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Decadal Time-Series of Invertebrate Zooplankton on the Newfoundland Shelf and Grand Banks 1991 – 1999

Série chronologique décennale de l'abondance du zooplancton invertébré sur la plate-forme de Terre-Neuve et les Grands bancs (1991 – 1999)

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Abstract

The invertebrate zooplankton of the Northeast Newfoundland shelf and Grand Banks was dominated by copepods that comprised over 80% of all the plankton. All zooplankton was low in abundance during the early part of the decade and peaked from 1997 to 1999, coincident with increased nekton abundance. The lower abundances of some smaller species, e.g. *O. similis,* are negatively biased in the early years by use of a larger mesh (.505 mm). However, even larger zooplankton whose catch should not be biased by mesh size, e.g. larger stages of *C. finmarchicus*, *C. hyperboreus*, chaetognaths amphipods, and euphausids, were all low in abundance in the early 90's. The most abundant copepod species were *O. similis*, followed by *Pseudocalanus sp*., *C. finmarchicus*, *T. longicornis*, and *C. hamatus,* all of which peaked in abundance from 1997-99. In terms of biomass the most dominant copepod was *C. finmarchicus*, which peaked in 1999. Although *C. hyperboreus* was relatively low in numbers compared to other copepods, its biomass, which peaked in 1994, was also significant due to its large individual size. Biomass of *Oithona* peaked in 1997, *Temora* in 1999. Cladocerans were the dominant other zooplankton peaking in 1997 followed by *Limacina* which peaked in 1996 and bivalve larvae which peaked in 1999. The ability of the 2 central or 4 more widespread lines to estimate mean abundance varied with species or group but generally was not reliable as an estimator of overall mean abundance due to relatively wide distributions. This type of pelagic survey with simultaneous sampling of invertebrate plankton and nekton, which is comprised mainly of planktivorous fish, offers potential in elucidating links between the annual productivity cycle and fish recruitment.

Résumé

Les copépodes représentaient 80 % du zooplancton des Grands Bancs et du nord-ouest de la plate-forme de Terre-Neuve. Faible durant la première partie de la décennie, l'abondance du zooplancton a atteint un sommet de 1997 à 1999, en même temps que le necton présentait une abondance accrue. Durant les premières années, l'abondance de certaines petites espèces (p. ex., *O. similis*) était biaisée négativement parce que des filets aux mailles plus grandes (0,505 mm) étaient alors utilisés. Toutefois, même les espèces de zooplancton de grande taille dont la capture ne devrait pas être biaisée par le maillage (p. ex., les plus grands stades de *C. finmarchicus*, de *C. hyperboreus*, de chétognathes, d'amphipodes et d'euphausiacés) étaient tous peu abondants au début des années 1990. L'espèce de copépode la plus abondante était *O. similis*, suivie de *Pseudocalanus*, de *C. finmarchicus*, de *T. longicornis* et de *C. hamatus*. L'abondance de toutes ces espèces était maximale de 1997 à 1999. En terme de biomasse, le copépode dominant était *C. finmarchicus*, dont la biomasse a atteint un sommet en 1999. Bien que le nombre de *C. hyperboreus* était faible par rapport à l'abondance des autres copépodes, sa biomasse, qui a atteint un sommet en 1994, était aussi importante en raison de sa grande taille. La biomasse de *Oithona* a atteint un sommet en 1997, et celle de *Temora*, en 1999. Les cladocères, dont l'abondance était maximale en 1997, constituaient l'autre groupe de zooplancton dominant, suivis de *Limacina* (maximum en 1996) et des larves de bivalves

(maximum en 1999). La capacité d’estimer l’abondance globale moyenne à l’aide de deux transects centraux ou de quatre transects plus étendus variait selon l’espèce ou le groupe et, en raison de répartitions relativement larges, n’était généralement pas fiable. Ce type de relevé pélagique comportant l’échantillonnage simultané du plancton invertébré et du necton (surtout composé de poissons planctivores) offre la possibilité de déterminer les liens entre le cycle de productivité annuel et le recrutement des poissons.

