. Lawrence; TBB: Bonne Bay; TDC: Cabot Strait; TIDM: Îles-de-la-Madeleine).

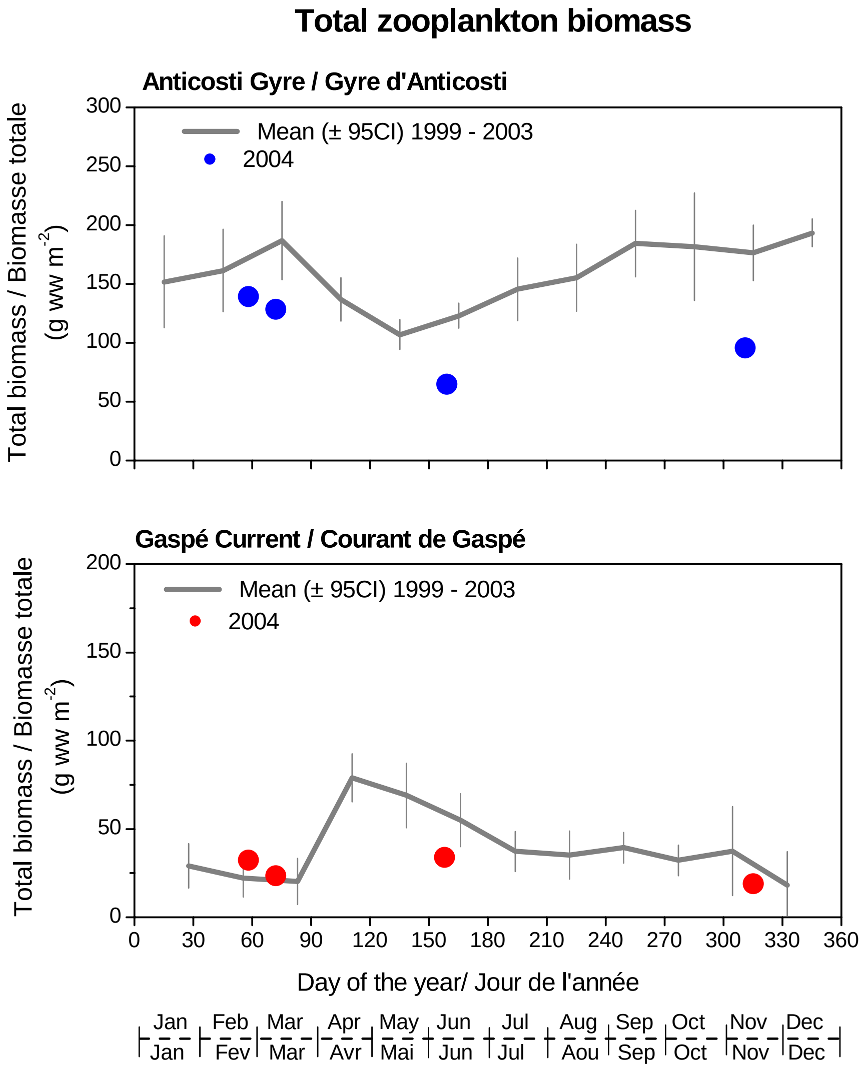

Figure 2. Monthly variations of the total zooplankton biomass at the Anticosti Gyre and the Gaspé Current stations in 2004. 1999-2003: average value (± 95 CI) for mesozooplankton.

