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Research Document 2004/080

Document de recherche 2004/080

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Oceanographic conditions in the Estuary and the Gulf of St. Lawrence during 2003: zooplankton

Conditions océanographiques dans l'estuaire et le golfe Saint-Laurent en 2003: zooplancton

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Ce document est disponible sur l'Internet à:

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ISSN 1499-3848 (Printed / Imprimé)

Canada

ABSTRACT

Zooplankton biomass, abundance, and species composition in the Québec Region (Lower St. Lawrence Estuary and Gulf of St. Lawrence) during 2003 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 and the northwest Gulf of St. Lawrence as measured in September of each year between 1994 and 2003.

The zooplankton biomass and abundance at the Québec fixed stations in 2003 were slightly higher than observations made in 2000, 2001, and 2002 at both stations. The relative proportion of copepods vs. the other groups of mesozooplankton increased from 70 to 95% between 1999 and 2003 in the Gaspé Current (GC) and from 70 to 85% between 1999 and 2001 in the Anticosti Gyre (AG). No larvacea were found at both fixed stations in 2003. The depth-integrated abundance of the *Calanus finmarchicus* stage composition showed that there were two periods of reproduction for this species at both stations in 2003. Reproduction occurred in summer (June-July) and fall (September-October) and was synchronized at both stations. The same situation was observed in 2000, 2001, and 2002. In 2003, the abundance of *Calanus finmarchicus* reached record high level since 1999 at both fixed stations (GC and AG). The zooplankton biomasses and abundances observed in early spring, late spring, and fall 2003 along the six AZMP sections were comparable to observations made in 2002, 2001, and 2000.

The mesozooplankton biomass in the Lower Estuary and the northwest Gulf of St. Lawrence in 2003 was slightly higher than in 2002 while the macrozooplankton biomass was comparable to the 2002 level. The year 2003 was characterized by a significant increase in the mean abundance of the pelagic amphipod *Themisto libellula* and the mysid *Boreomysis arctica* and a significant decrease in the mean abundance of the chaetognath *Sagitta elegans* and the gelatinous zooplankton *Aglantha digitale*, *Obelia* spp., and *Boreo* spp. The significant relationships between the mean annual abundance of the hyperiid amphipod *T. libellula* and the percentage of Labrador Shelf water supported the hypothesis that the significant increase in the mean abundance of this species observed in 2001, 2002, and 2003 in the Lower Estuary and the Gulf of St. Lawrence is associated with the intrusion of the cold Labrador Shelf water into the Gulf of St. Lawrence via the Strait of Belle Isle (Harvey et al 2003).

Résumé

L’information présentée dans ce rapport décrit l’état du zooplancton dans le Saint-Laurent en 2003. Ces résultats proviennent de l’analyse des données de deux stations fixes situées dans la gyre d’Anticosti et le courant de Gaspé et de six sections répartis 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 2003, que nous comparons ensuite aux observations recueillies en 1999, 2000, 2001 et 2002 dans le cadre du programme de la zone Atlantique (PMZA) et aux observations sur le macrozooplancton recueillies de 1994 à 2003.

La biomasse et l’abondance de zooplancton observées dans la gyre d’Anticosti (GA) et le courant de Gaspé (CG) en 2003 étaient plus élevées qu’en 1999, 2000, 2001 et 2002 aux mêmes stations. L’abondance relative des copépodes par rapport au reste du mésozooplancton (larvacé, ostracode, mérozooplancton, etc.) a augmenté de 70 à 95% entre 1999 et 2003 dans le CG et de 70 à 85% entre 1999 et 2001 dans la GA. Contrairement aux années précédentes (1999 à 2002), nous n’avons observé aucun larvacé aux deux stations fixes (CG et GA) au cours de l’année 2003. L’espèce de copépode *Calanus finmarchicus* s’est reproduite à deux reprises au cours de l’été et de l’automne 2003 aux deux stations fixes. La première période de reproduction s’est produite en juin-juillet et la seconde en septembre-octobre. Cette situation est semblable à celle observée en 2000, 2001 et 2002. De plus, 2003 représente l’année de la plus forte abondance de cette espèce dans le CG et la GA par rapport aux années précédentes (1999 à 2002). Finalement, la biomasse et l’abondance du zooplancton observée au printemps et à l’automne 2003 le long des six sections correspondaient aux observations faites en 2002, 2001 et 2000 dans l’ensemble des régions.

La biomasse de mésozooplancton a légèrement augmenté dans l’EM et le nord-ouest du GSL en 2003 par comparaison avec 2002 alors que la biomasse de macrozooplancton n’a pas varié de façon significative. Des changements importants dans l’abondance moyenne de certaines espèces de macrozooplancton ont cependant été observés. Nous avons observé une importante augmentation de l’abondance moyenne de l’amphipode pélagique *Themisto libellula* et du mysidacé *Boreomysis arctica* ainsi qu’une diminution de l’abondance du chaetognath *Sagitta elegans* ainsi que du zooplancton gélatineux (*Aglantha digitale*, *Obelia* sp. et *Boreo* sp.). En 2003, l’abondance moyenne de l’amphipode pélagique *Themisto libellula* a augmenté de façon importante par rapport à 2002 et la relation positive significative entre la proportion d’eau du plateau du Labrador qui pénètre dans le GSL pendant l’hiver et l’abondance de *T. libellula* dans l’estuaire maritime et le nord-ouest du golfe du Saint-Laurent mesuré depuis 1994 est demeurée hautement significative en 2003. Selon cette relation, cette espèce pourrait être considérée comme une espèce indicatrice de l’intrusion massive dans le golfe du Saint-Laurent d’eaux froides provenant du plateau du Labrador via le détroit de Belle Isle (Harvey *et al* 2003).

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 September 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 geography-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 2003 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 2003.

SPATIAL AND TEMPORAL VARIABILITY OF ZOOPLANKTON SPECIES COMPOSITION, ABUNDANCE, AND BIOMASS AT TWO FIXED STATIONS AND SIX SECTIONS OF THE AZMP IN 2003

Material and Methods

The sampling dates of two fixed stations (Anticosti Gyre and Gaspé Current) and along six sections (St. Lawrence Estuary, Sept-Îles, Bonne Bay, Anticosti, Cabot Strait, Îles-de-la-Madeleine) are given in Figure 1. In 2003, zooplankton samples were collected during 12 visits to the fixed stations and three visits to the sections. 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 2003. 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. In 2003, the zooplankton biomass varied between 109 and 282 g ww · m^{-2} at the Anticosti Gyre (AG) station and between 23 and 103 g ww · m^{-2} at the Gaspé Current (GC) station (Fig. 2). The minimum and the maximum biomasses occurred in May-June and September-October respectively at the AG station while the minimum and the maximum biomasses were observed in November and April respectively in the GC. The annual minimum (AG) and maximum (GC) zooplankton biomasses occurring in late spring seem to be typical since the same situation was observed in 1999, 2000, 2001, and 2002. The mean biomass for 2003 was 3.0 times higher in the AG (175.4 g ww · m^{-2}) than in the GC (55.8 g ww · m^{-2}). 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 mean integrated zooplankton biomass in the AG was slightly higher in 2003 (175.4 g ww · m^{-2}) than in 1999, 2000, 2001, and 2002 while the mean integrated zooplankton biomass in the GC was 1.2 times higher than in 2002 and 1.7 higher than in 2001 and 2000 (Fig. 3).

The total abundance of zooplankton in 2003 varied between 56,400 and 451,466 individuals · m^{-2} in the GC and between 35,059 and 319,280 individuals · m^{-2} in the AG. At both stations, the total abundance of zooplankton observed in 2003 was ca. 1.5 times higher than in 2000, 2001, and 2002 (Fig. 4). Data from 1999 was not included in this comparison because the mesh of the net used in 1999 was 158 μm compare to 202 μm for the other years. Copepod eggs, juveniles, and adults were clearly dominant, accounting for more than 80% of the zooplankton community for all sampling dates at the AG and the GC. The same situation was observed in 2002 and 2001 at both stations (but not in 2000) while the other zooplankters represented more than 50% of the zooplankton assemblage in spring and summer at the AG and in summer in the GC. At the AG, the ostracoda were present on all sampling dates and accounted for ca. 10% of the zooplankton assemblage from April to July. Contrary to the situation observed during the previous years (1999-2002), where the larvacea accounted for ca. 10% of the zooplankton assemblage in July and August in both the GC and the AG, no larvacea were found in 2003 at either station. A closer examination of the relative proportion of copepods vs. the other groups of mesozooplankton showed that the mean integrated annual proportion of copepods in the zooplankton community increased from 70 to 95% between 1999 and 2003 in the GC and from 70 to 85% between 1999 and 2001 in the AG (Fig. 5). This change in the relative abundance of copepods vs. the other groups of mesozooplankton is due to: 1) an increase in the mean integrated annual abundance of copepod species from 60,000 to 120,000 from 2001 to 2003 at both stations and 2) a decrease of the mean integrated annual abundance of other zooplankton groups from 29,000 to 6,000 ind. $\cdot$ m^{-2} and from 35,000 to 14,000 ind. $\cdot$ m^{-2} from 1999 to 2003 in the GC and the AG respectively (Fig. 6).

