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Oceanographic conditions in the Estuary and the Gulf of St. Lawrence in 1999 : zooplankton

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Abstract

This report describes : 1) an overview of the spatial variability of the mesozooplankton and krill biomass in the lower St. Lawrence Estuary and the northwest Gulf of St. Lawrence (GSL) measured in September in each year between 1994–1999 and 2) results on the temporal variability of the zooplankton biomass, abundance, and species composition at two fixed stations of the Atlantic Zonal Monitoring Program (AZMP; Anticosti Gyre and Gaspé Current) in 1999.

Within the lower St. Lawrence Estuary and the northwest GSL, the biomass of mesozooplankton and krill was not evenly distributed and showed very high interannual variability. The estimated average wet biomass of mesozooplankton varied between 106.5 and 209.2 $t \cdot km^{-2}$ from 1994 to 1999 with the highest and the lowest values found in 1994 and 1996 respectively. From 1994 to 1999, the overall average biomass of mesozooplankton for the whole lower St. Lawrence Estuary and northwest GSL was estimated at $1.6 \cdot 10^6 \pm 0.3 \cdot 10^6$ t. Likewise, the estimated average biomass of krill varied between 7.2 and 38.1 $t \cdot km^{-2}$ from 1994 to 1999 with the highest and the lowest values found in 1994 and 1996 respectively. The overall average biomass of krill for the whole lower St. Lawrence Estuary and northwest GSL was estimated to be $1.7 \cdot 10^5 \pm 0.9 \cdot 10^5$ t.

The temporal variability of the zooplankton biomass, abundance, and species composition at the two AZMP fixed stations (Anticosti Gyre and Gaspé Current) showed that copepods were clearly dominant at all sampling dates in 1999, accounting for more than 80% of the zooplankton community for both stations. Small copepods (*Oithona similis*, *Oncea borealis*) dominated in abundance at all sampling dates at both stations except in the Gaspé Current in July and August, where larger species (*Calanus finmarchicus*, *C. glacialis*, *Metridia longa*) were more abundant. Total zooplankton biomass was much higher in the Anticosti Gyre than in the Gaspé Current for all seasons in 1999 except in May, when the biomass was equal at both stations. The integrated copepod abundance showed the same pattern of variation with season at both stations, with a maximum abundance of copepod eggs in spring and a maximum abundance of adult copepods and copepodite stages (CI-CV) in late fall. The total integrated abundance of adult copepods and copepodite stages (CI-CV) did not vary significantly between stations for all seasons. Finally, all proposed indices describing the state of the zooplankton community at each station in 1999 varied with season and their annual mean values varied between stations. However, it is too soon to say if they will be useful to describe the interannual variability of the zooplankton community or to detect any changes of the environmental conditions.

Résumé

Le présent rapport inclut les éléments suivants : 1) un survol de la variabilité spatiale de la biomasse de mésozooplancton et de krill dans le bas de l'estuaire du fleuve Saint-Laurent et le nord-ouest du golfe du Saint-Laurent (GSL) mesurée en septembre de chaque année de 1994 à 1999 et 2) les résultats de l'étude de la variabilité temporelle de la biomasse, de l'abondance et de la composition taxinomique du zooplancton à deux stations fixes du Programme de monitorage de la zone atlantique (PMZA : gyre d'Anticosti et courant de Gaspé) en 1999.

Dans le bas de l'estuaire du Saint-Laurent et le nord-ouest du GSL, la biomasse de mésozooplancton et de krill n'était pas uniformément distribuée, montrant une très forte variabilité d'une année à l'autre. La biomasse humide moyenne estimative de mésozooplancton variait de 106,5 à 209,2 t km^{-2} de 1994 à 1999, la valeur la plus élevée et la plus faible ayant été observée en 1994 et 1996, respectivement. De 1994 à 1999, la biomasse moyenne totale estimative globale de mésozooplancton dans l'ensemble du bas de l'estuaire du Saint-Laurent et du nord-ouest du GSL se chiffrait à $1{,}6\ 10^{6} \pm 0{,}3\ 10^{6}$ t. De même, la biomasse moyenne estimative de krill variait de 7,2 à 38,1 t km^{-2} de 1994 à 1999, la valeur la plus élevée et la plus faible ayant été observée en 1994 et 1996, respectivement. La biomasse moyenne totale estimative de krill dans l'ensemble du bas de l'estuaire du Saint-Laurent et du nord-ouest du GSL se chiffrait à $1{,}7\ 10^{5} \pm 0{,}9\ 10^{5}$ t.

La variabilité temporelle de la biomasse, de l'abondance et de la composition taxinomique du zooplancton aux deux stations fixes PMZA (gyre d'Anticosti et courant de Gaspé) a révélé que les copépodes prédominaient clairement à toutes les dates d'échantillonnage en 1999, constituant plus de 80 % de la communauté zooplanctonique aux deux stations. Les petits copépodes (*Oithona similis, Oncea borealis*) étaient les plus abondants à toutes les dates d'échantillonnage aux deux stations, sauf dans le courant de Gaspé en juillet et août, lorsque de grosses espèces (*Calanus finmarchicus, C. glacialis, Metridia longa*) étaient plus abondantes. La biomasse totale de zooplancton était nettement plus élevée dans le gyre d'Anticosti que dans le courant de Gaspé pendant toutes les saisons en 1999, sauf en mai, lorsque la biomasse était égale aux deux stations. L'abondance intégrée des copépodes montre le même modèle de variation selon la saison aux deux stations, l'abondance maximale d'oeufs de copépodes se manifestant au printemps et l'abondance maximale de copépodes adultes et de stades copépodites (CI-CV), à la fin de l'automne. L'abondance totale intégrée de copépodes adultes et de stades copépodites (CI-CV) ne variait pas de façon significative d'une station à l'autre pendant toutes les saisons. En dernier lieu, tous les indices proposés décrivant l'état de la communauté zooplanctonique à chaque station en 1999 variaient selon la saison, tandis que leurs valeurs annuelles moyennes variaient selon la station. Il est toutefois trop tôt pour établir s'ils seront utiles pour décrire la variabilité interannuelle de la communauté zooplanctonique ou déceler tout changement dans les conditions du milieu.

Introduction

In 1993, a permit for an exploratory fishery on species of krill (euphausids) and large planktonic copepods in the genus *Calanus* was issued for the lower St. Lawrence Estuary. In 1994, a zooplankton survey was initiated to estimate biomass of the targeted taxa in order to establish quotas for this fishery, in the event that it becomes a full-fledged industry. Since 1996, the fishery in the lower St. Lawrence Estuary has been inactive. The survey has nevertheless continued each September, for the purpose of establishing a baseline of zooplankton biomass and interannual variability in the lower estuary. The purpose of this document is to provide an overview of the spatio-temporal variability of the mesozooplankton and krill biomass in the lower St. Lawrence Estuary and the northwest Gulf of St. Lawrence from 1994 -1999.

In addition, the Atlantic Zonal Monitoring Program (AZMP) has recently been established for the Canadian east coast (Therriault et al. 1998). One of the underlying goals of the AZMP is to collect biological, chemical, and physical data to characterize and understand the causes of oceanographic variability at the seasonal, interannual, and decadal time scales in the Gulf of St. Lawrence. The purpose of this document is to provide an overview of the temporal variability in 1999 of the zooplankton biomass, abundance, and species composition at two fixed stations (Anticosti Gyre and Gaspé Current) of the AZMP.