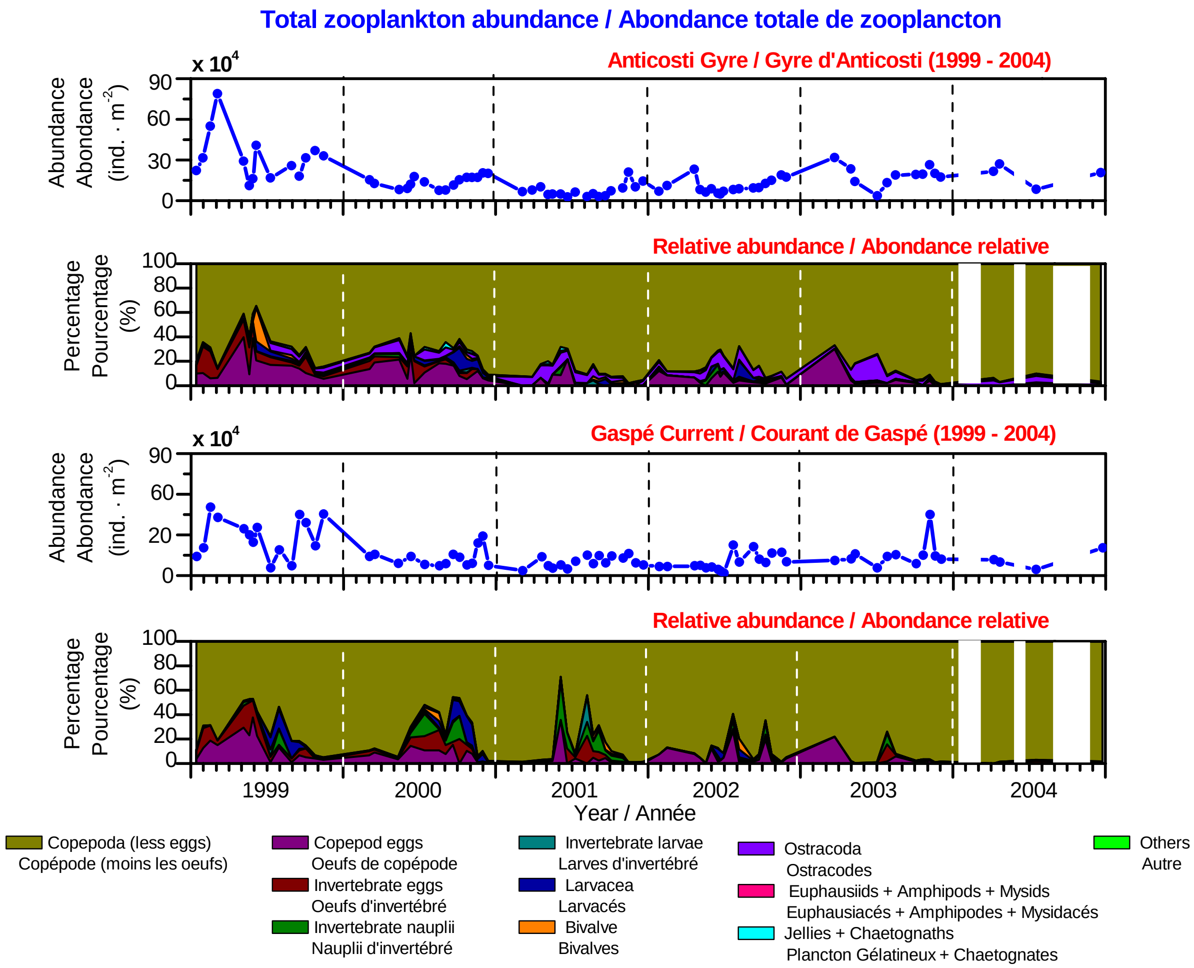

Figure 3. Interannual variations in integrated zooplankton abundance and community structure for the Anticosti Gyre and Gaspé Current fixed stations from 1999 to 2004.

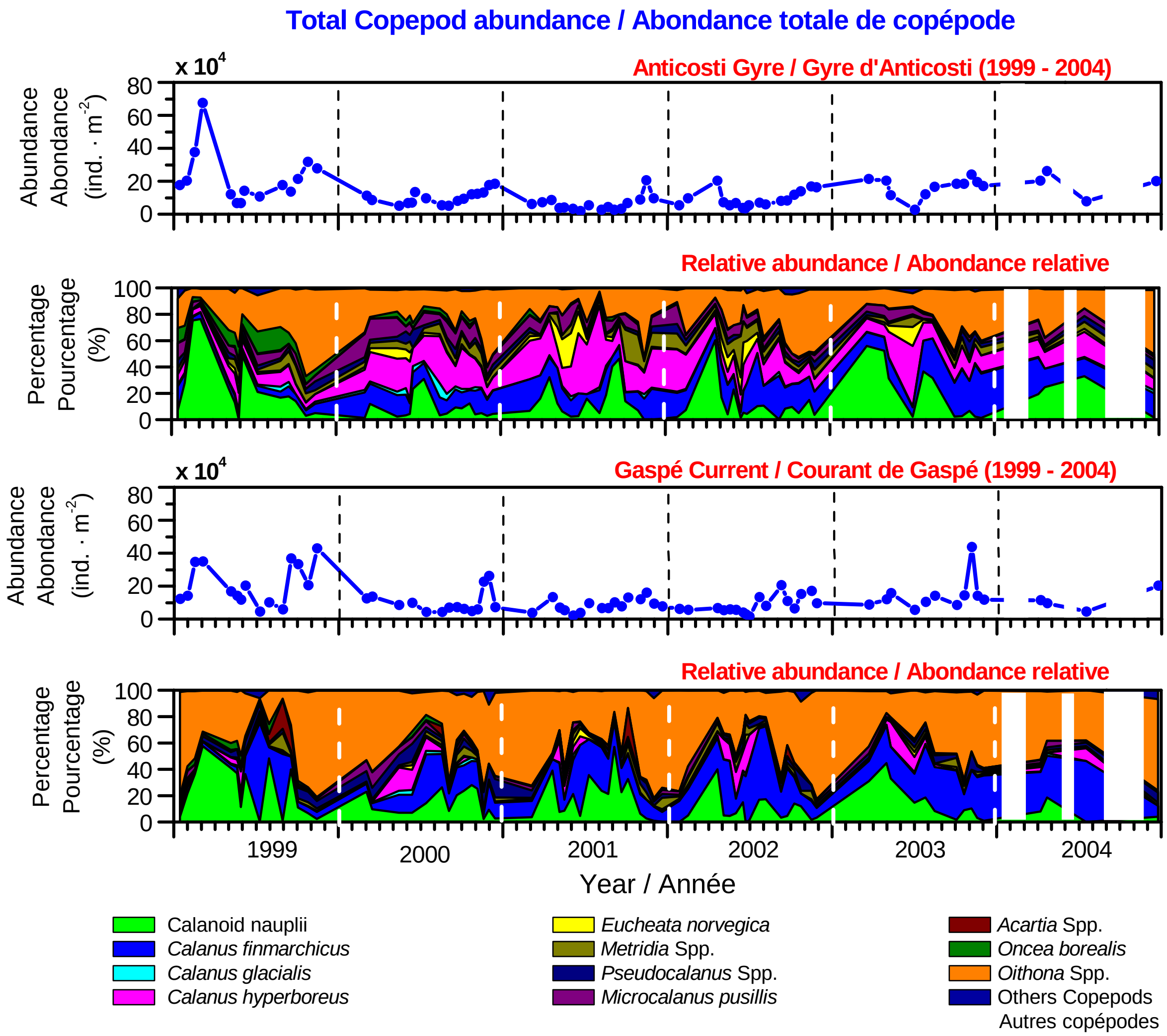

Figure 4. Interannual variations in the integrated copepod abundance and community structure at the Anticosti Gyre and Gaspé Current fixed stations from 1999 to 2003.