In 2003, the total abundance of copepods integrated over the water column varied between 55,955 and 436,228 individuals $\cdot$ m^{-2} in the GC and between 25,895 and 239,572 individuals $\cdot$ m^{-2} in the AG (Fig. 7). Furthermore, the mean integrated annual abundance of copepods observed in 2003 was 1.6 and 1.9 times higher than in 2000, 2001, and 2002 in the GC and the AG (not shown). In both the GC and the AG, the minimum copepod abundances occurred in June and the maximum late October and were synchronized with the minimum and the maximum values observed in 1999, 2000, 2001, and 2002. Close examination of the monthly variations of the copepod community structure revealed that copepod nauplii accounted for an average of 16% of the copepod community in 2003 in the GC as opposed to 15% in 2000, 18% in 2001, and 9% in 2002. In the AG, this difference in the proportion of copepod nauplii was more important than in the GC, with values of 21% in 2003 vs. 9, 13, and 11% in 2000, 2001, and 2002 respectively. Finally, the large copepod species (*Calanus finmarchicus* and *C. hyperboreus*) were dominant for all sampling dates in the AG whereas in the GC, the small copepod *Oithona similis* was dominant for all sampling dates except in July, when larger species such as *C. finmarchicus* and *C. hyperboreus* were more abundant.

Finally, the depth-integrated abundance of the *Calanus finmarchicus* stage composition reveled two periods of reproduction for this species at both stations in 2003. Based on the increased occurrence of the copepodite stages CI, CII, CIII, CIV, and CV, the first and the second periods of reproduction occurred in summer (June-July) and fall (September-October) and were synchronized at both stations (Fig. 8). The same situation was observed in 1999, 2000, 2001, and 2002. Furthermore, Figure 9 shows the mean integrated annual abundance of *C. finmarchicus* copepodite stages CIV and CV for the period from August to December. This portion of the population represents the individuals of the first and second generations that are in diapause (first generation) or that will enter in diapause (second generation) during the next fall and that will produce the next generation the following summer (June-July) and fall (September-October).

Their abundance varied annually as a function of the biological (recruitment vs. mortality) and the physical (water temperature, advection) processes and could be used as an index to evaluate the annual production of *C. finmarchicus*. According to the results presented on Figure 9, the abundance of CIV and CV at the GC in autumn increased between 2000 and 2003 and was 3.8 times higher in 2003 (30,078 ind. $\cdot$ m^{-2}) than in 2000 (8,369 ind. $\cdot$ m^{-2}) (Fig. 9). On the other hand, the mean integrated annual abundance of the stage CIV and CV copepodites at the AG, for the period of August to December was stable at ca. 28,000 ind. $\cdot$ m^{-2} between 1999 and 2002 and increased to 62,240 ind. $\cdot$ m^{-2} in 2003.

Figure 10 shows the mean integrated annual abundance of *C. finmarchicus* and *Metridia longa* during the summer/autumn period (April/October) in the LSLE in 1979 and 1980, at station Rimouski from 1992 to 1998, and in the GC from 1999 to 2003. These results show that the relative abundance of these two species in the GC from 1999 to 2003 is comparable to the situation previously observed in 1979 and 1980 in the LSLE but very different from the levels observed at station Rimouski from 1992 to 1998 by S. Plourde (unpublished data). The increase in abundance of midwater copepod species (mainly *M. longa*) and the subsequent decline in the relative abundance of *C. finmarchicus* in the 1990s appears to be related to a change in environmental conditions associated with a decadal climate variation in the GSL-LSLE region, "i.e., a major cooling event from the late 1980s to mid 1900s during which the minimal temperature of the CIL was below the long-term average" (Plourde et al. 2002). On the other hand, it is unclear whether deep advection of large numbers of *M. longa* from adjacent GSL, a local increase in growth and reproduction, or some combination of these two mechanisms promoted the increase in *M. longa* population size during the 1990s (Plourde et al. 2002).

Sections. The total zooplankton biomass varied between 0.2 and 298 g ww $\cdot$ m^{-2} along the six sections sampled in April, June, and November 2003 in the LSLE and the GSL (Fig. 11). The biomass increased with the depth along all sections for the three sampling periods. The highest biomasses were found along sections located over the Laurentian Channel (St. Lawrence Estuary, Sept-Îles, Anticosti, and Cabot Strait) and the lowest were in the northern (Bonne Bay) and the southern (Îles-de-la-Madeleine) regions. The zooplankton biomass was higher in early spring (April) and fall (November) than in late spring (June) along sections located in the LSLE (St. Lawrence Estuary and Sept-Îles), except at the shallow stations on both ends of each section (Fig. 11). On the other hand, the zooplankton biomasses were similar in early spring, late spring, and fall along all other sections (Anticosti, Cabot Strait, Bonne Bay, and Îles-de-la-Madeleine). The zooplankton biomasses observed in 2003 along all sections in late spring and fall were comparable to observations made in 2000, 2001, and 2002 (Fig. 12).

The overall abundance of zooplankton integrated over the water column varied between 7,000 and 380,000 ind. $\cdot$ m^{-2} along all sections in April, June, and November (Fig. 13). The total abundances of zooplankton were higher in early spring (April) and fall (November) than in late spring (June) along all sections except for the Îles-de-la-Madeleine and the Cabot Strait sections, where the abundance was higher in fall than in early or late spring. There were no significant variations in the mean annual abundance of zooplankton along the sampled sections in late spring and fall 2000, 2001, 2002, and

2003 except in fall 2001 along the Cabot Strait, Bonne Bay, and Anticosti sections, where the mean zooplankton abundance was almost half of that observed in fall 2000, 2002, and 2003 (Fig. 14). Finally, the mean annual abundances of *C. finmarchicus* observed in 2003 along all sections were comparable to observations made in summer and fall 2002, 2001, and 2000 except in fall along the Sept-Îles and Anticosti sections, where the abundance of *C. finmarchicus* was respectively 2.5 and 1.5 higher than in 2002 (Fig. 15).

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 2003

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. 16). 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. 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 in 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 abundance 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 total mesozooplankton biomass observed in September 2003 in the LSLE and in the NWGSL is higher than the September 1995, 1996, 1998, 2000, and 2001 observations, comparable to the September 1997, 1999, and 2002 measurements, and 1.4 times lower than in September 1994 (Fig. 17). Likewise, the total macrozooplankton biomass observed in September 2003 is comparable to the 1996 1998, 1999, 2000, 2001, and 2002 measurements, slightly lower than the September 1997 observations, and 4.4 and 3.3 times lower than in September 1994 and 1995 respectively. On the other hand, the relative abundance of the three most important macrozooplankton groups in terms of biomass (euphausiids, mysids, hyperiid amphipods) varied significantly as a function of the year. The relative euphausiids abundance decreased from 87% to 55% between 1994 and 1995, remained stable at ca. 50% of the macrozooplankton assemblage between 1995 and 2002, and decreased slightly to 40% in 2003. The relative abundance of the mysid *Boreomysis artica* increased from 3% in 1994 to 29% in 2000 and decreased again to ca.16% in 2001, 2002, and 2003. Finally, the relative abundance of the hyperiid amphipods increased from 8% in 1994 to 40% 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 26% in 2001, 33% in 2002, and 44% in 2003.

Figure 18 shows the interannual variations in the total abundance 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 32 ind. · m^{-2} in 2003. 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 and 7 ind. · m^{-2} in 2003. 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} and decreased again to 10 ind. · m^{-2} in 2003. The mean abundance of the gelatinous zooplankton (mostly cnidarians) varied between 15 and 4 ind. · m^{-2}, with the minimums observed at the beginning (1994 and 1995) and the end (2000, 2001) of the time series and the maximum between 1996 and 1999. Nevertheless, from 2001 to 2002, the mean abundance of the gelatinous zooplankton increased significantly from 6 to 35 ind. · m^{-2} and decreased again to 23 ind. · m^{-2} in 2003. 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}) and increased again to 40 ind. · m^{-2} in 2003. Finally, 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 in 2000, 2001, 2002, and 2003 to reach 1 ind. · m^{-2} in 2003. 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 2003, the mean abundance of *T. libellula* increased greatly from 0.17 to 13 ind. · m^{-2}. In 2003, the mean abundance of *T. libellula* was similar to that observed in 1995 and 1998.

We hypothesized that this significant increase in the mean abundance of *Themisto libellula* observed in 2001, 2002, and 2003 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 significant negative relationship (R^2 = 0.62) between the annual CIL core temperature index (Gilbert et al. 2004) and the mean annual abundance of *T. libellula* sampled since 1994 in the LSLE and the NWGSL and between the abundance of *T. libellula* and the percent of the Labrador Shelf water (R^2 = 0.72) (Fig. 19).

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; Brodie et al. 1978; Kawamura 1980). Major changes were documented in the abundance and distribution of several species since the 1980s (e.g. Myers et al. 1997; Sears and Calambokidis 2002; Nielson et al. 2004). The effects of what appears to be a wide scale reduction in the abundance of euphausiids on the condition and survival of individuals of the different species and on the structure of ecosystems remain 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 preys (Madin et al. 1997).

ACKNOWLEDGEMENTS

The authors wish to thank the sea-going staff of the Ocean Sciences Branch (IML) and the officers and crews of the *Martha L. Black, George R. Pearkes*, *Tracy*, *Pierre Radisson*, and *Desgroseillers*, who provided excellent support in carrying out the surveys. Véronique Lesage (IML), Stéphane Plourde (IML), and Glen Harrison (BIO) provided a comprehensive and constructive review of the manuscript.