Zooplankton biomass in the lower St. Lawrence Estuary and the northwest Gulf of St. Lawrence from 1994 -1999

Methods

The survey involves sampling with a 1 m^2 BIONESS plankton net equipped with 333-µm mesh nets at each of up to 44 stations along 8 transects covering the lower Estuary and the northwest Gulf of St-Lawrence from Les Escoumins to Sept-Îles (Fig. 1). In 1994, only transects K through T were surveyed. Transects G and I, at the head of the Laurentian Channel, were sampled in 1995, 1996, 1997, 1998, and 1999 whereas transect U in the Anticosti Gyre was only sampled in 1997, 1998 and 1999. The survey occurred in September of each year usually during a period of 10 days in the middle of the month (Table 1). In 1999, the survey occurred during two different periods of 5 days, from 27 to 31 August (transects G, I, K, M, O, R) and from 9 to 15 September (transects O, R, T, U), due to ship time problems. A series of 7 stations, distributed along two transects (O and R), were sampled during each period to determine if the results from each period could be considered as quasi-synoptic. At each station, the water column was sampled twice, each time with two nets (bottom-150m and 150-0m; 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, as well as wet weight of fish (the Atlantic soft pout, *Melanostigma atlanticum*), pandalid shrimp, and gelatinous zooplankton, were measured on board immediately after the tow. In 1998 and 1999, larger samples were 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.

- **Krill**: adult and juvenile euphausids (*Meganyctiphanes norvegica*, *Thysanoessa inermis* and *T. raschii*). This category also includes mysids that were commonly found in deep samples.
- **Mesozooplankton**: Predominantly copepods, but also other mesozooplankton, including chaetognaths and amphipods. Excludes gelatinous zooplankton, decapods, and krill (as defined above).

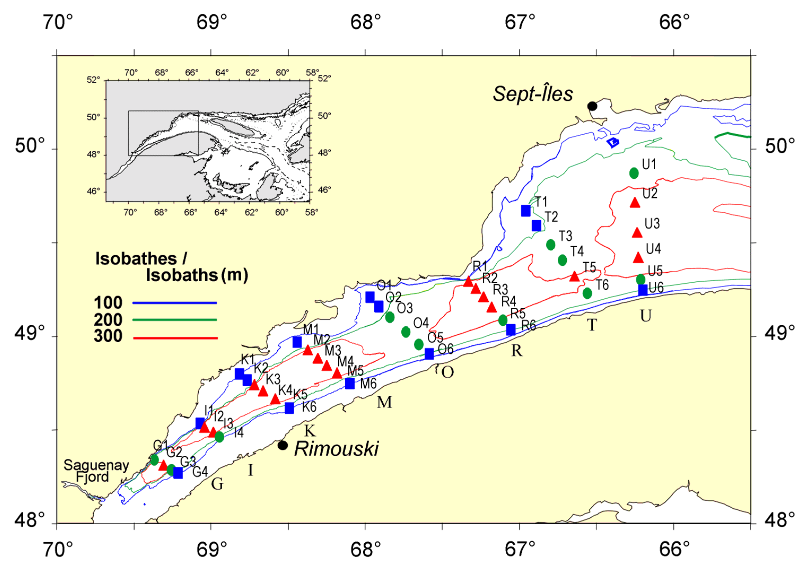

Fig. 1. Map showing station locations of annual zooplankton survey in the lower St. Lawrence Estuary and the northwest Gulf of St. Lawrence. Survey takes place in September of each year, since 1994.

Table 1. Schedule of September zooplankton surveys 1994-1999.

Year	Mission	Period	Total No. of stations sampled
1994	CSS PARIZEAU	4 - 9 Sept.	30
1995	CSS PARIZEAU	22 - 26 Sept.	37
1996	CSS PARIZEAU	13 - 18 Sept.	35
1997	NGCC MARTHA L. BLACK	16 - 23 Sept.	38
1998	NGCC MARTHA L. BLACK	11 - 17 Sept.	42
1999	NGCC MARTHA L. BLACK	27 – 31 Aug. 9 – 15 Sept.	27 23

Wet weights for each tow were divided by volume filtered (m^3) as measured by a General Oceanic flow meter installed in the mouth of the BIONESS. Integrated biomass for the water column (g ww · m^{-2}) was calculated by multiplying the standardized wet weight by the depth interval sampled by the net and, for station depths >150 m, summing the upper and lower water column values. The distribution and magnitude of integrated biomass of mesozooplankton and krill are presented using contour plots covering the whole geographic area sampled every year. The total biomass (in tons) of krill and mesozooplankton for the whole lower St. Lawrence Estuary and northwest GSL was estimated by multiplying the median value of each integrated biomass interval observed on contour plots by the total area corresponding to this biomass value within the Estuary and the northwest Gulf.

Results and discussion

Comparisons of mesozooplankton and krill biomass collected on transects O and R during the first (27-31 August) and the second (9-15 September) parts of the 1999 cruise showed no significant difference in the biomass of mesozooplankton and krill sampled during these two periods (Fig. 2).

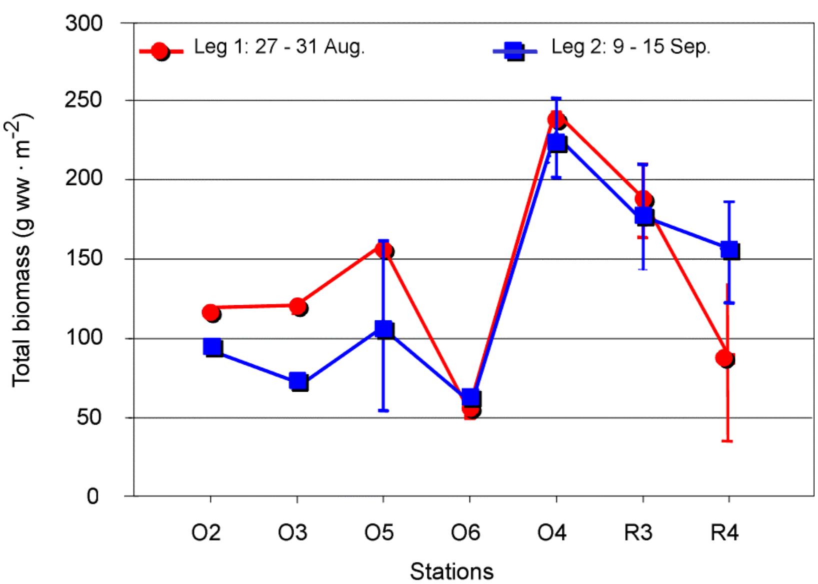

Fig. 2. Comparison of total biomass between the first and second leg of the 1999 cruise.

The mesozooplankton biomass was not evenly distributed within the lower St. Lawrence Estuary and the northwest GSL in each of the 6 years, 1994, 1995, 1996, 1997, 1998, and 1999 and showed a very high interannual variability (Fig. 3). In 1994, the integrated mesozooplankton biomass varied between 35 and 759 g ww · m^{-2} with the highest values found in the western part of the sampled area. The integrated biomass increased with station depth, reflecting the abundance of large copepod species (*Calanus hyperboreus, C. finmarchicus*) at depth in the Laurentian Channel (Fig. 3).