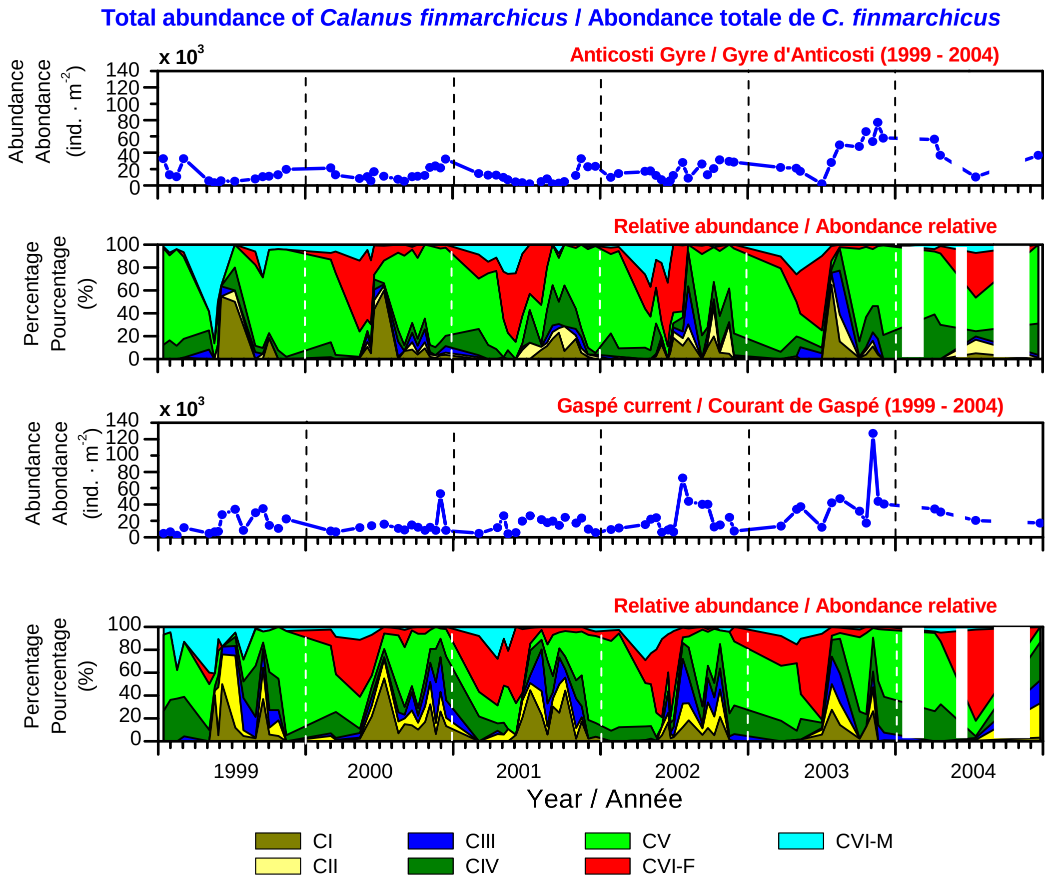

Figure 5. Monthly variations in the depth-integrated abundance of *Calanus finmarchicus* stages at the Anticosti Gyre and the Gaspé Current stations from 1999 to 2004.

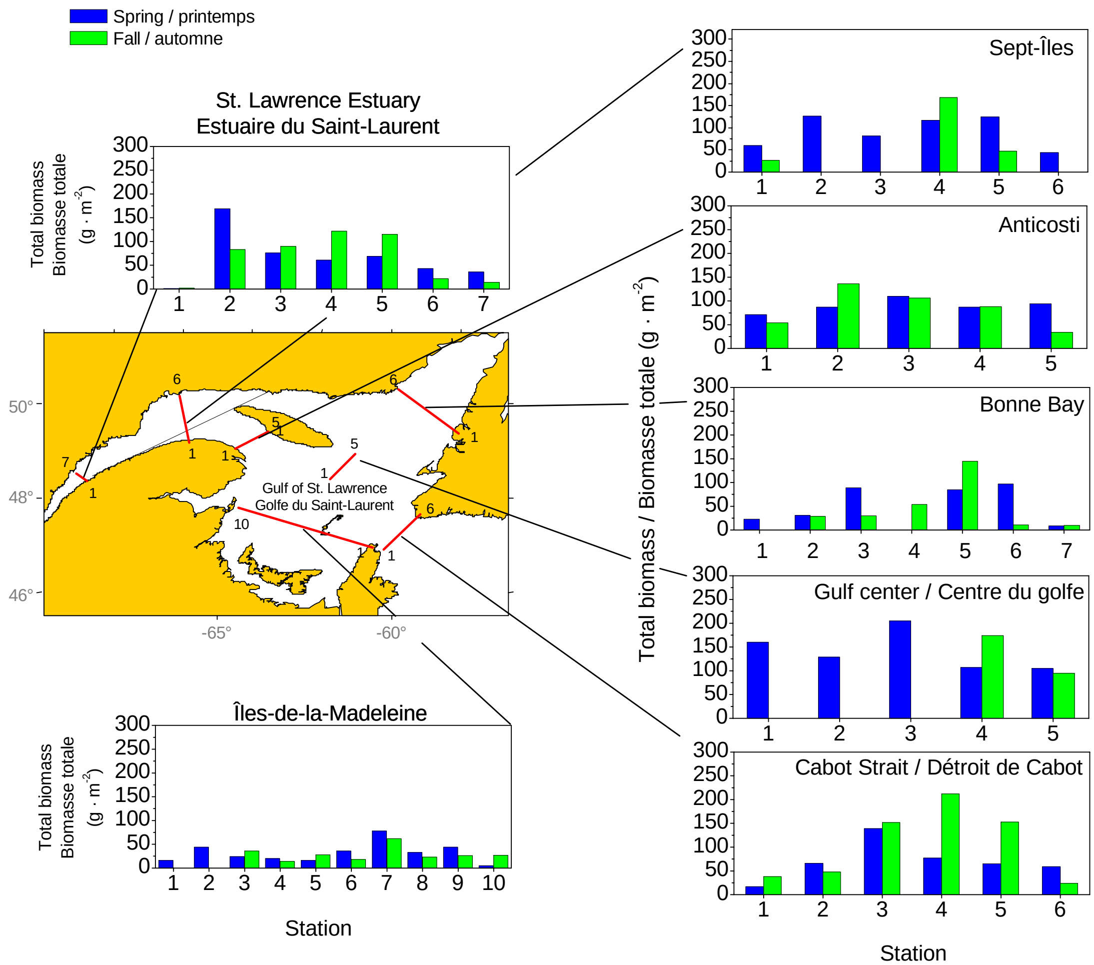

Figure 6. Total zooplankton biomass (wet weight) along the seven sections sampled in June and November 2004 in the Lower Estuary and the Gulf of St. Lawrence.