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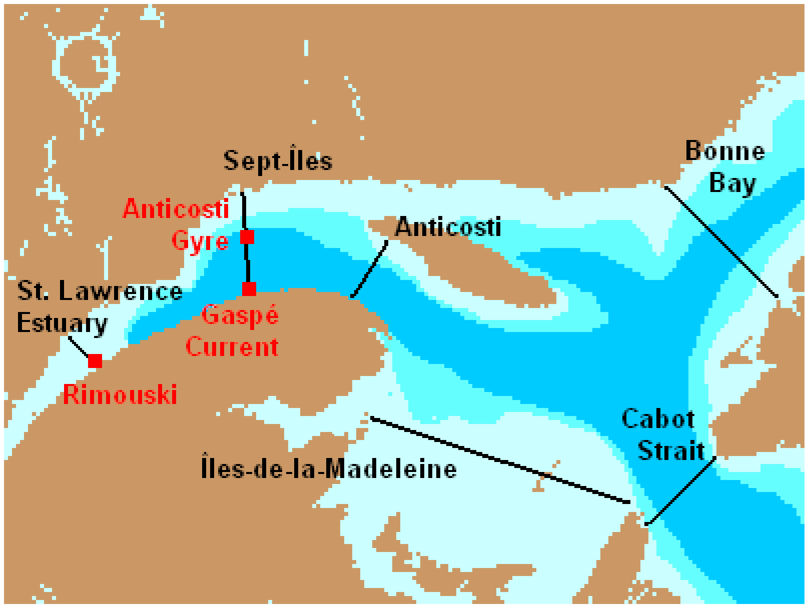


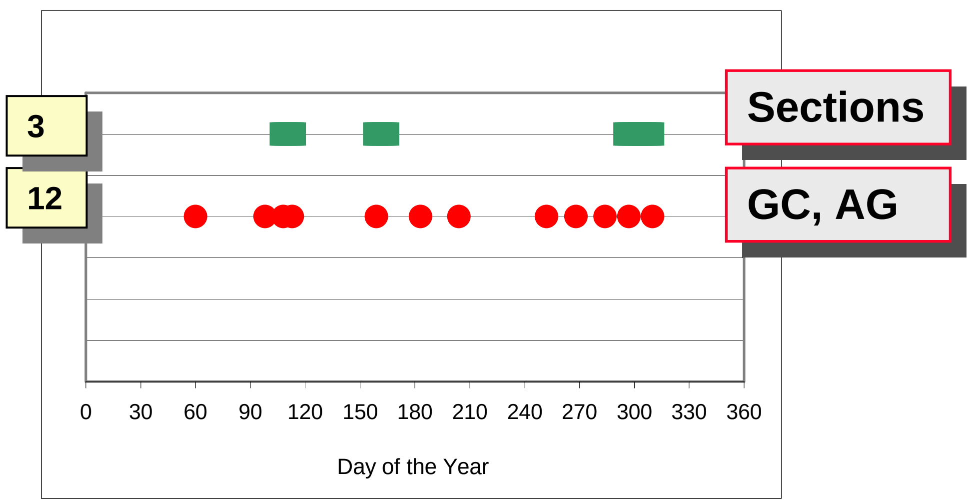


Figure 1. Dates of 2003 sampling at the Atlantic Zonal Monitoring Program (AZMP) sections (lines) and fixed stations (dots) (GC: Gaspé Current; AG: Anticosti Gyre).

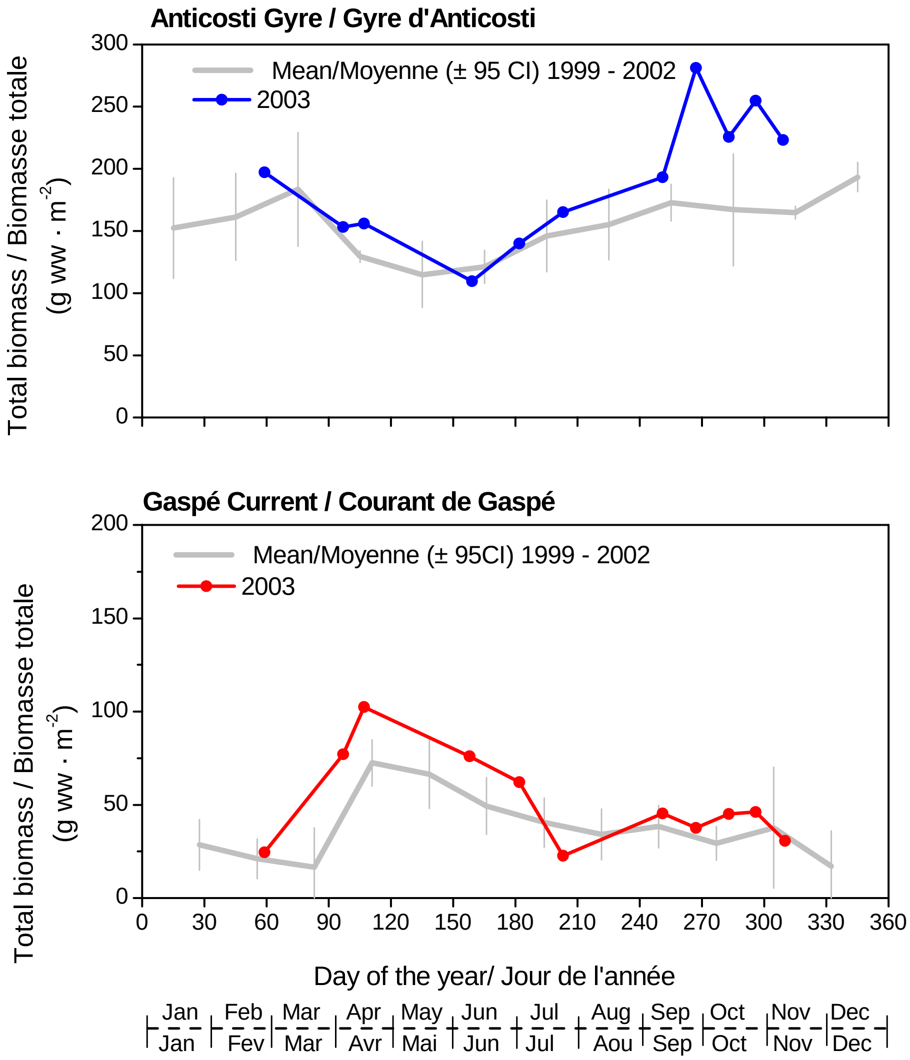


Figure 2. Monthly variations of the total zooplankton biomass at the Anticosti Gyre and the Gaspé Current stations in 2003. 1999-2002: average value (± 95 CI) for mesozooplankton.

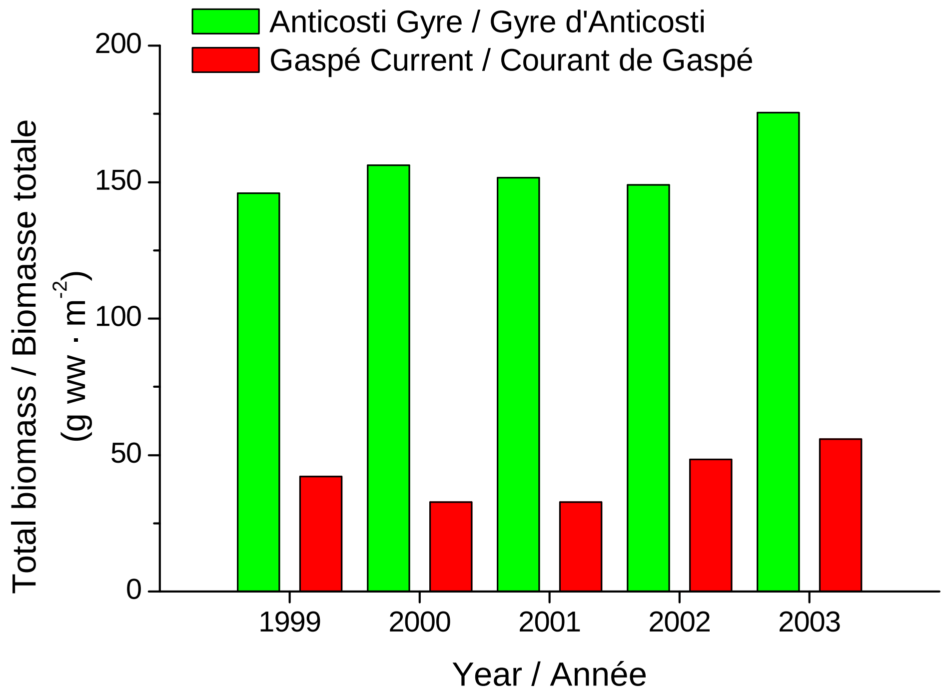


Figure 3. Annual mean integrated zooplankton biomass at the Anticosti Gyre and Gaspé Current stations from 1999 to 2003.