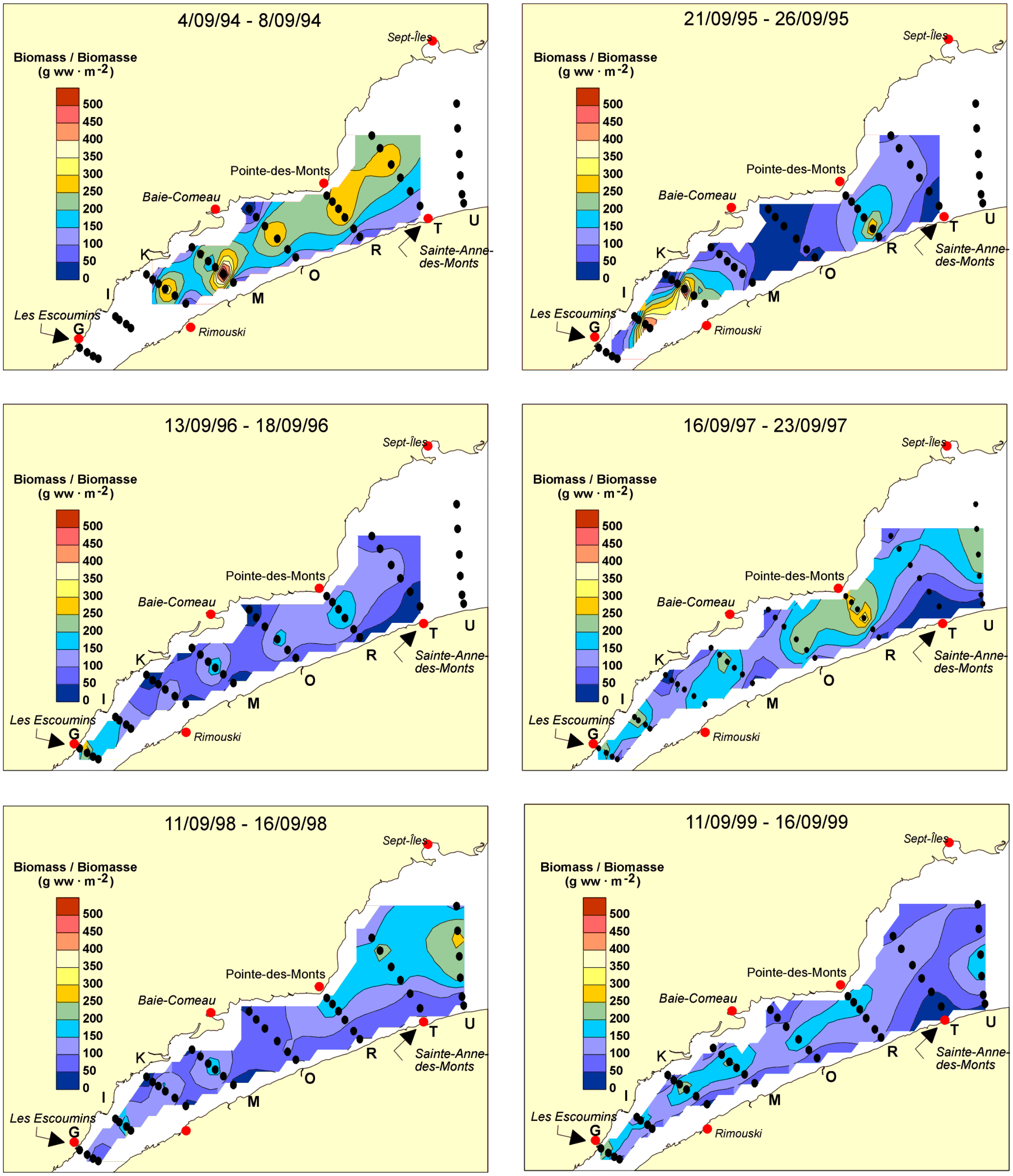

Fig. 3. Contour plots presenting the integrated biomass of mesozooplankton (g ww · m^{-2}) for the whole geographic area sampled each year since 1994.

The estimated total mesozooplankton biomass for the whole sampled area (9,421 km^2) was 1,971,446 metric tons (t) corresponding to an average value of 209.2 t·km^2 in the lower St. Lawrence Estuary and the northwest GSL in 1994 (Table 2 and Fig. 3). In 1995, the integrated mesozooplankton biomass varied between 1 and 646 g · ww m^{-2} with the highest values found along transects I and K at the head of the Laurentian Channel (Fig. 3). The total biomass for the whole area sampled (10,287 km^2) was estimated at 1,303,565 t corresponding to an average value of 126.7 t·km^2 in 1995 (Table 2 and Fig. 3). Likewise, the estimated mesozooplankton biomass in 1996 was lower than in 1994 and 1995, ranging from 13 to 398 g ww · m^{-2}. This was also observed for the total and the average biomass, which were respectively 1.7 and 2 times lower in 1996 (10,628 km^2; 1,131,463 t; 106.5 t·km^{-2}) than in 1994 (Table 2 and Fig 3). In 1997 and 1998, the biomass of mesozooplankton ranged from 10 to 405 g · ww m^{-2} and 21 to 300 g ww · m^{-2} respectively, and both the total and the average biomass were slightly higher in 1997 (12,706 km^2; 1,910,412 t; 150.4 t·km^{-2}) and 1998 (13,960 km^2; 1,801,801 t; 129.1 t·km^{-2}) than in 1996 but remained approximately 1.5 times lower than in 1994 (Table 2 and Fig. 3). Contrary to the situation observed in 1994 and 1995, where the highest abundance of mesozooplankton was found in the western part of the sampled area, the highest mesozooplankton abundance in 1997 and 1998 were found along transects R and U respectively, which are both located in the eastern end of the sampled area. In 1999, the integrated mesozooplankton biomass varied between 18 and 273 g ww · m^{-2} with the highest values found in the western part of the sampled area. The estimated total mesozooplankton biomass for the whole sampled area (11,396 km^2) was 1,316,882 metric tons (t), corresponding to an average value of 115.6 t·km^{-2} in the lower St. Lawrence Estuary and the northwest GSL. The estimated biomass of mesozooplankton in 1999 was as low as in 1996 with an average value 1.8 times lower than in 1994.