Introduction

The past decade has been characterized by extreme oceanographic conditions in the Newfoundland area (record low temperatures in the earlier years) followed by a warming trend (Colbourne 2000). There was a collapse of major groundfish stocks (Lilly et al. 2000) and increases in abundance of crab (Dawe et al. 2000) and shrimp (Orr et al. 2001). There have also been coincident dramatic changes in capelin biology (Carscadden 2001).

All of these marine resources spend at least part of their life cycle as pelagic larval or juvenile planktivores in the pelagic environment. Capelin and other dominant planktivores, e.g. Arctic cod and sand launce, may be pelagic at any time during their life cycle, whereas a large constituent of the nekton consists of ephemeral pelagic juveniles of commercial (and non- commercial) fish species, which are also planktivores. Abundance of several species of these pelagic juveniles has increased in the area during the second half of the decade (Dalley et al. 2000).

Since most of the fish biomass in the pelagic ecosystem is planktivorous , the invertebrate zooplankton community, and changes in it, over the past decade are important in understanding relationships between success of pre-recruits and plankton production as their food source. During pelagic surveys carried out from 1994 to 1999 (Dalley et al. 2000), larval capelin (and snow crab in 1999) abundance was estimated from plankton subsamples at sea. Dry weight biomass of small, mid-size and larger mesozooplankton size fractions was determined, and an increase in biomass since 1994 has been noted (Dalley et al. 2000). However, the invertebrate zooplankton community structure and annual variation in it has not been documented from these surveys.

In this document we present a preliminary description of annual and geographic variation in the mesozooplankton community during the pelagic surveys. Data is reported from a small set of stations for 1991-1999 and a larger set from 1994 – 1999 covering a larger geographic area. We report on the densities of snow crab larvae over both time series and the geographic distribution of larvae from all stations in 1994 and 1997. Distribution of crab larvae from the 1999 pelagic survey was presented in Dalley et al. (2000).

Methods and Materials

The two ship pelagic surveys were carried out during late summer for six years 1994-1999. A smaller area in the central portion of this large area was sampled back to 1991 (Figure 1), although mesh sizes were coarser (Table 1). A description of the design and methods used in the surveys is contained in Dalley et al. (2000). Although funding did not allow full ‘zoo’ or ‘ichthio’ plankton sorting, aboard ship sub-sampling allowed estimates of capelin larvae and crab in 1999. The remaining samples were archived. Through support from Canada’s Ocean Climate Fund a portion of the samples have been selected and zooplankton community structure, total abundance of dominant zooplankton at 10 stations from 1991 – 1999 (Figure 1a), and at 24 – 26 stations over a larger geographic area (north and south) from 1994 to 1999 (Figure 1b). Geographic distribution of invertebrate zooplankton was examined for 1994 and 1997 surveys when samples from all stations were examined (Figure 2).

The sorting, identification and enumeration was carried out through a contract with Sprytech Biological Services. The terms of reference required all zooplankton to be separated into major groupings e.g. amphipods, bivalves, chaetognaths, cladocerans, pteropods, etc. and identified to species where possible. Copepods were identified to species and developmental stages of major *Calanus* species identified and enumerated.

Biomass of dominant copepods was estimated using average mean weights at developmental stages according to Tremblay (1981). Of the major copepods *C. finmarchicus* and *C. hyperboreus* were staged and a mean weight at each stage is used to calculate biomass. For the remaining species a mean value for late stage copepodids is used in the calculation. In the calculation of biomass only one time series was used. This used mean abundances from the 2 lines from 1991 to 1993 and mean abundances of the 4 biomonitoring lines in subsequent years.

Results

A rich variety of invertebrate plankton was sampled during the pelagic surveys. A taxonomic breakdown of all zooplankton collected is listed in Table 2.

Numerically copepods dominated the zooplankton community (Figure 3, top and bottom)). On average they constituted 84.9% (range = 72.6% - 94.3%) of all zooplankton in the 9-year time series (2 transect lines), and 82.6% (range = 74.3% - 89.9%) in the six-year series (4 transect lines). From 1991 to 1994 abundance of all zooplankton was low in both series in comparison to the later years. There was an initial increase in 1995 followed by a sharp increase each of the next two years, with a peak in 1997. There was a slight decrease in 1998, increasing again in 1999. (Figure 3, top).