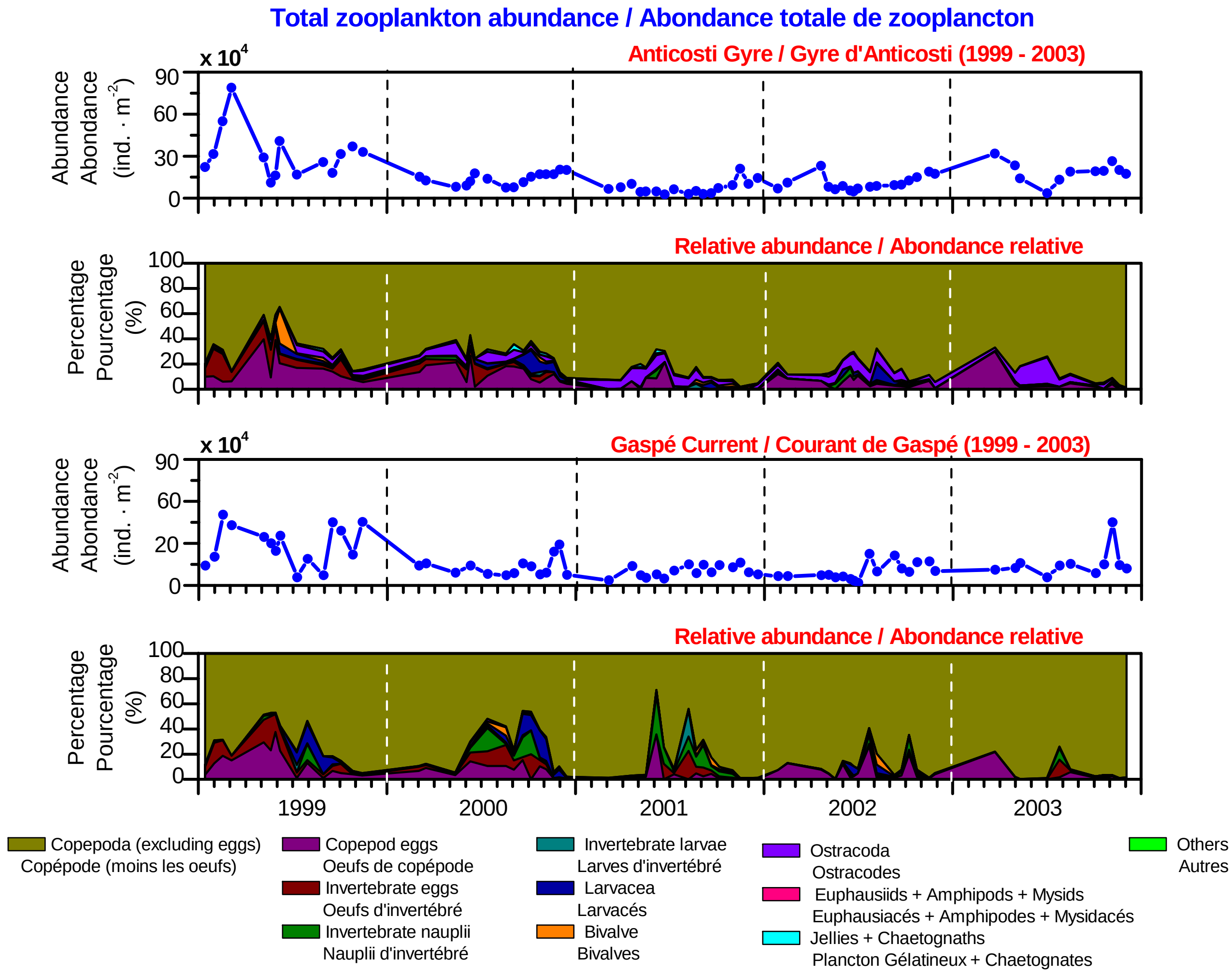


Figure 4. Interannual variations in integrated zooplankton abundance and community structure for the Anticosti Gyre and Gaspé Current fixed stations from 1999 to 2003.

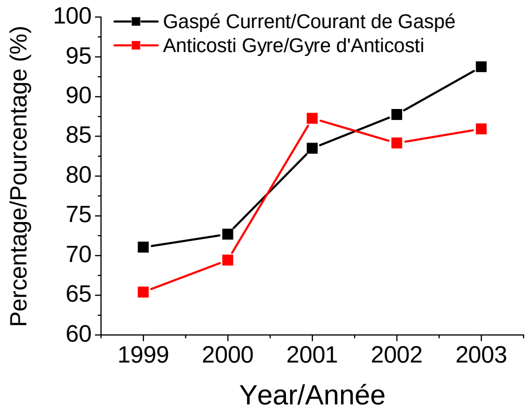


Figure 5. Mean integrated annual proportion of copepods in the zooplankton community at the Gaspé Current and Anticosti Gyre stations from 1999 to 2003.

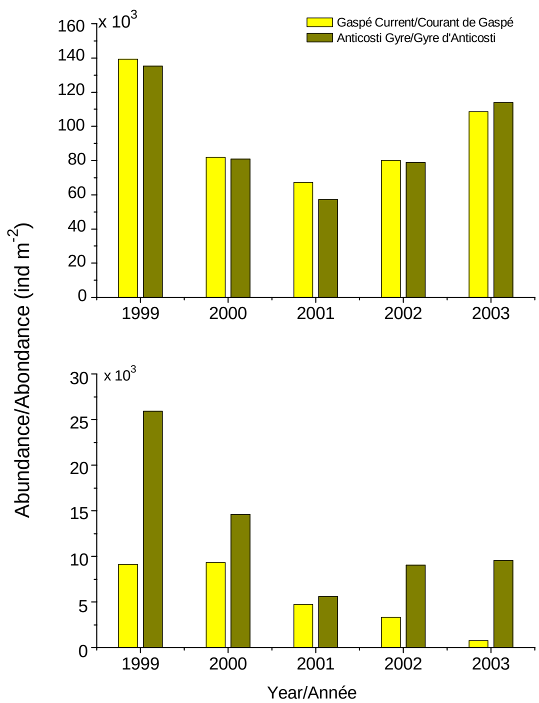


Figure 6. Mean integrated annual abundance of copepods (upper panel) and other mesozooplankton taxa (lower panel) at the Gaspé Current and the Anticosti Gyre stations from 1999 to 2003.

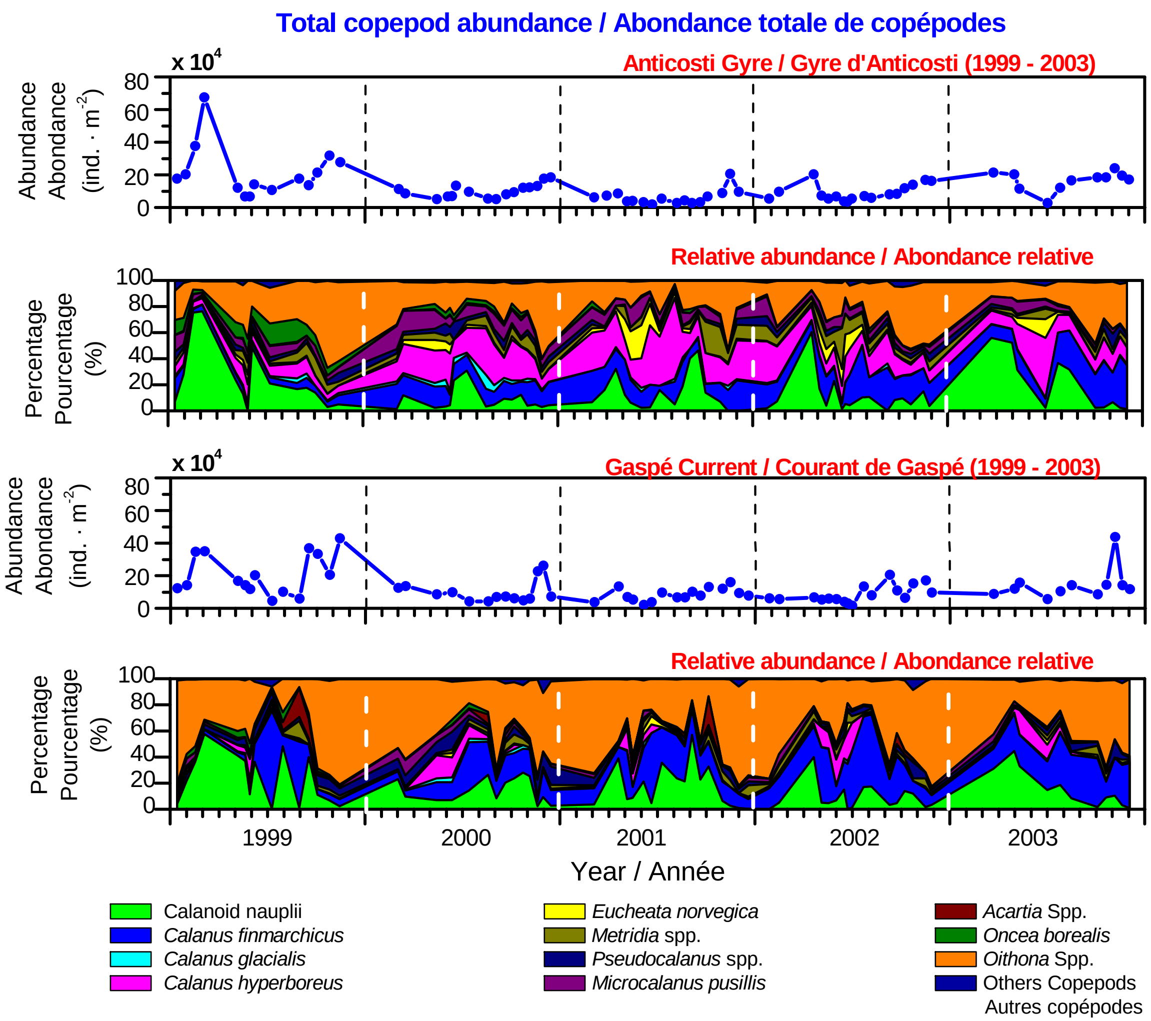


Figure 7. Interannual variations in the integrated copepod abundance and community structure at the Anticosti Gyre and Gaspé Current fixed stations from 1999 to 2003.