Krill biomass also showed a very high interannual variability and was not evenly distributed within the lower St. Lawrence Estuary and the northwest GSL (Fig. 4). The krill biomass is less dependent on depth than mesozooplankton biomass, as euphausid species are also found at the shallower stations, particularly along the north shore of the estuary (Fig. 4). The estimates of krill biomass in 1994 varied between 10 and 145 g ww · m^{-2}, with the highest values found in the western part of the sampled area. The estimated total biomass for the whole sampled area (9,421 km^2) was 358,546 metric tons (t), corresponding to an average value of 38.1 t·km^{-2} in the lower St. Lawrence Estuary and the northwest GSL in 1994 (Table 2 and Fig. 4). In 1995, the integrated krill biomass varied between 0 and 178 g ww · m^{-2} with the highest values found at the head of the Laurentian Channel in the western part of the sampled area (Fig. 4). The average biomass was slightly lower in 1995 (10,287 km^2; 197,028 t; 18.8 t·km^{-2}) than in 1994 (9,421 km^2; 358,546 t; 38.1 t·km^{-2}) (Table 2 and Fig 4). Likewise, the estimated krill biomass in 1996, ranging from 13 to 398 g · ww m^{-2}, was lower than in 1994 and 1995. This was also observed for the total and the average biomass, which were respectively 4.6 and 5.3 times lower in 1996 (10,628 km^2; 76,324 t; 7.2 t · km^{-2}) than in 1994 (9,421 km^2; 358,546 t; 38.1 t · km^{-2}). Krill biomass recovered somewhat in 1997 (12,706 km^2, 169,494 t, 13.3 t · km^{-2}) and 1998 (13,960 km^2, 143,583 t, 10.3 t · km^{-2}), although still approximately 3 fold lower than 1994 levels (Table 2 and Fig. 4). In 1999, the integrated krill biomass varied between 0 and 89 g ww · m^{-2} with the highest values found in the western part of the sampled area. The estimated total krill biomass for the whole sampled area (11,396 km^2) was 93,665 metric tons (t), corresponding to an average value of 8.2 t·km^{-2} in the lower St. Lawrence Estuary and the northwest GSL. The estimated krill biomass in 1999 was as low as in 1996, with an average value 4.6 times lower than in 1994.

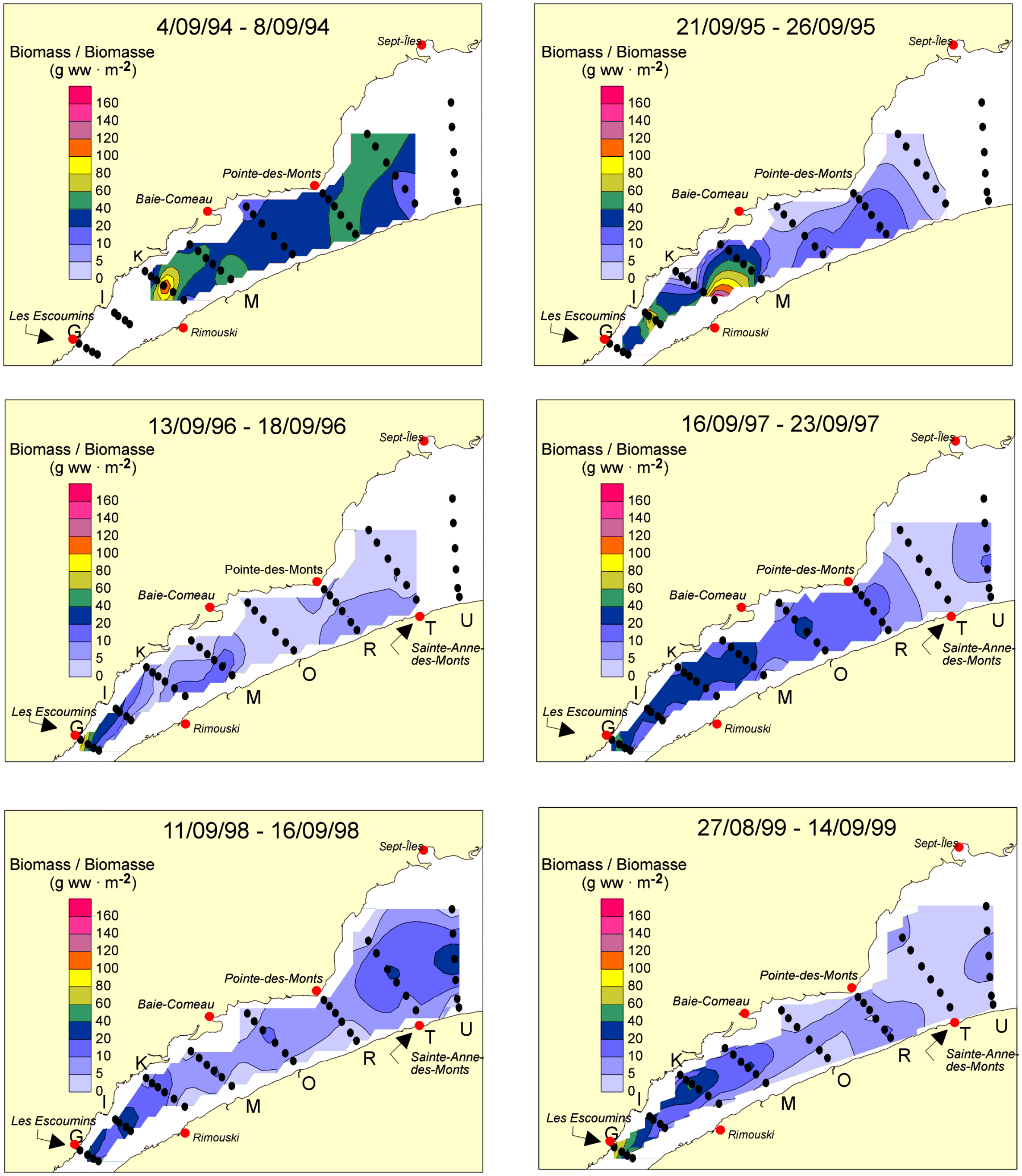

Fig. 4. Contour plots presenting the integrated biomass (g ww · m^{-2}) of krill for the whole geographic area sampled each year since 1994.

Table 2. Total biomass (in tons) of mesozooplankton and krill for the whole lower St. Lawrence Estuary and northwest GSL from 1994 to 1999.

Year	Total area sampled (km^2)	Mesozooplankton		Krill	
		Total biomass (tons)	Standardized biomass ($t\ ww \cdot km^{-2}$)	Total biomass (tons)	Standardized biomass ($t\ ww \cdot km^{-2}$)
1994	9,422	1,971,446	209.2	358,546	38.1
1995	10,287	1,303,565	126.7	197.028	18.8
1996	10,628	1,131,463	106.5	76,324	7.2
1997	12,706	1,910,412	150.4	169,494	13.3
1998	13,960	1,801,801	129.1	143.583	10.3
1999	11,396	1,316,882	115.6	93,665	8.2

In summary, total mesozooplankton and krill biomass observed in September 1999 in the lower St. Lawrence Estuary and in the northwest GSL are comparable to September 1996 measurements, slightly lower than September 1995, 1997, 1998, and respectively two and five times lower than in September 1994. At the present time, there is no solid mechanistic explanation for the fluctuations of the total biomass of mesozooplankton and krill within the lower St. Lawrence Estuary and the northwest GSL and throughout the years. Nevertheless, it is expected that current Atlantic GLOBEC modeling studies of the influence of circulation on the distribution and abundance of *Calanus finmarchicus* will provide insight into possible physical mechanisms affecting mesozooplankton distribution and abundance in the lower Estuary and the northwest Gulf of St. Lawrence.

Another survey is planned for fall 2000. Our objective is to continue the September surveys, contingent on funding, for an additional 4-year period. This would provide a 10-year baseline of zooplankton biomass for the estimation of interannual variation.