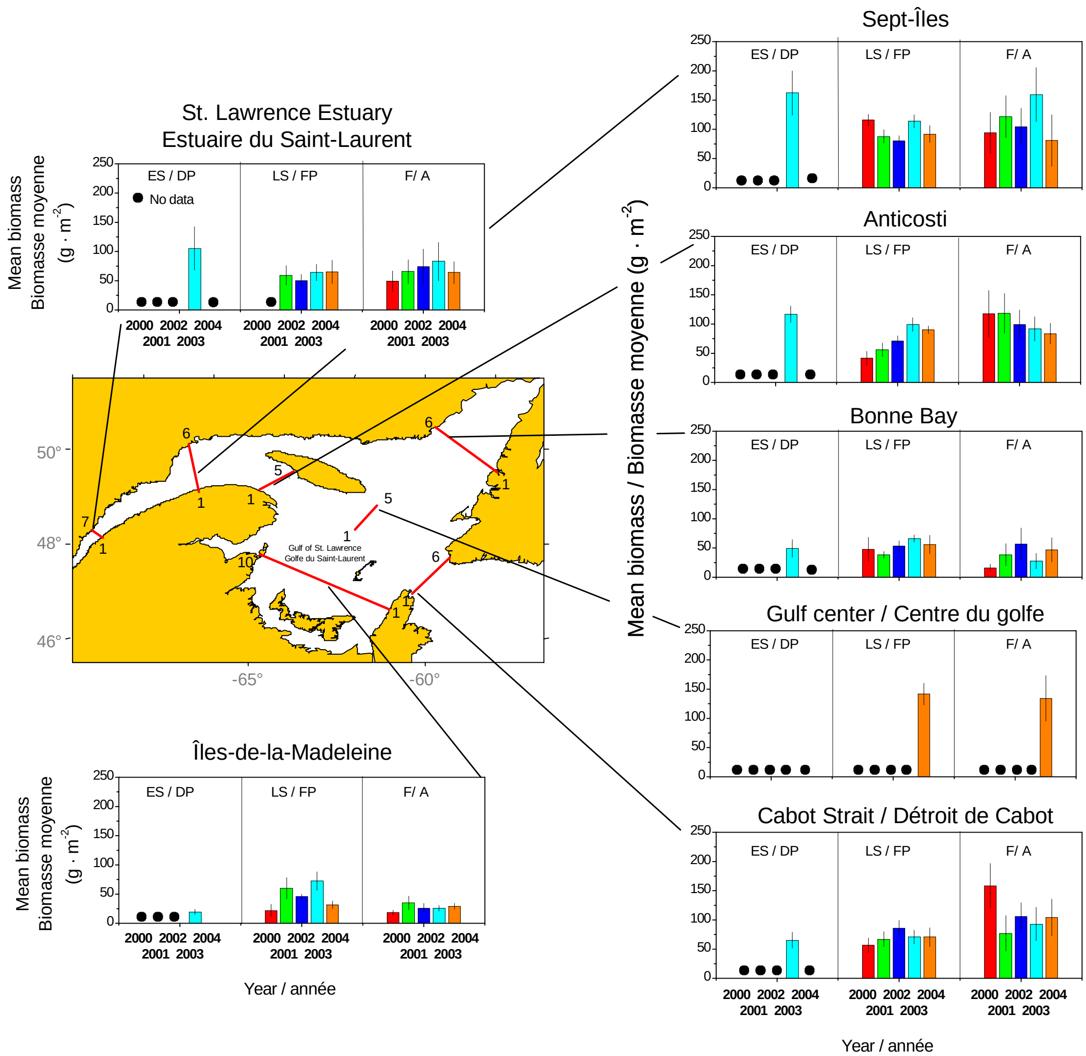

Figure 7. Seasonal averages zooplankton biomass (wet weight ± SE) along the seven sections sampled in late spring (LS) and fall (F) of 2000, 2001, 2002, in early spring (ES), late spring, and fall 2003, and in late spring and fall of 2004 in the Lower Estuary, and the Gulf of St. Lawrence.