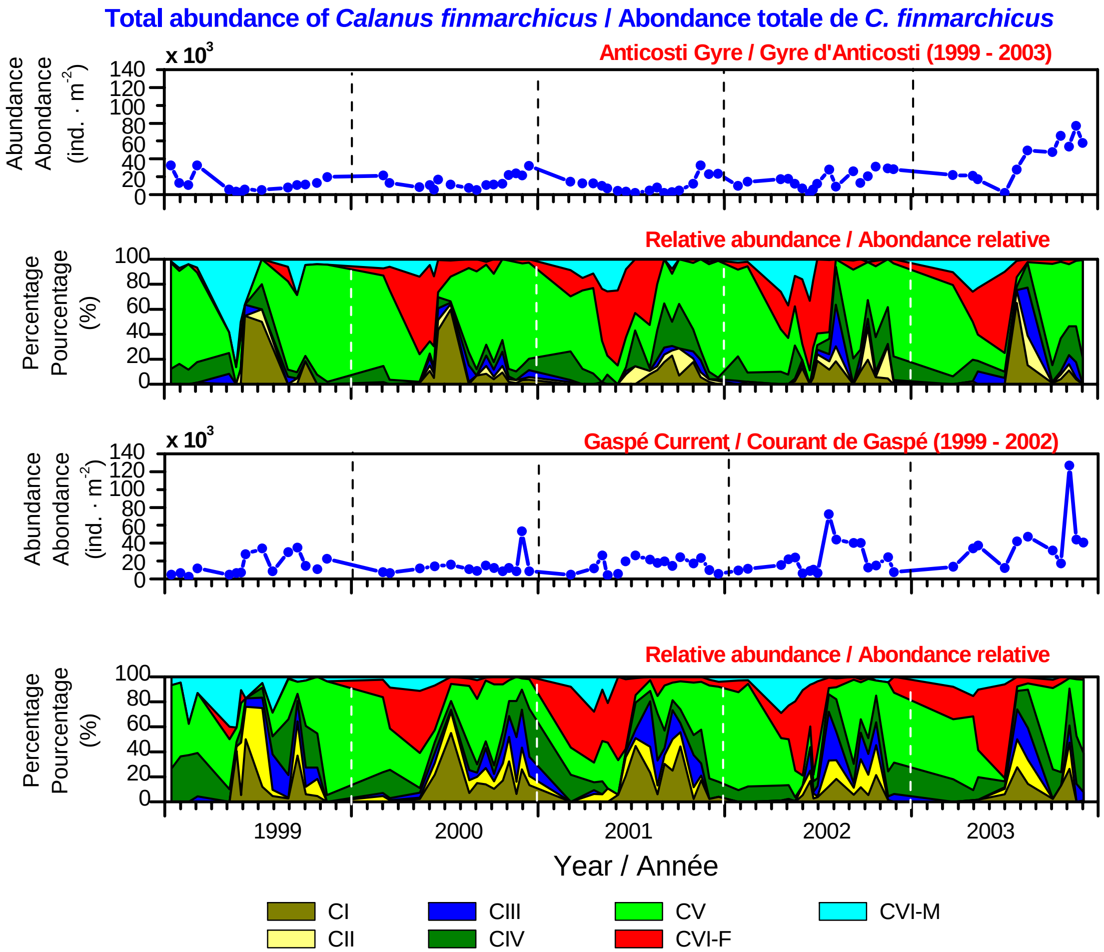


Figure 8. Monthly variations in the depth-integrated abundance of the *Calanus finmarchicus* stage composition at the Anticosti Gyre and the Gaspé Current stations from 1999 to 2003.

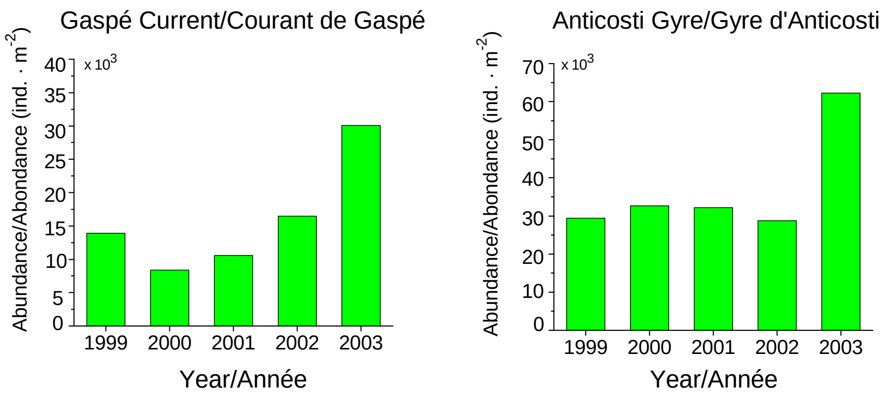


Figure 9. Mean integrated abundance of *C. finmarchicus* copepodite stages CIV and CV from August through December at the Gaspé Current and Anticosti Gyre stations from 1999 to 2003.

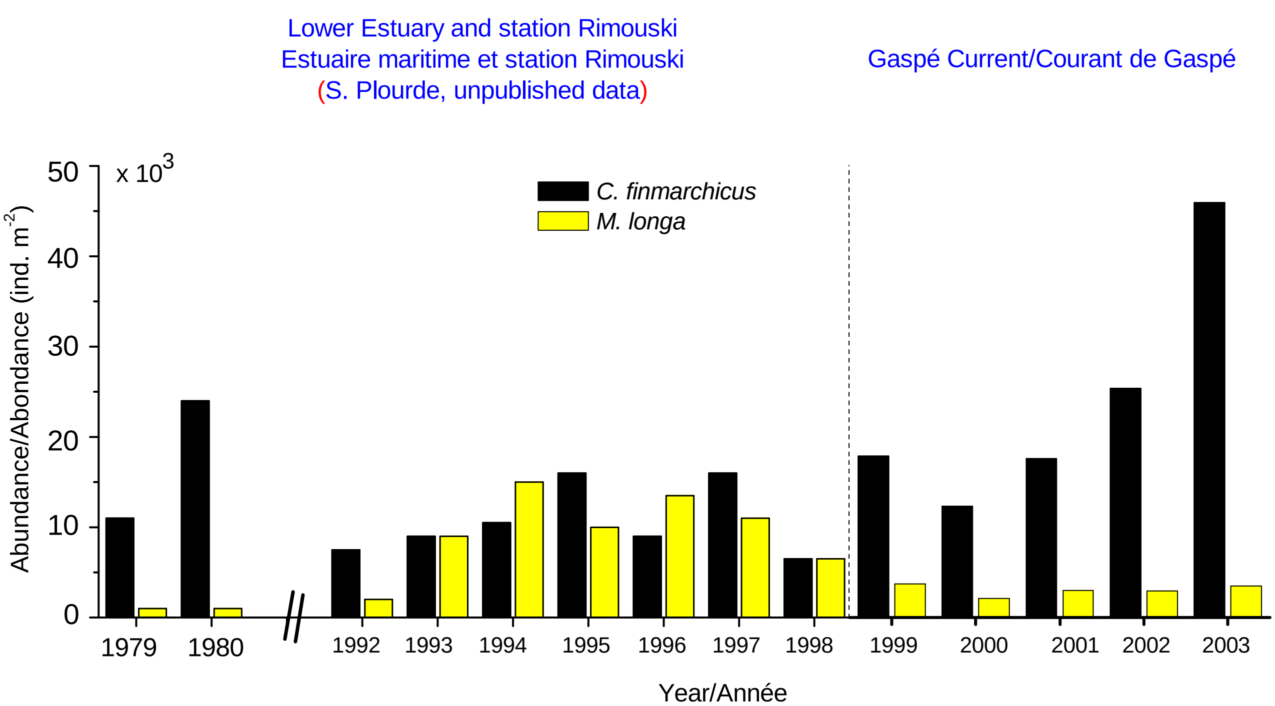


Figure 10. Mean integrated abundance of *C. finmarchicus* and *Metridia longa* from May through October in the Lower Estuary in 1979 and 1980, at station Rimouski from 1992 to 1998, and at the Gaspé Current station from 1999 to 2003.