Temporal variability of zooplankton abundance, species composition, and biomass at two stations of the Atlantic Zonal Monitoring Program (Anticosti Gyre and Gaspé Current) in 1999

Methods

The sampling record at the fixed station (Anticosti Gyre: 49º 43' 00", 66º 15' 00"; Gaspé Current: 49º 14' 49") is given in Table 3. Zooplankton samples were collected during 14 visits of the fixed stations in 1999. Samples were obtained by vertical tows from bottom-to-surface tows using a 50 cm Bongo net equipped with 158-µm mesh nets at each station. Samples were preserved in 4% buffered formaldehyde and analyzed for wet weight upon return to the laboratory. Zooplankton samples were analyzed by counting and identifying 200-300 organisms from a subsample. Wet weights for each tow were divided by volume filtered (m^3), measured by a General Oceanic flow meter installed in the mouth of the Bongo. Integrated biomass ($g\ ww \cdot m^{-2}$) was calculated by multiplying the standardized wet weight by the depth interval sampled.

Table 3. Numbers of bi-weekly occupations at two fixed stations of the zonal monitoring program (Anticosti Gyre and Gaspé Current) in 1999.

	Total No.	Dates of zooplankton samples collection in 1999											
Stations	of samples	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Anticosti Gyre	14	2	1	1	0	3	1	1	1	2	1	1	0
Gaspé Current	14	2	1	1	0	3	1	2	1	2	0	1	0

The variables analyzed were the monthly variations of both the zooplankton community structure and the copepod community structure. Furthermore, we proposed a series of indices describing the state of the zooplankton community at each station in 1999. Those indices are: 1) the monthly variations of the depth-integrated zooplankton biomass, 2) the monthly variations of the depth-integrated copepod abundance, 3) the monthly variations of the depth-integrated abundance of *Calanus* species, 4) the monthly variations of the depth-integrated abundance of *Metridia longa*, 5) the monthly variations of the depth-integrated total number of species, and 6) the monthly variations of the depth-integrated Shannon-Wiener diversity index (H’).

Results and discussion

Monthly variations of the zooplankton community structure

Juvenile and adult copepods were clearly dominant, accounting for an average of 68% and 74% of the zooplankton community at all sampling dates in the Anticosti Gyre and the Gaspé Current respectively (Fig. 5). The second most important taxonomic category was copepod eggs, representing between 6% and 32% of the total zooplankton community for all sampling dates at the Anticosti Gyre station and between 1% and 29% at the Gaspé

Current station. The relative abundance of copepod eggs and copepod nauplii decreased during summer and fall while the relative abundance of copepodite stages and adult copepods increased during the same periods. Invertebrate eggs were also relatively abundant in spring at both stations, representing between 4 % and 22 % of the total zooplankton community, but their relative abundance decreased at both stations during summer and fall. Mollusk larvae, mostly bivalve, were rare at all sampling dates except in June in the Anticosti Gyre, where they represented 28% of the total zooplankton assemblage (Fig. 5). All other zooplankters (gastropods, larvacea, ctenophores, ostracods, polychaetes) represented an average of 9 % and 5 % of the zooplankton community at all sampling dates in the Anticosti Gyre and the Gaspé Current respectively. They mostly occurred during the summer season at both stations.

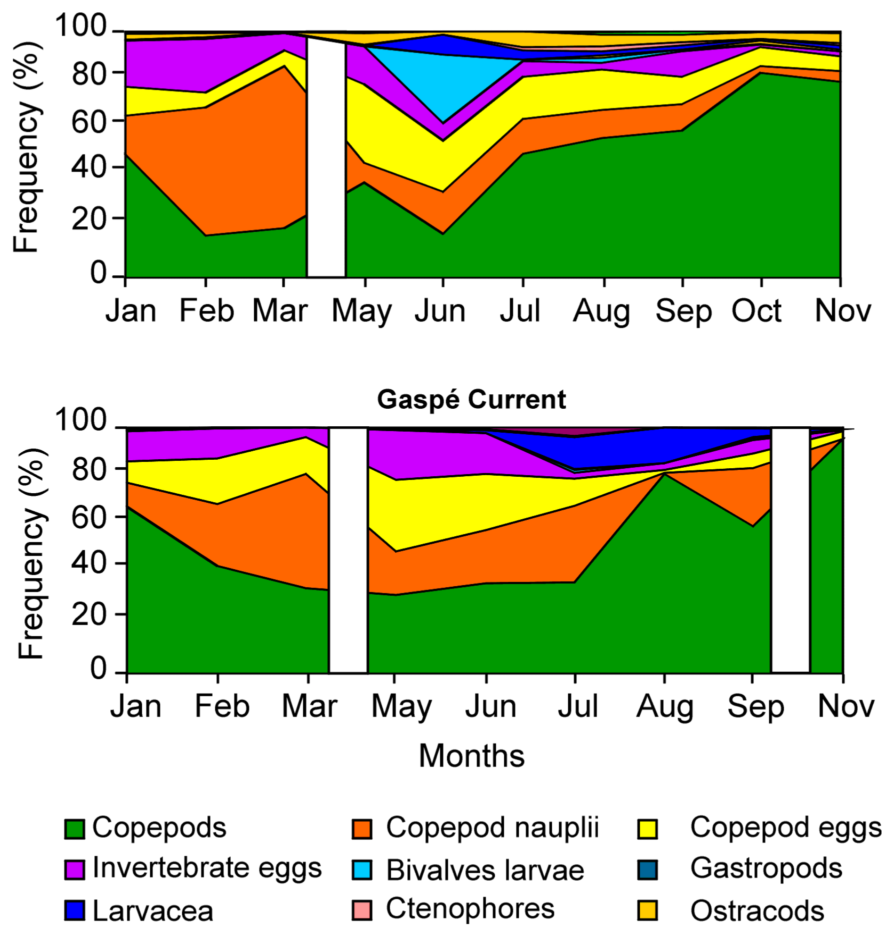

Fig. 5. Monthly variations in composition (% of total abundance) of the zooplankton community at the two fixed stations of the AZMP in 1999.

Monthly variations of the copepod community structure

A closer examination of the monthly variations of the copepod community structure showed that small copepods (*Oithona similis*, *Oncea borealis*) were dominant at all sampling dates at both stations except in the Gaspé Current in July and August, when larger species (*Calanus finmarchicus*, *C. glacialis*, *Metridia longa*, *Acartia* sp.) were more abundant (Fig. 6). *Oithona similis* and *Oncea borealis* accounted for an average of 54% of the copepod community at all sampling dates in the Anticosti Gyre and between 7 and 87% in the Gaspé Current. The important increase of the relative abundance of larger copepod species during the summer months in the Gaspé Current corresponds to the situation observed in 1979 in the lower St. Lawrence Estuary by Plourde et al. (in prep.). Finally, *Calanus hyperboreus*, *Euchaeta norvegica*, *Microcalanus pusillis*, and *Metridia longa* showed a greater relative abundance in the Anticosti Gyre than in the Gaspé Current while the inverse was true for *Acartia* sp, *C. finmarchicus*, *C. glacialis*, and *Pseudocalanus* sp. (Fig. 6).