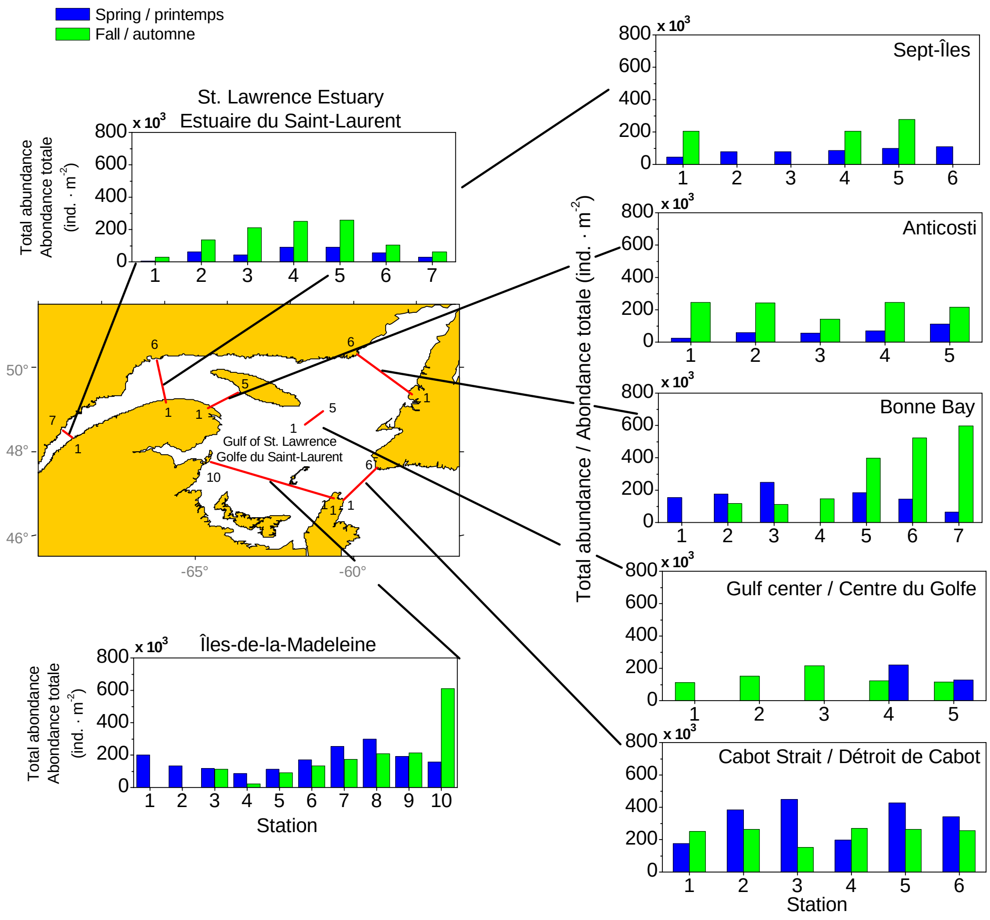

Figure 8. Integrated zooplankton abundance along the six sections sampled in June and November 2004 in the Lower Estuary and the Gulf of St. Lawrence.

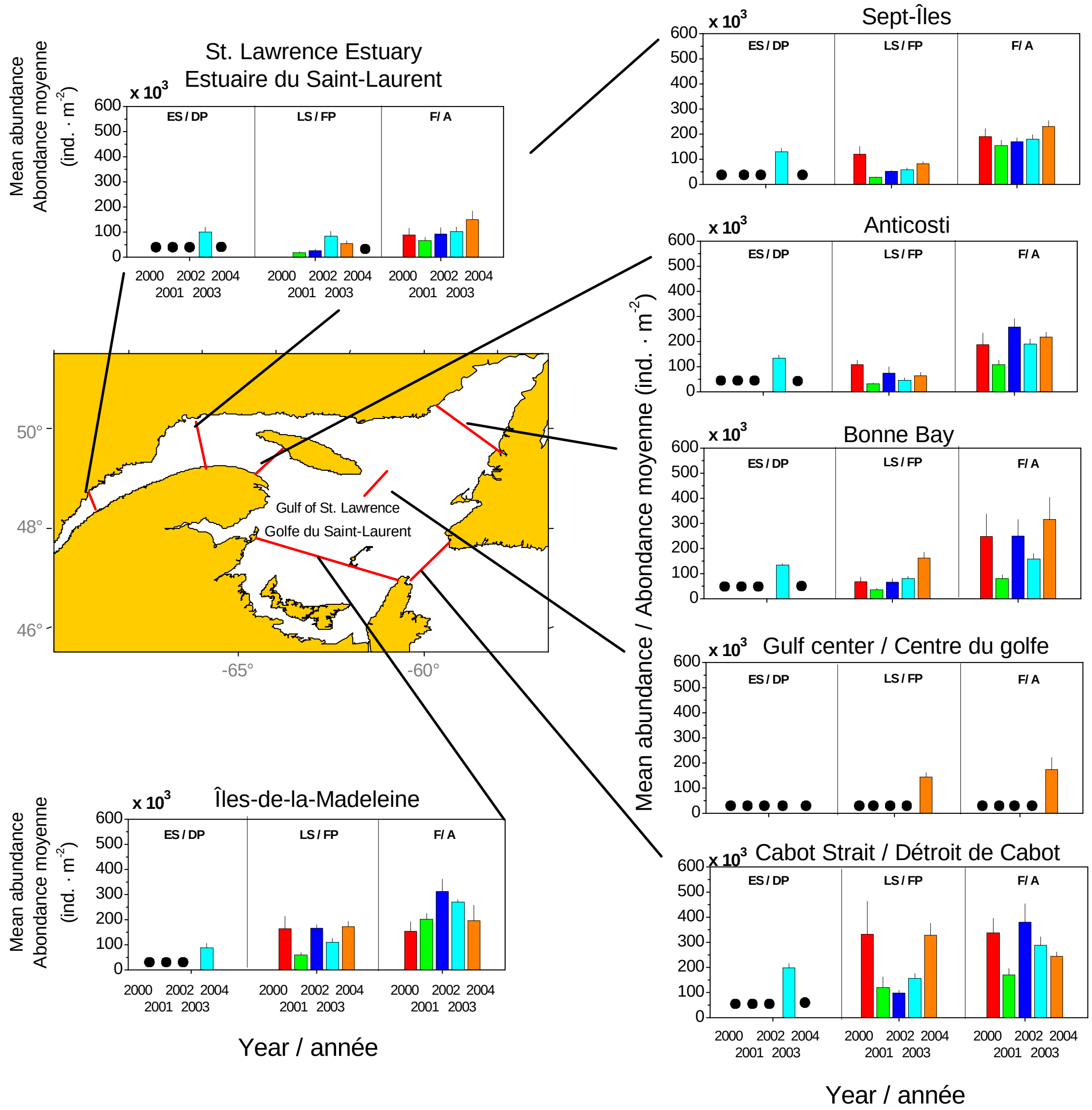

Figure 9. Seasonal averages zooplankton abundance (± SE) along the seven sections sampled in late spring (LS) and fall (F) of 2000, 2001, 2002, in early spring (ES), late spring, and fall 2003, and in late spring and fall of 2004 in the Lower Estuary, and the Gulf of St. Lawrence.