The trends in zooplankton abundance using the 4 lines from 1994-99 (Figure 3, bottom) are similar to those from the longer times series (Figure 3, top). Both time series illustrate that the trends in abundance, of copepods and other zooplankton were similar. Both had peaks in numbers in 1997 and 1999 and abundance in all 4 recent years was higher than earlier years.

In 1997, when abundance was high, density of copepods (all species combined) was highest at stations over the central portion of the Northeast Newfoundland Shelf, the northern Grand Bank, the southwest portion of the Grand Bank and at stations inshore (Figure 4, right). In 1994, when abundance was relatively low (an order of magnitude less than 1997) copepods appeared more evenly distributed and in contrast to 1997 highest densities occurred in the most northern stations with relatively low densities on the Grand Bank. Stations in the inshore had relatively high densities in both years.

Highest concentrations of other zooplankton (Figure 5, left) also occurred to the north, and in White and Notre Dame Bay in 1994. In 1997, when mean abundance was higher, highest densities occurred on the western portion of the Grand Bank and south of the Avalon Peninsula of Newfoundland (Figure 5, right). Relatively high concentrations of zooplankton also occurred in the Northeast coast bays.

Of all copepods sampled from all stations, all years, the most abundant was *Oithona similus* constituting 52.6% of all copepods. *Pseudocalanus* sp. constituted 14.2%, *Calanus finmarchicus* 9.8%, unidentified copepods 8.5%, *Temora longicornis* 6.4%, and *Centropages hamatus* 6.2%, while all other species constituted 2.3% of all copepods. Mean abundance of each of these 5 dominant copepods was greater than the highest ranking other zooplankton. The next most abundant copepod (mean of all stations, all years combined) was *Calanus hyperboreus,* although overall its mean abundance was relatively low. Its overall mean abundance was 1,214.3/m2 compared to 14,901.3 for *C. hamatus*, 15,490.7 for *T. longicornis*, 23,345.7/m2 for *C. finmarchicus*, 34,271 for *Pseudocalanus* and 126,641.8/m2 for *O. similus*. A taxonomic breakdown of all copepods sampled during the surveys is also shown in Table 2.

Abundance of the 5 dominant copepods was relatively low at the two lines from 1991 to 1995 (Figure 6, top) which, depending on its size, may be biased due to large (505micron) mesh size in these years. While there was an increase in all species of copepods after 1994 the most dramatic increases were for *Oithona similis*, the most numerous this species which peaked in abundance in 1997. Unlike the other species, *O. similis* decreased in abundance in 1998 and 1999. *C. finmarchicus, Pseudocalanus sp*. and *T. longicornis* all exhibited a trend towards increasing abundance in the most recent years. *Centropages hamatus*, which ranked next in abundance also peaked in abundance in 1997. Trends in abundance of copepods were similar for both time series. In both series there was a general increase in abundance of *C. finmarchicus* since 1994 (Figure 6).

Unlike other copepods, which were low in abundance in 1994, the large *Calanus hyperboreous* was relatively abundant and dropped sharply in 1995. In the 2 line series highest abundance occurred in 1997 whereas using the 4 lines highest abundance occurred in 1996. Using 2 lines there was a drastic decrease in mean abundance from 1997 to 1998 whereas the 4 lines indicated an increase for the same period. Abundance was relatively low using either estimate in 1999 (Figure 7).

For the most part *C. finmarchicus* consisted of older larger copepodite stages C-III to C-V (Table 3). Due to its large size and individual dry weight (Tremblay, 1981) compared to the other species of copepods *C. finmarchicus* was dominant in terms of copepod biomass (Figure 8). Biomass increased from 1991 to 1993, decreased to a minimum biomass in 1994 and increased each year thereafter. Despite the relatively low abundance of *C. hyperboreus* compared to other species it was also significant in terms of copepod biomass, being second to *C. finmarchicus* in most years. Its highest biomass occurred in 1994, minimum in 1991, and relatively high biomass from 1996 to 1998.

Highest biomass of *O. similis* and *C. hamatus* occurred in 1997 while that of *T. longicornis* and *Pseudocalanus sp.* occurred in 1999 (Figure 8).