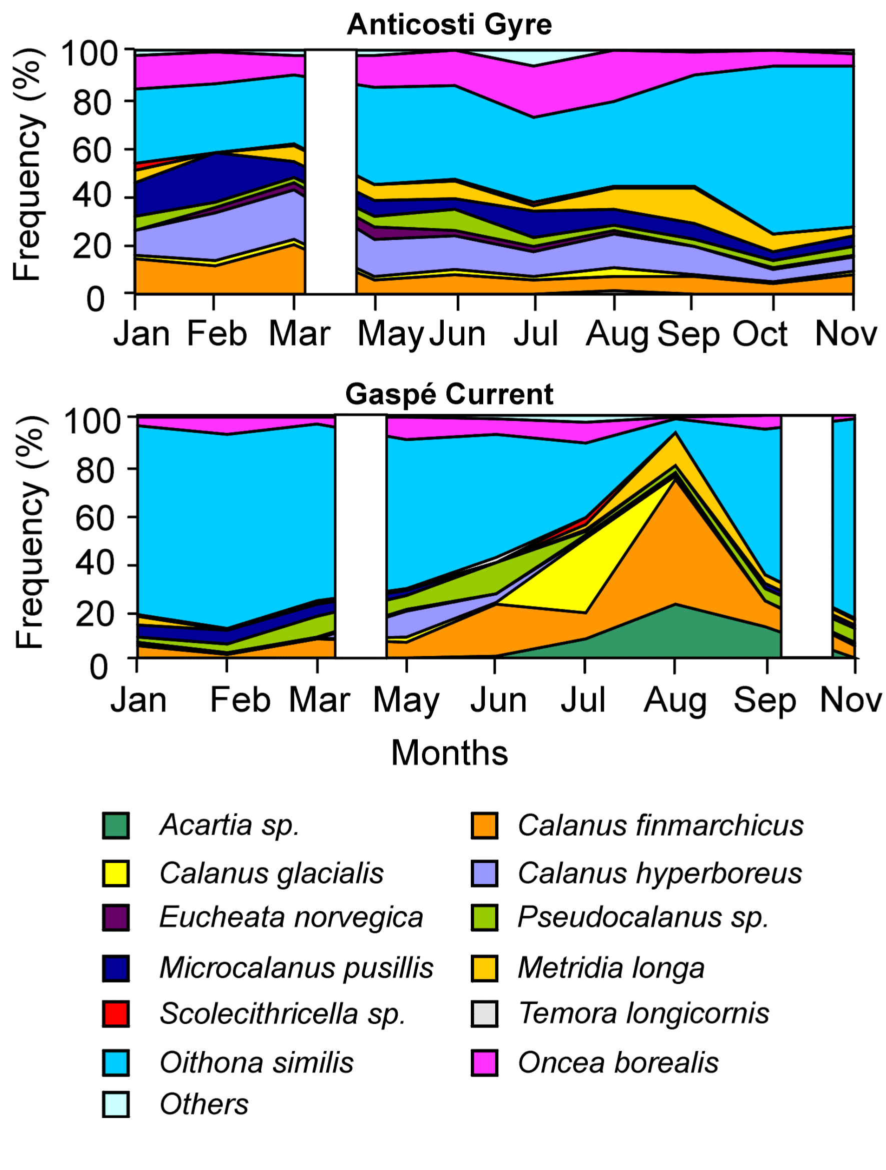

Fig. 6. Monthly variations in composition (% of total abundance) of the copepod community at the two fixed stations of the AZMP in 1999.

Proposed indices describing the state of the zooplankton community at each station in 1999

1. *Monthly variations of the zooplankton biomass*

In 1999, the total zooplankton biomass varied between 103 and 228 g ww · m-2 at the Anticosti Gyre station and between 9 and 83 g ww · m-2 at the Gaspé Current station (Figure 9). The maximum and the minimum biomass occurred in March and May respectively at the Anticosti Gyre station while the minimum and the maximum biomass were observed in February and May respectively in the Gaspé Current. The mean biomass for 1999 was 4 times higher in the Anticosti Gyre (146.2 ± 34.4 g ww · m-2) than in the Gaspé Current (37.7 ± 22.4 g ww · m-2). The higher biomass at the Anticosti Gyre station was largely due to the higher abundance of Calanus hyperboreus as well as to the greater depth of this station (337 m versus 165 m) (Fig. 7).

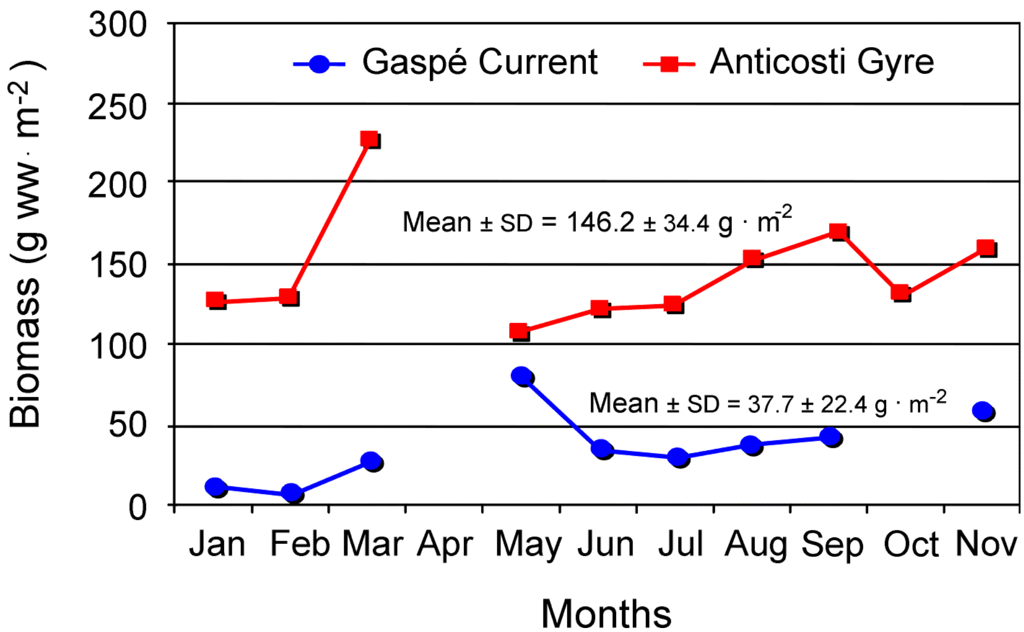

Fig. 7. Monthly variations (and annual statistics) of the zooplankton biomass in 1999.

2. *Monthly variations of the integrated copepod abundance*

The abundance of copepod eggs integrated over the water column varied between 29,000 and 139,000 eggs · m^{-2} in the Anticosti Gyre and between 800 and 94,000 eggs · m^{-2} in the Gaspé Current (Fig. 8). Copepods eggs were present at all sampling dates at both stations; the maximum abundance occurred in June and May in the Anticosti Gyre and the Gaspé Current respectively. This period coincides with the reproductive period of most of the copepod species found in the Gulf of St. Lawrence except for *Calanus hyperboreus*. The mean abundance for the whole year was 1.5 times higher in the Anticosti Gyre (58,400 eggs · m^{-2}) than in the Gaspé Current (39,300 eggs · m^{-2}).