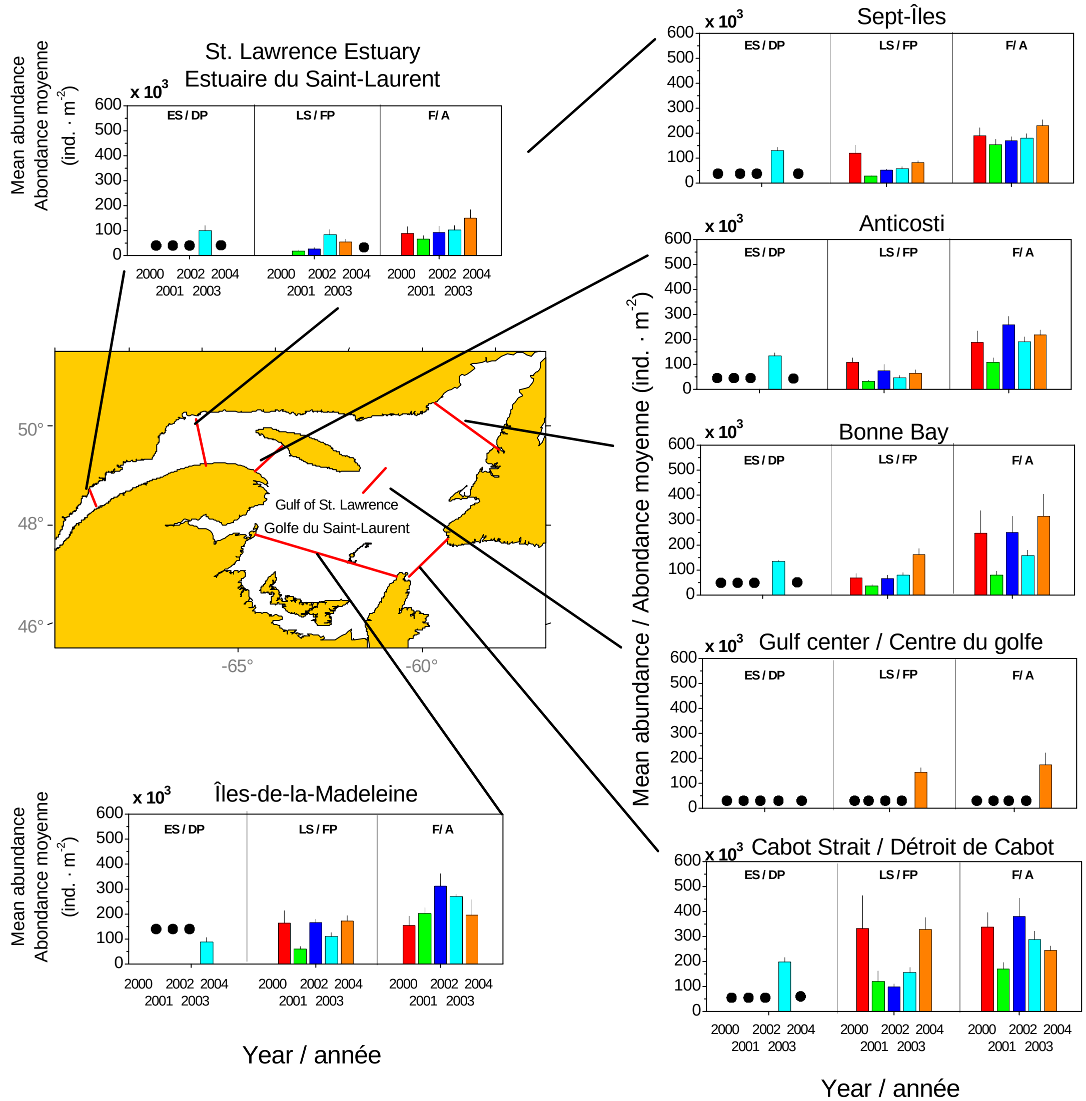

Figure 10. Seasonal averages abundance of *Calanus finmarchicus* (± SE) along the seven sections sampled in late spring (LS) and fall (F) of 2000, 2001, 2002, in early spring (ES), late spring, and fall 2003, and in late spring and fall of 2004 in the Lower Estuary, and the Gulf of St. Lawrence.