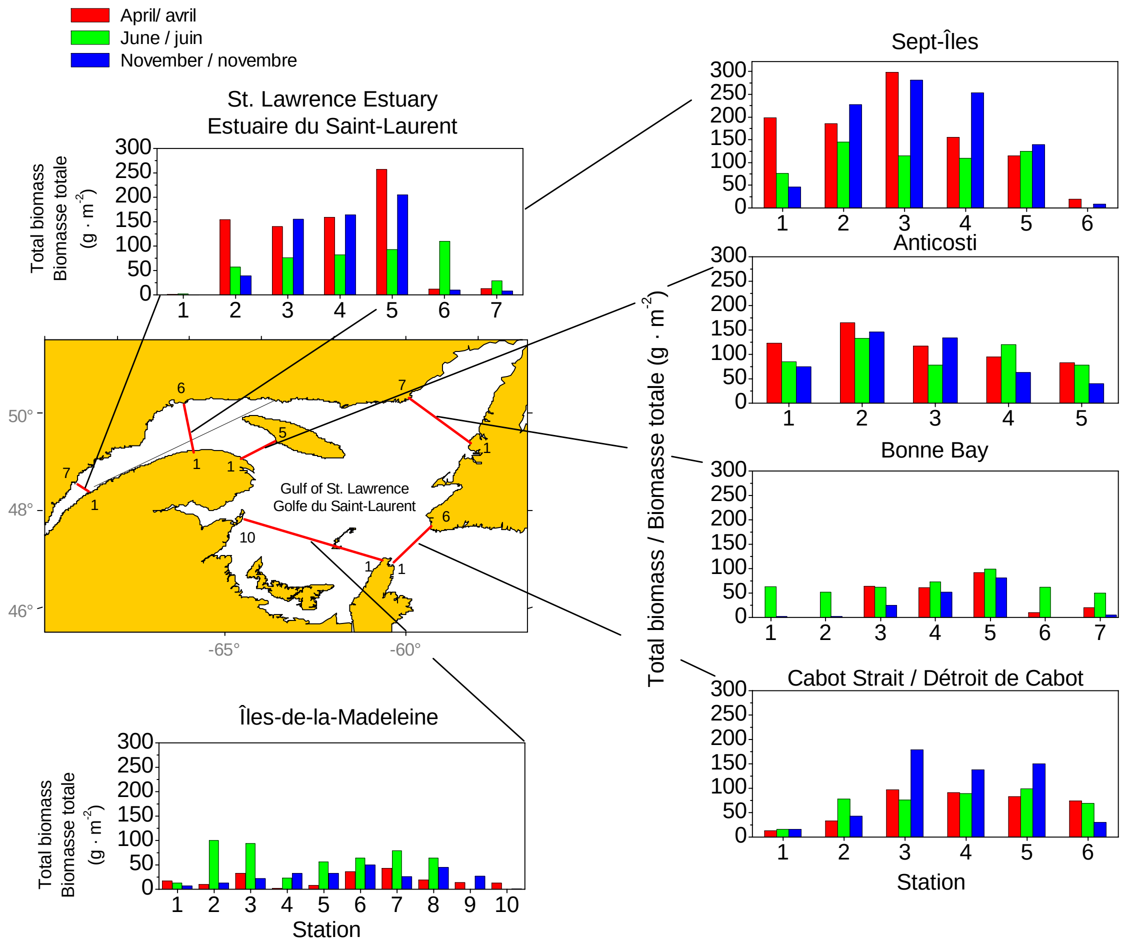
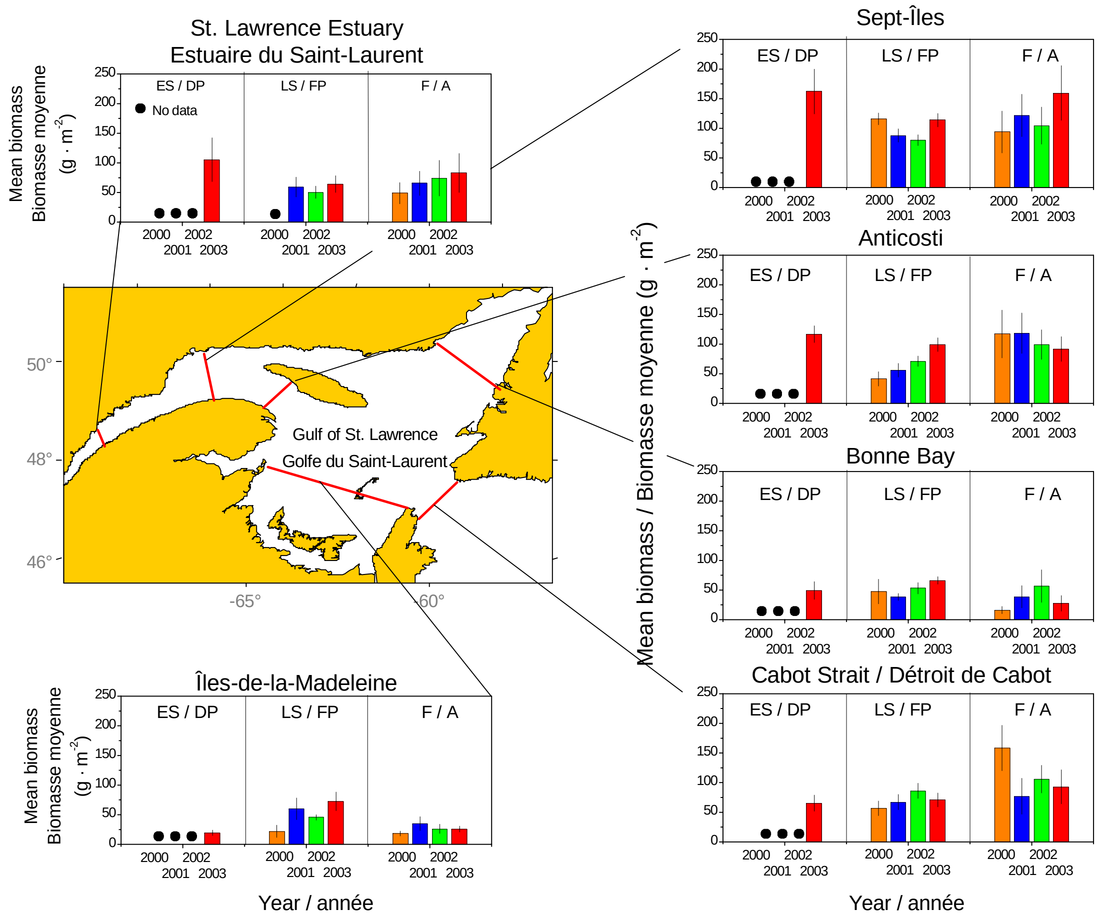


Figure 11. Total zooplankton biomass (wet weight) along the six sections sampled in April, June, and November 2003 in the Lower Estuary and the Gulf of St. Lawrence.



ES / DP: **E**arly **S**pring / **d**ébut du **p**rintemps LS / FP: **L**ate **S**pring / **f**in du **p**rintemps F / A: **F**all / **a**utomne

Figure 12. Mean zooplankton biomass (wet weight ± SE) along the six sections sampled in late spring and fall of 2000, 2001, 2002, and in early spring, late spring, and fall 2003 in the Lower Estuary, and the Gulf of St. Lawrence.

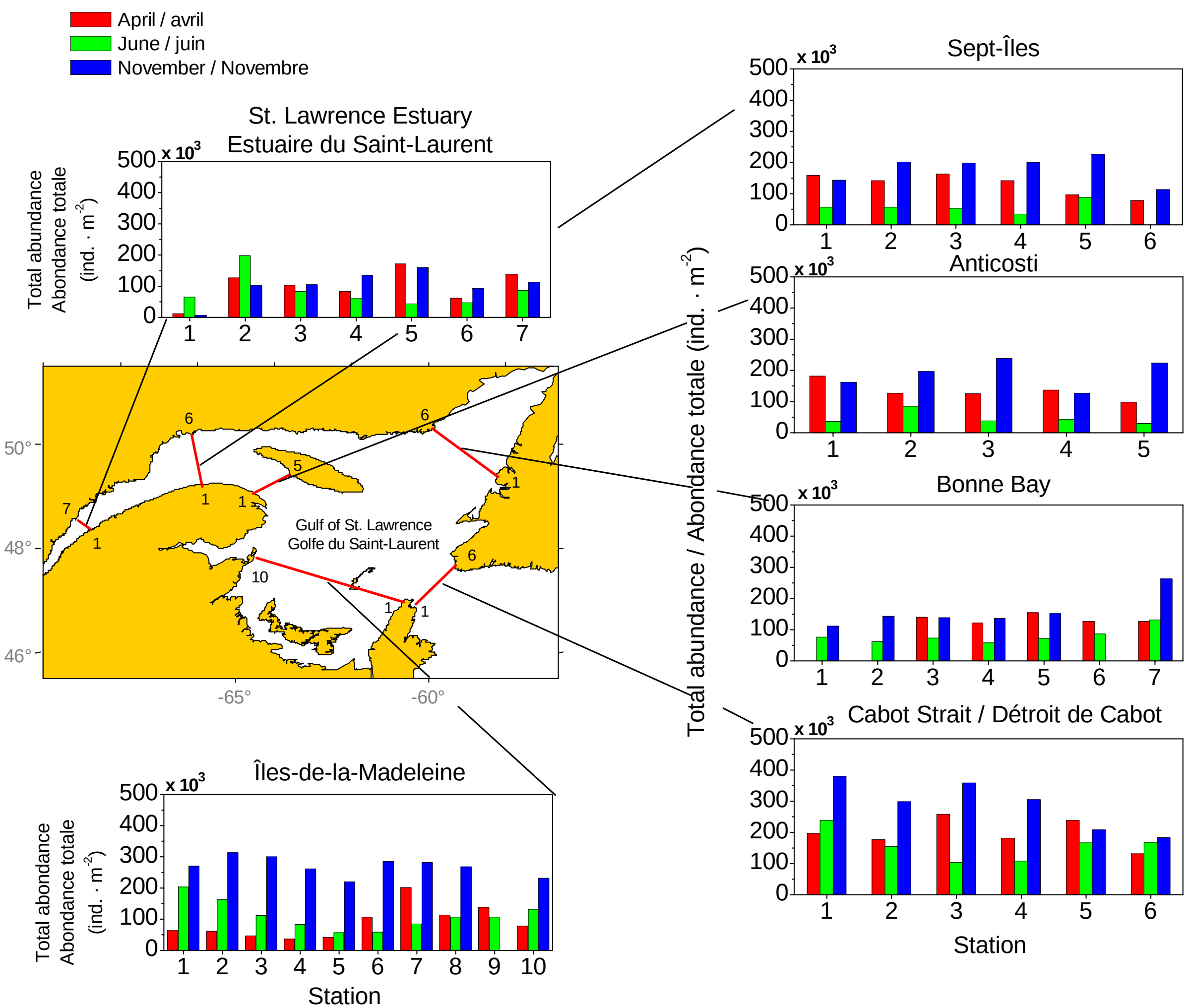


Figure 13. Integrated zooplankton abundance along the six sections sampled in April, June, and November 2003 in the Lower Estuary and the Gulf of St. Lawrence.