Likewise, the depth-integrated abundance of copepod nauplii varied between 17,000 and 510,000 ind. · m^{-2} in the Anticosti Gyre and between 500 and 233,000 ind. · m^{-2} in the Gaspé Current (Fig. 8). There were two peaks of abundance of copepod nauplii at the Anticosti Gyre station. The first one occurred in February and coincided with the reproductive period of *Calanus hyperboreus*, which reproduces during winter, while the second peak occurred in June and coincided with the reproductive period of most other copepod species. At the Gaspé Current station, the first peak of abundance of copepod nauplii occurred in March, one month later than in the Anticosti Gyre, and the second in September, three months later than in the gyre. The mean abundances for the whole year were equal to 129,000 and 67,000 ind. · m^{-2} in the Anticosti Gyre and the Gaspé Current respectively.

Finally, the depth-integrated total abundance of juveniles (copepodites CI-CV) and adults copepods varied between 76,000 and 534,000 ind. · m^{-2} in the Anticosti Gyre and between 56,000 and 377,000 ind. · m^{-2} in the Gaspé Current (Fig. 8). At the Anticosti Gyre station, the minimum and the maximum abundance occurred in spring (April–May) and fall (August–November) respectively while at the Gaspé Current station the minimum and the maximum abundance occurred in summer (July–August) and fall (September–November) respectively. The mean abundance for the whole year was 1.5 times higher in the Anticosti Gyre (228,000 ind. m^{-2}) than in the Gaspé Current (156,000 ind. · m^{-2}).

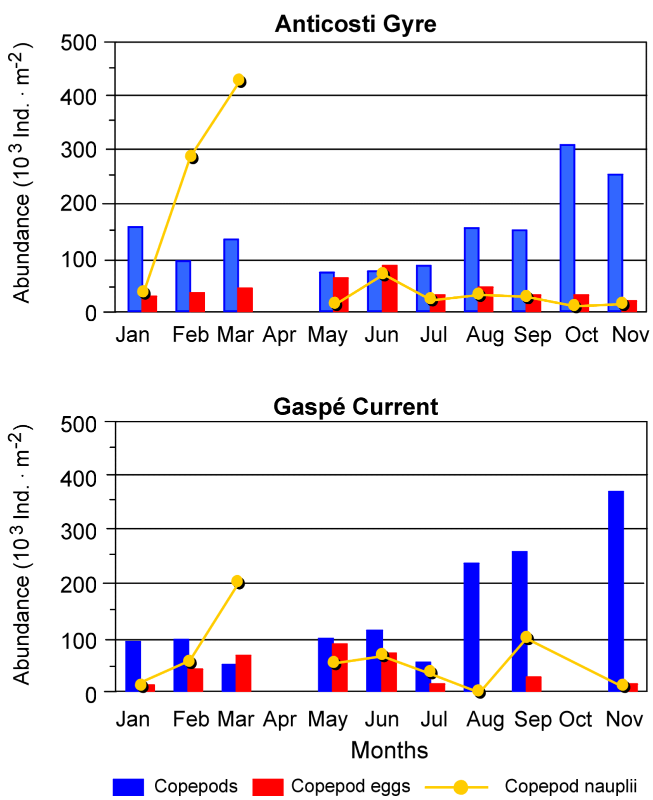

Fig. 8. Monthly variations of the integrated copepod abundance.

3. *Monthly variations of the total abundance of Calanus species*

The rational behind the choice of this index is that the three *Calanus* species (*C. finmarchicus, C. glacialis, C. hyperboreus*) found in the Estuary and the Gulf of St. Lawrence represented ca. 80% of the total zooplankton biomass. Any important change in the total zooplankton biomass observed in the future should also correspond to a similar change in the abundance of one or more of these species. This will permit us to interpret the change in biomass as a function of the environmental variables by using our knowledge of the ecology of each species.

In 1999, the total abundance varied between 17,359 and 69,889 ind. · m^{-2} at the Anticosti Gyre station and between 1717 and 32,318 ind. · m^{-2} at the Gaspé Current station (Fig. 9). The minimum and the maximum abundance of *Calanus* were observed in May and October respectively in the Anticosti Gyre and in February and August in the Gaspé Current. The mean abundance of *Calanus* for the whole year was 2.7 times higher in the Anticosti Gyre (45,300 ind. · m^{-2}) than in the Gaspé Current (16,800 ind. · m^{-2}). The monthly pattern of variation for this index roughly corresponds to the monthly pattern for the total zooplankton biomass (Fig. 9) as previously suggested.

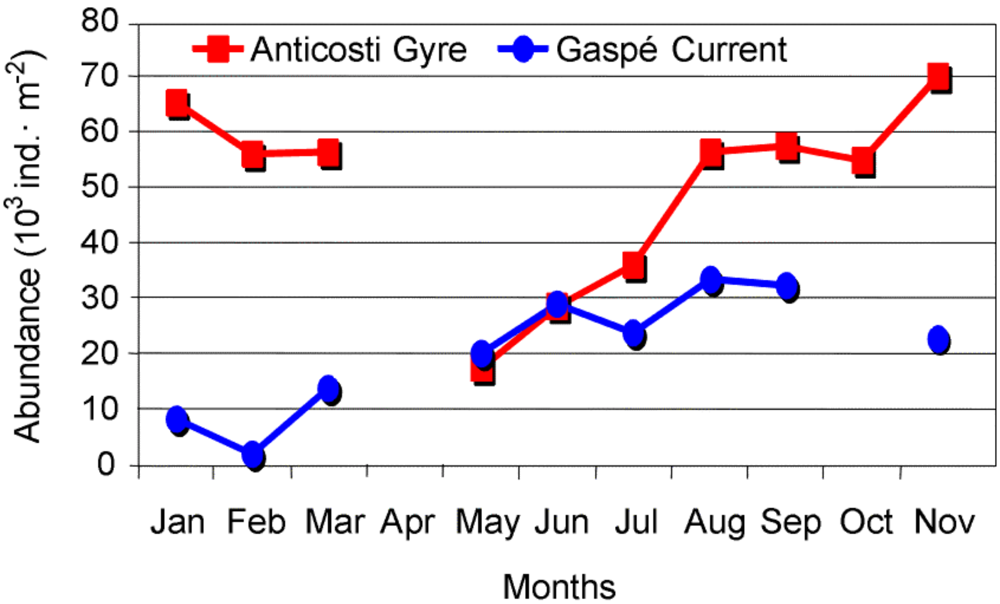

Fig. 9. Monthly variations of the total abundance of *Calanus* species.

4. *Monthly variations of the total abundance of Metridia longa.*

The abundance of this species was chosen as an index because of its arctic origin. We believe that, because this species is well adapted to live in a very cold environment, its abundance will change quickly as a function of changes in the environmental conditions in the Estuary and the Gulf of St. Lawrence, mostly the seawater temperature.

In 1999, the total abundance of *Metridia longa* varied between 5,125 and 43,945 ind. · m^{-2} at the Anticosti Gyre station and between 933 and 10,844 ind. · m^{-2} at the Gaspé Current station (Fig. 10). The minimum and the maximum abundance of *M. longa* were observed in February and September respectively for both stations. The mean abundance of *M. longa* for 1999 was 4.3 times higher in the Anticosti Gyre (13,900 ind. · m^{-2}) than in the Gaspé Current (3200 ind. · m^{-2}).