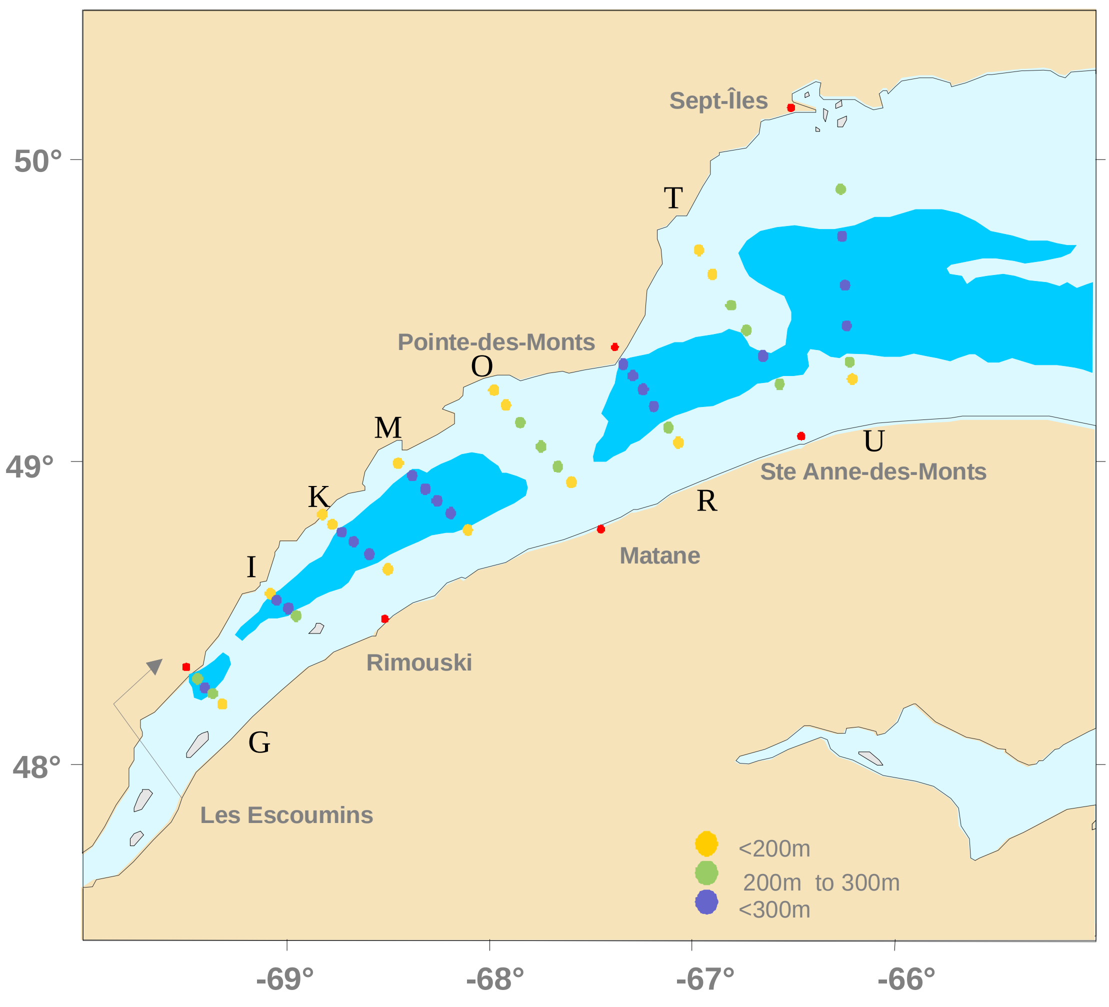

Figure 11. Map showing station locations of the annual zooplankton survey in the Lower St. Lawrence Estuary (sections G to O) and the northwest Gulf of St. Lawrence (sections R to U). The survey has taken place in September of each year since 1994.

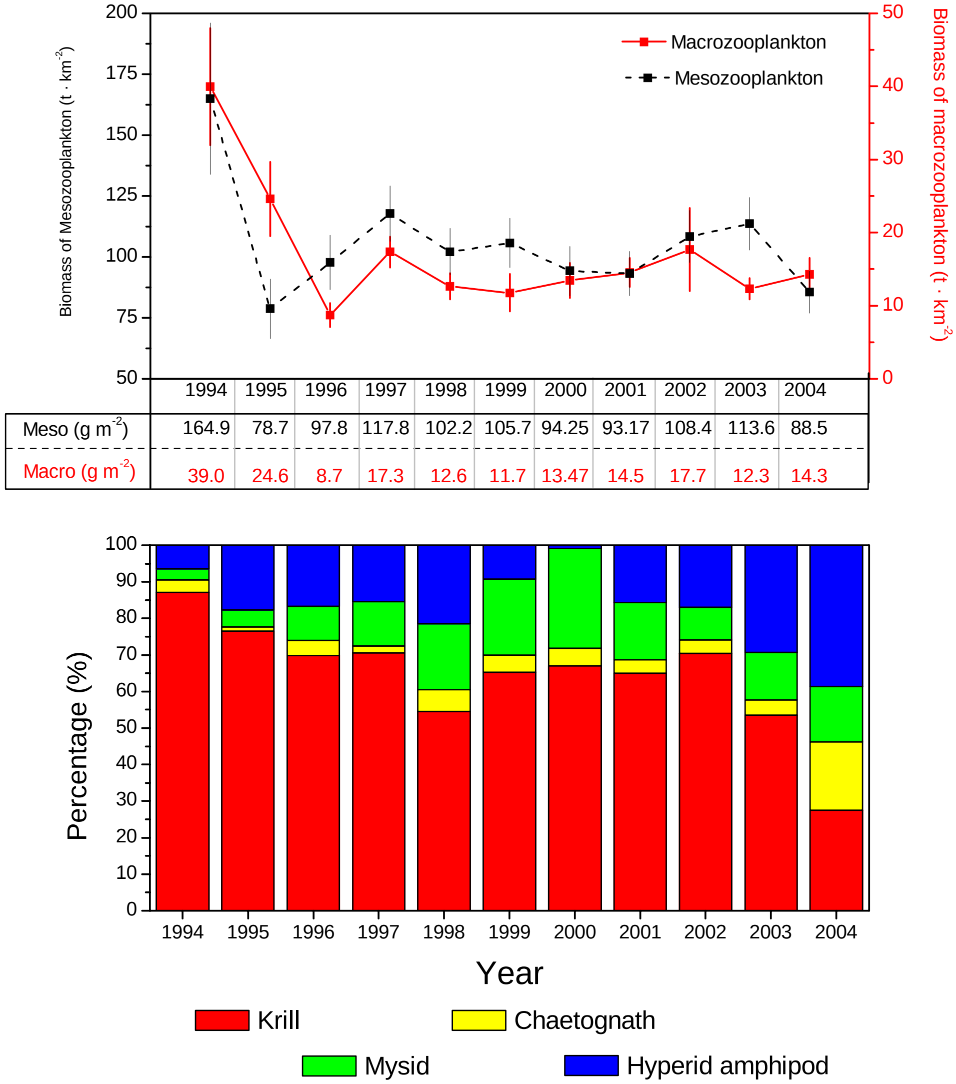

Figure 12. Mean biomass (± SE) of mesozooplankton and macrozooplankton in the Lower St. Lawrence Estuary and the northwest Gulf of St. Lawrence from 1994 to 2004 (upper panel) and relative contribution of the four most important macrozooplankton groups to the biomass (lower panel).