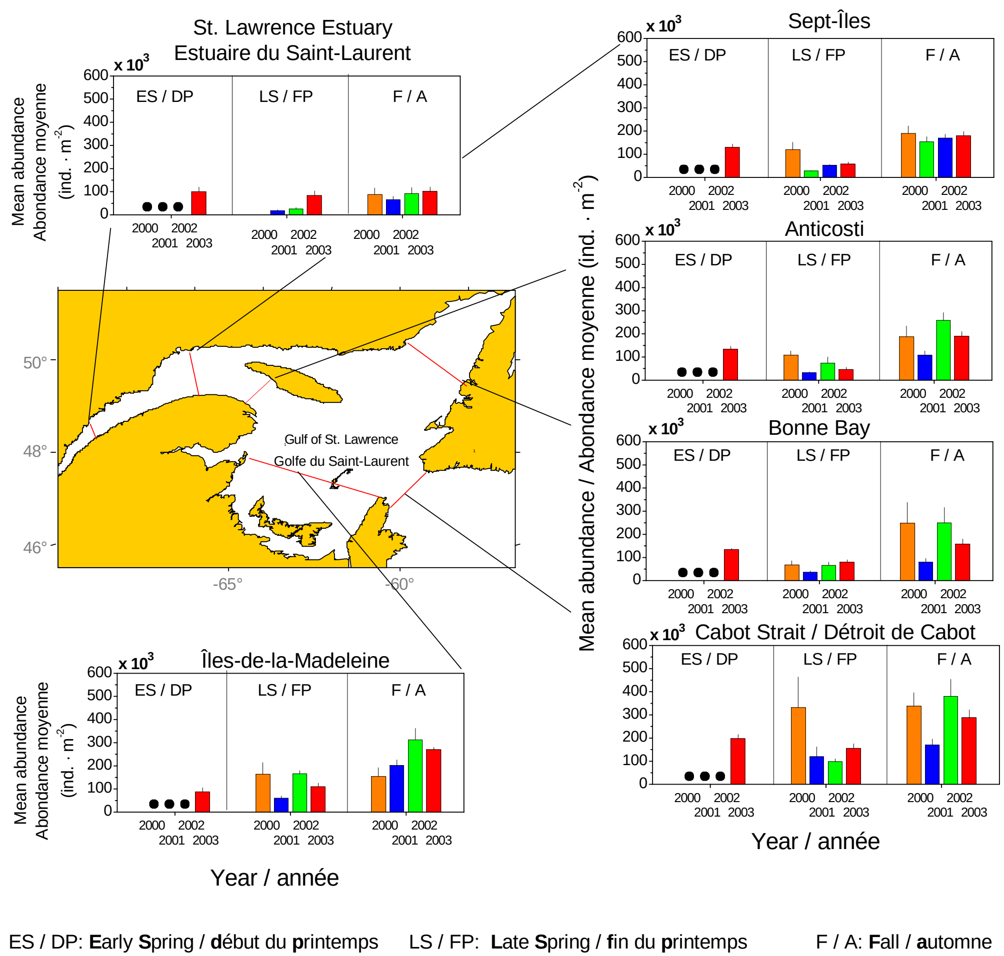


Figure 14. Mean zooplankton abundance (± SE) along the six sections sampled in late spring and fall 2000, 2001, 2002, and in early spring, late spring, and fall 2003 in the Lower Estuary and the Gulf of St. Lawrence.

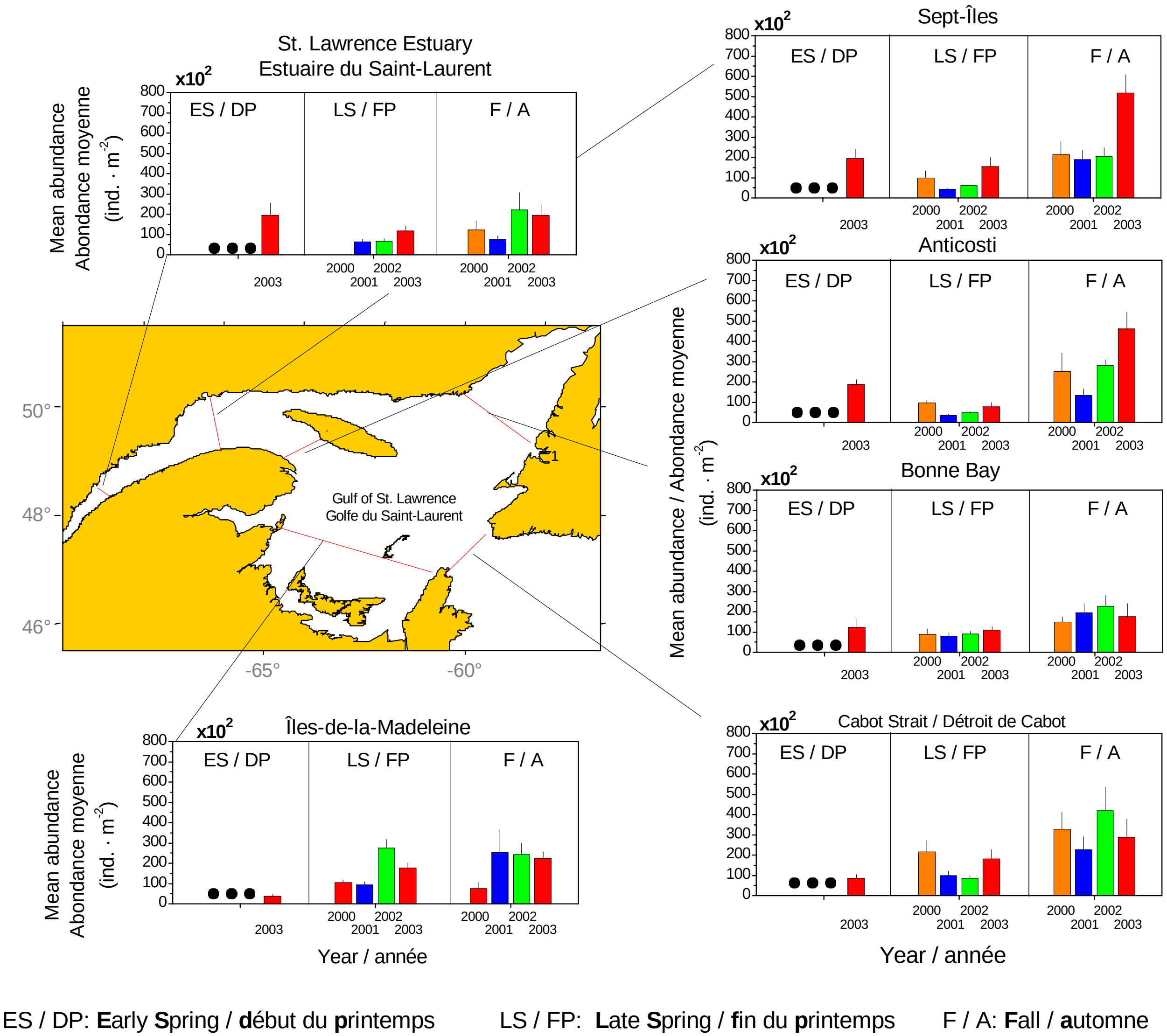


Figure 15. Mean abundance of *Calanus finmarchicus* (± SE) along the six sections sampled in late spring and fall 2000, 2001, 2002, and in early spring, late spring, and fall 2003 in the Lower Estuary and the Gulf of St. Lawrence.

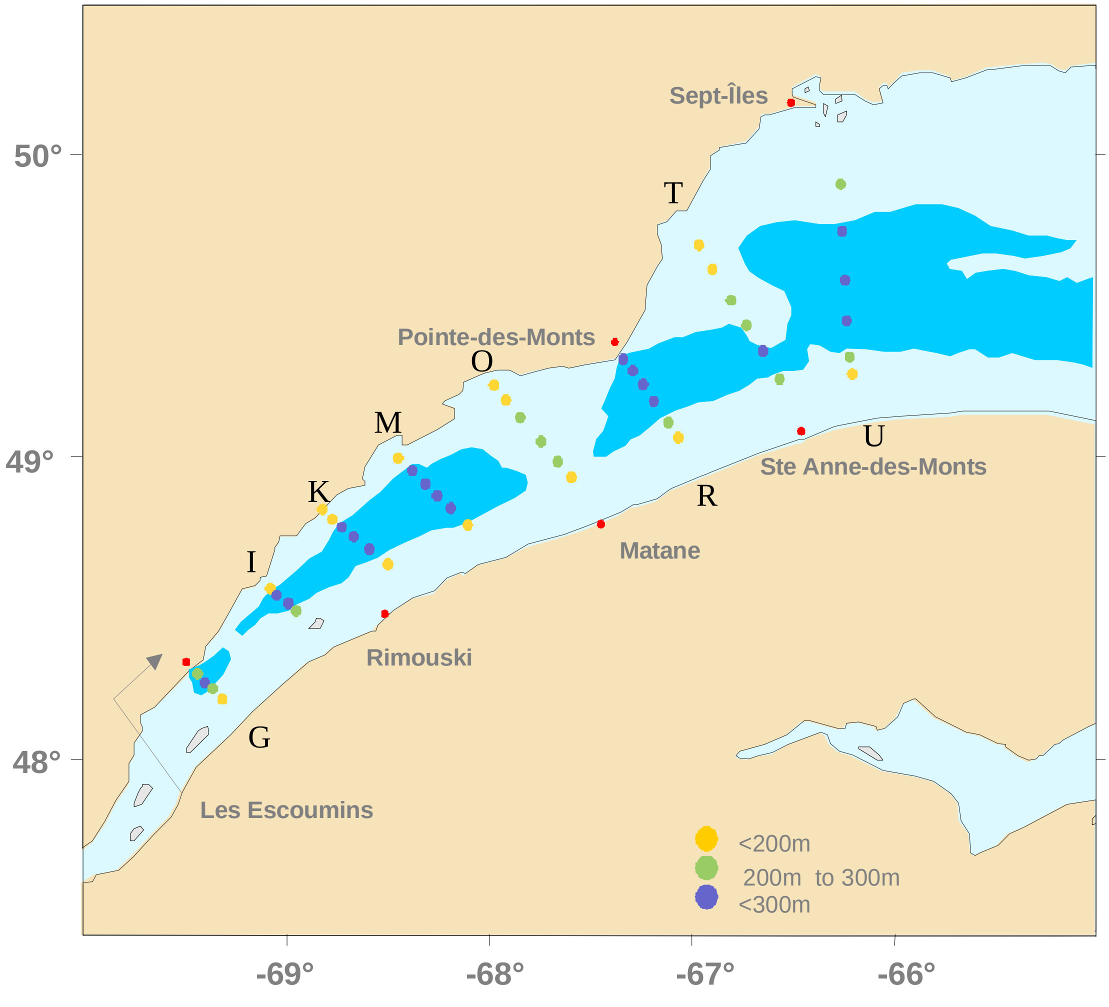
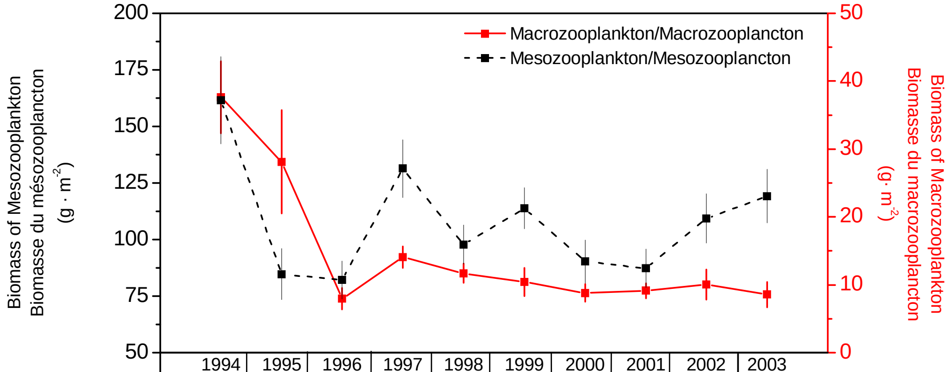