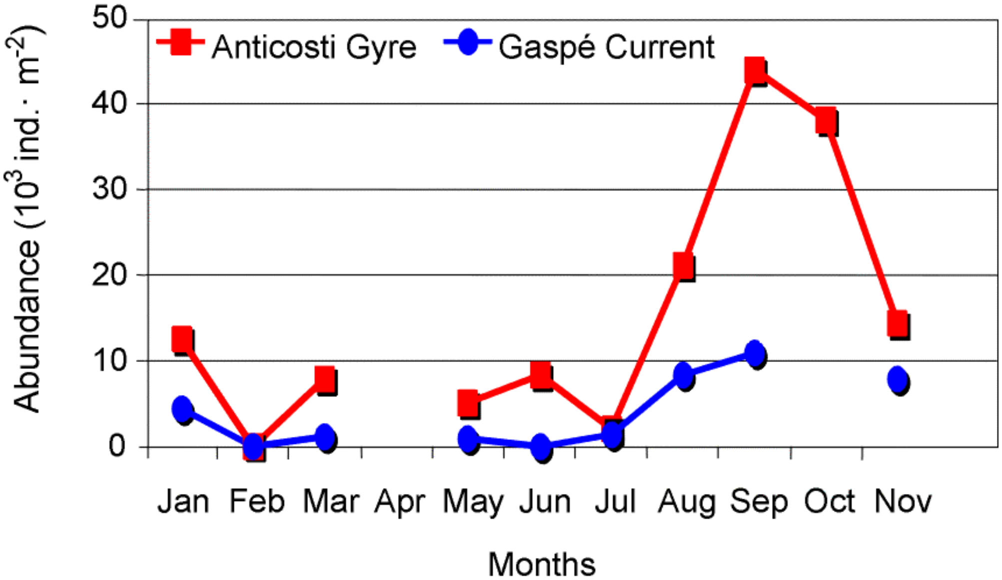

Fig. 10. Monthly variations of the total abundance of *Metridia longa.*

5. *Monthly variations of the total number of species (q)*

The number of species (q) is the index of diversity most often used in ecology (Legendre and Legendre, 1998). Because it is more sensitive to the presence of rare species than higher-order indices, we believe that this index could be useful to detect any changes in the zooplankton community structure due to changes of the environmental conditions within the Gulf of St. Lawrence.

In 1999, the total number of species varied between 33 and 42 at the Anticosti Gyre station and between 23 and 31 species at the Gaspé Current station (Fig. 11). The maximum and the minimum number of species were observed in January and February respectively in the Anticosti Gyre and in November and March in the Gaspé Current. The mean total number of species for the whole year was 36 in the Anticosti Gyre and 29 in the Gaspé Current (Fig. 11).

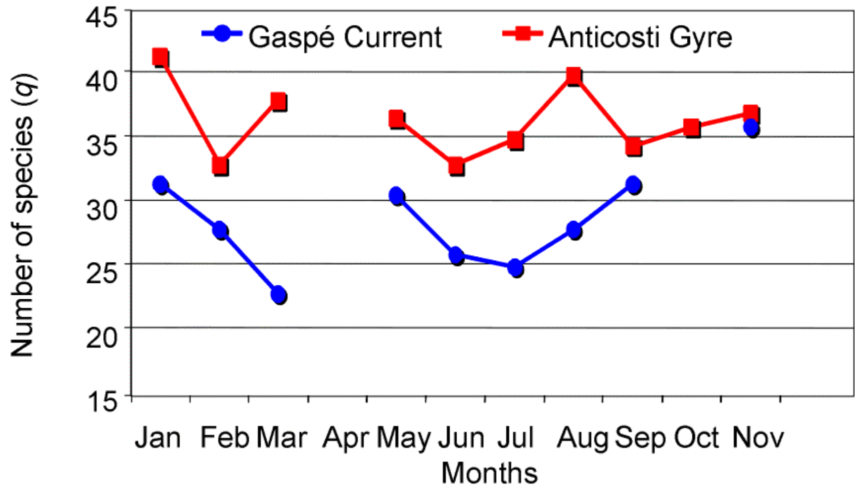

Fig. 11. Monthly variations of the total number of species.

6. *Monthly variations of the Shannon-Wiener Diversity index (H´)*

The Shannon-Wiener Diversity index (H´) may be defined as a measure of species composition, both in terms of the number of species and their relative abundances. It is a synthetic biotic index that captures multidimensional information relative to the species composition of a community.

In 1999, H´ varied between 0.68 and 1.28 at the Anticosti Gyre station and between 0.64 and 0.96 at the Gaspé Current station (Fig. 12). The minimum and the maximum diversities were observed in March and August respectively in the Anticosti Gyre and in November and September in the Gaspé Current. The mean annual diversity was 1.04 in the Anticosti Gyre and 0.86 in the Gaspé Current (Fig. 12).

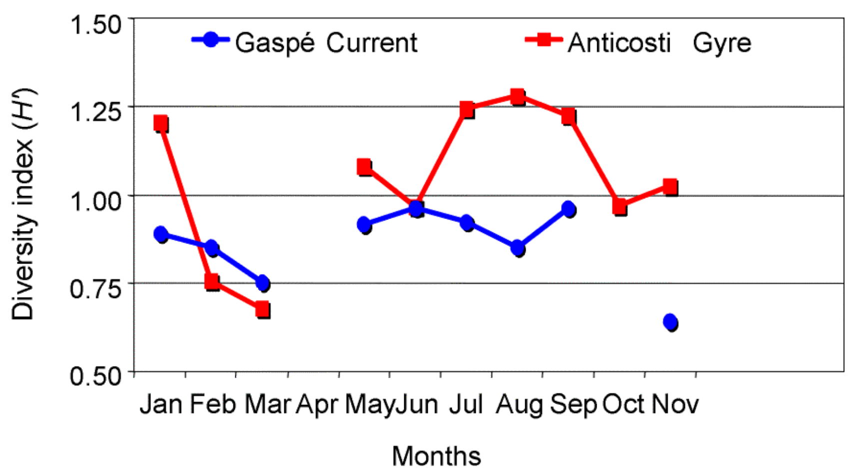

Fig.12. Monthly variations of the Shannon-Wiener Diversity index (H´).

Conclusion

In summary, copepods were clearly dominant at all sampling dates in 1999, accounting for more than 80% of the zooplankton community in the Anticosti Gyre and the Gaspé Current. Small copepods (*Oithona similis, Oncea borealis*) were dominant in abundance at all sampling dates at both stations except in the Gaspé Current in July and August, where larger species (*Calanus finmarchicus, C. glacialis, Metridia longa*) were more abundant. Total zooplankton biomass was much higher in the Anticosti Gyre than in the Gaspé Current for all seasons in 1999 except in May, when the biomass was equal at both stations. The integrated copepod abundance showed the same pattern of variations with season at both stations, with a maximum abundance of copepod eggs in spring and a maximum abundance of adult copepods and copepodite stages (CI-CV) in late fall. The total integrated abundance of adult copepods and copepodite stages (CI-CV) did not vary significantly between stations for all seasons. Finally, all proposed indices varied with season and their annual mean values varied between stations, but it is too soon to say if they will be useful to describe the interannual variability of the zooplankton community and to detect any changes of the environmental conditions.

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