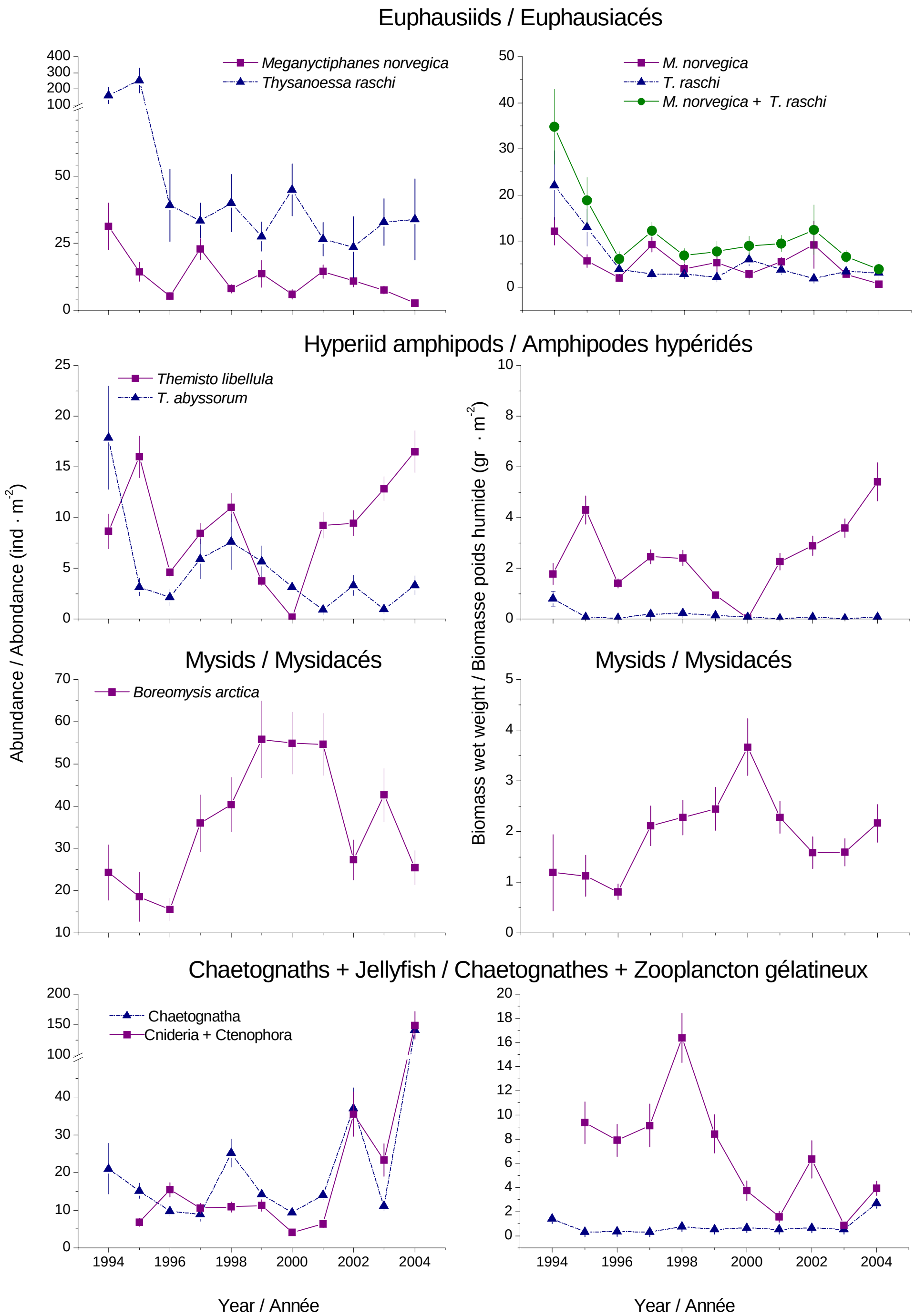

Figure 13. Mean abundance (± SE) of the most important species of macrozooplankton in the Lower St. Lawrence Estuary and the northwest Gulf of St. Lawrence from 1994 to 2004.

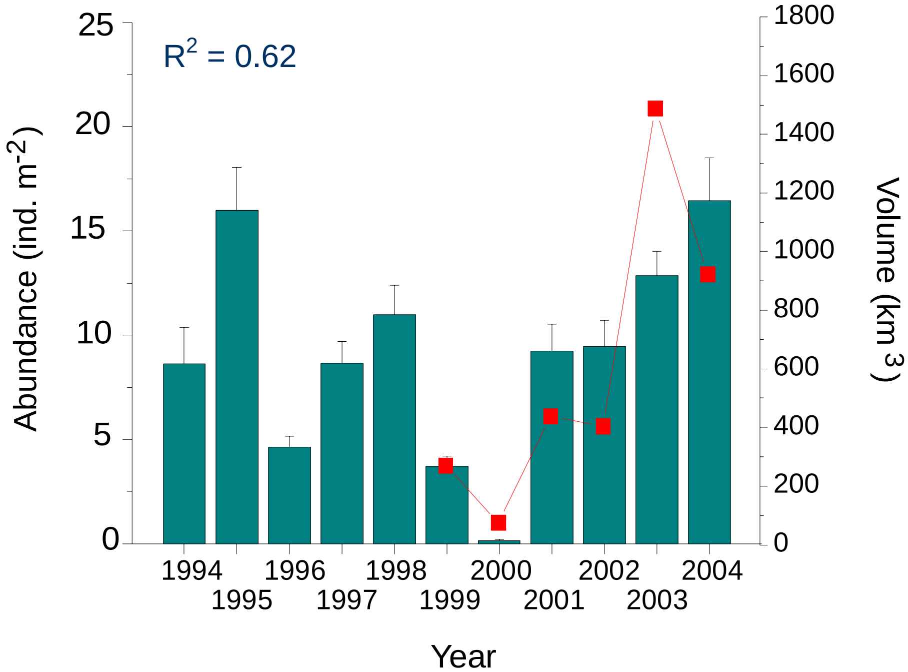

Figure 14. Relationship between the annual CIL core temperature index (dots) and the annual mean abundance of the hyperiid amphipod *Themisto libellula* (bars) in the Lower St. Lawrence Estuary and the northwest Gulf of St. Lawrence from 1994 to 2004.