Figure 16. Map showing station locations of the annual zooplankton survey in the Lower St. Lawrence Estuary and the northwest Gulf of St. Lawrence. The survey has taken place in September of each year since 1994.



	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Meso	161.5	84.7	82.2	131.4	97.8	113.8	90.3	87.3	109.4	119.2
Macro	37.6	28.1	8.0	14.0	11.7	10.4	8.8	9.1	10.1	8.6

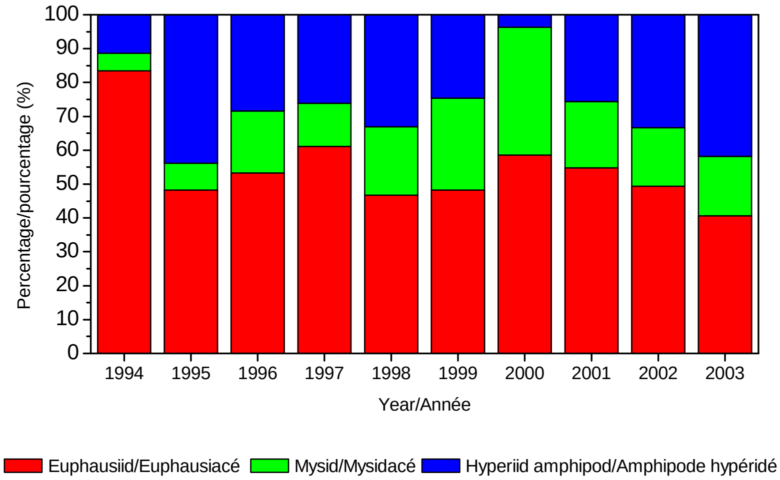


Figure 17. Mean biomass (± SE) of mesozooplankton and macrozooplankton in the Lower St. Lawrence Estuary and the northwest Gulf of St. Lawrence from 1994 to 2003 (upper panel) and relative abundance of the three most important macrozooplankton groups in terms of biomass (lower panel).

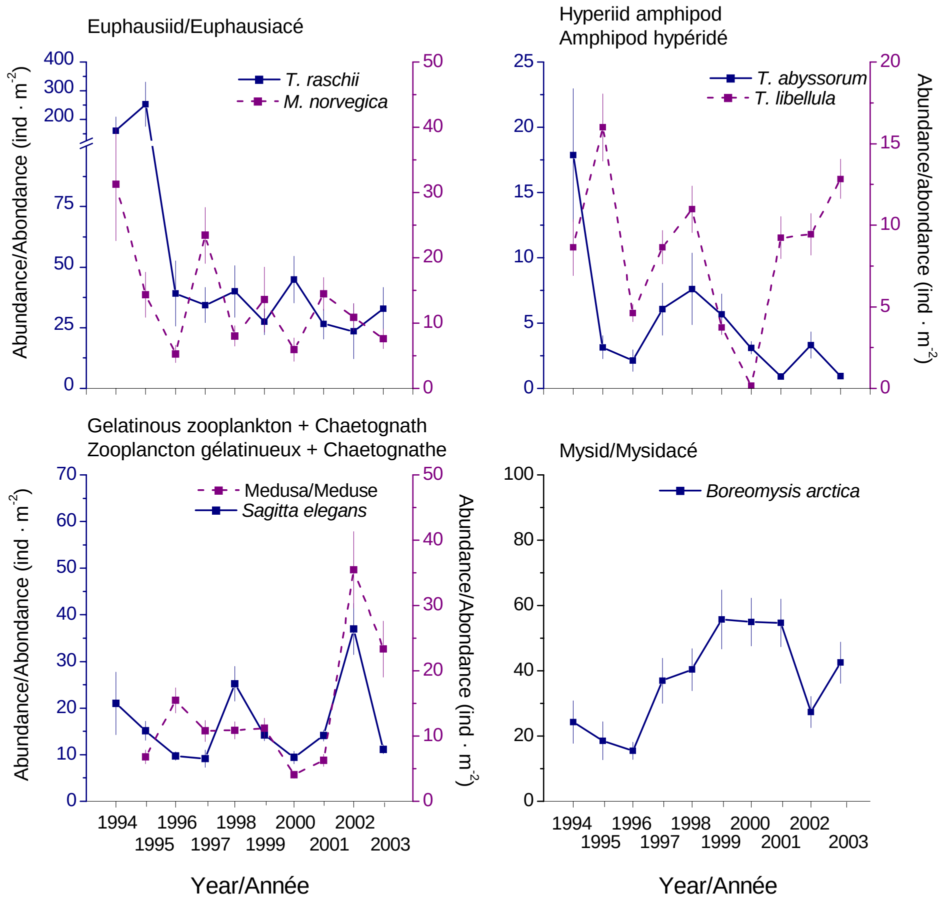


Figure 18. Mean abundance (± SE) of the most important species of macrozooplankton in the Lower St. Lawrence Estuary and the northwest Gulf of St. Lawrence from 1994 to 2003.

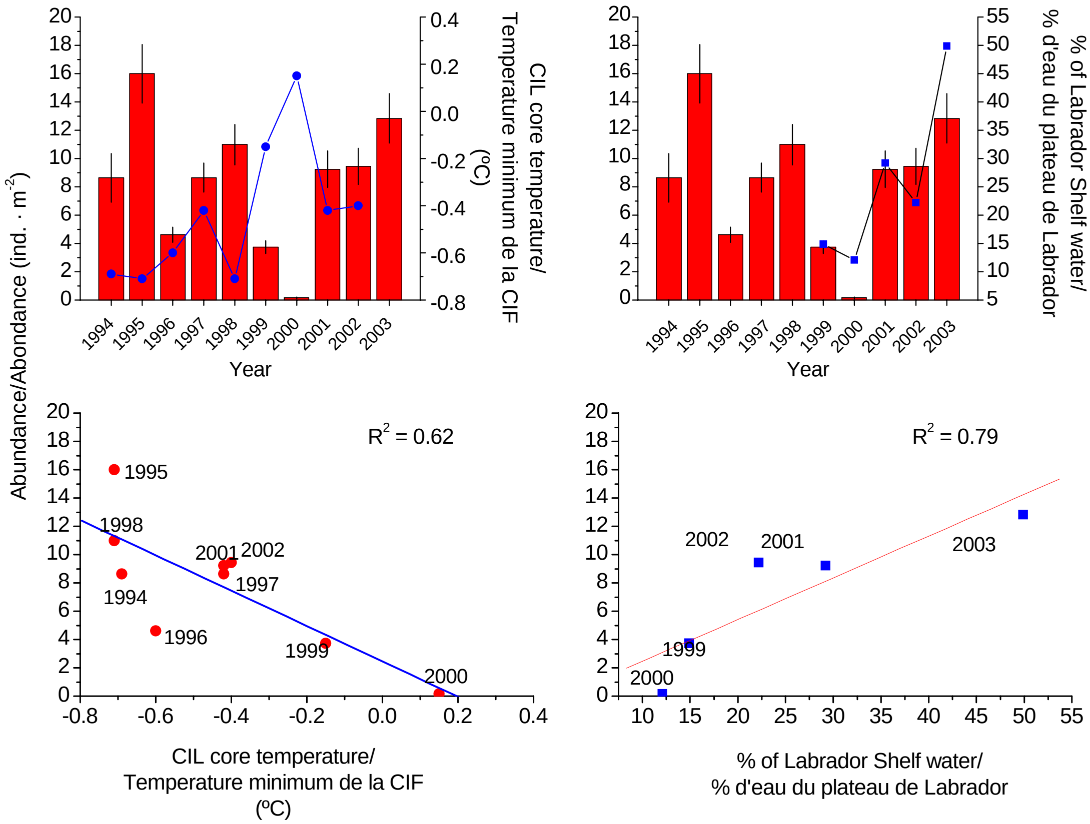


Figure 19. Relationship between the annual CIL core temperature index and the annual mean abundance of the hyperiid amphipod *Themisto libellula* in the Lower St. Lawrence Estuary and the northwest Gulf of St. Lawrence from 1994 to 2003.