Trends in abundance of zooplankton, other than copepods, were also similar for the 2 time series (Figure 9). The most numerous non-copepod zooplankton were cladoceans (2+ species of *Evadne* and 1 of *Podon*), and unshelled pteropods (at least 2 species of unshelled pteropods or *Limacina*). Highest densities of *Cladocera* occurred in 1997 whereas that of *Limacina* occurred in 1996. Larvaceans, mostly *Fritillaria* and *Oikopleura,* were relatively abundant and increased to a peak in 1997 after which density decreased in 1998 and 1999. On the other hand bivalve larvae which peaked in abundance in 1996, decreased in 1997, and increased again in the final 2 years having maximum densities in 1999. Although jellyfish of the phylum *Cnidaria* ranked relatively high in terms of abundance compared to most other species they were low in abundance and varied little compared to the 4 preceding groups.

Groups of other, relatively large zooplankton that would not be affected by mesh size, also showed a tendency for increased abundance in recent years (Figure 10). At least 2 species of pelagic juvenile polychaete worms, *Tomopteris sp.* peaked in abundance in 1998, as did arrowworms, which were also relatively high in abundance in 1991. Euphausids were relatively low in abundance in 1996 increasing in 1997 and 1998. There was a further increase in euphausids in 1999 according to the 4 lines. Hyperid amphipods increased in abundance in 1995 over 1994 in both time series. In 1996 amphipods decreased using 2 lines but increased using the 4 lines. Both series indicated an increase in abundance in 1999 over 1998. Mysids which were low in abundance in earlier years, increased in 1998 and again in 1999.

For 1994 and 1997 we can compare abundance estimates of abundance derived from the 2 central and the 4 more widespread lines with those derived from all stations during the 2 years (Table 4). The total abundance of all zooplankton, copepods, and nearly all species and groups was greater (up to 2 orders of magnitude in some) in 1997 than in 1994, whichever mean abundance is used. Only chaetognaths and *C. hyperboreus* were similar in the 2 years. Also of note is the fact that the mean abundance estimates were generally higher, including the all-zooplankton and all-copepod categories, when all stations are used. The large geographic survey area also allows for delineation of extent of distribution of certain northern and southern species or groups during 1994 and 1997.

Estimates of abundance for *C. finmarchicus*, using the lines, were within the range estimated using all the stations (Figure 11). Both sets of lines estimated abundance to be lower than all stations in 1994 whereas the estimate in 1997 was similar to that using the 2 sets of lines. In 1994 highest abundances were found in stations not on the lines whereas in 1997 highest densities were found on the 2 lines (Figure 12).

Estimates of abundance of *C. hyperboreus* were also substantially higher when all the stations were used (Figure 13). C. *hyperboreus*, a northern species, was patchy in distribution and highest abundances during both years were found between, rather than on the lines (Figure 14). Distribution was restricted almost exclusively to the area north of the Grand Banks.

Abundance of *O. similus*, the most abundant copepod during the surveys, was closely estimated by the lines at low abundance in 1994, but underestimated at high abundance in 1997 (Figure 15). The species was distributed throughout the area in both years. There were again large areas of high abundance off the lines, especially on the NE shelf and the southern Grand Bank (Figure 16). Abundances were relatively high at stations on the western grand Bank in 1997.

Pseudocalanus sp., the second most abundant copepod, was also estimated to be lower in abundance using the lines, than using all stations (Figure 17) This was especially true at higher abundances in 1997. In 1997, the lines underestimated abundance due to high densities inshore and in the southwest portion of the survey area (Figure 18). This genus was distributed throughout the area in 1994 and 1997. When abundances were high in 1997 areas of highest density were inshore and the southwestern Grand Banks.

Cladocerans, the most abundant non-copepod zooplankton were closely estimated by both sets of lines at low abundance in 1994 (Figure 19). In 1997 mean abundance was closely approximated by the 4 lines and overestimated by the 2 lines. This is due to the higher than average abundances on the 2 lines in 1997 (Figure 20). As a group, cladocerans were distributed throughout the area. In 1994 several high-density stations occurred sporadically, one in the north, several inshore and on the northern Grand Bank and one on the southern Grand Bank. In 1997 when mean abundance was high, highest densities occurred in the southern portion of the survey area.

Snow crab, which, due to their relatively large size would not be biased by mesh size in the earlier years, increased gradually in abundance from 1991 to 1994 with lower densities in 1995 and 1996. There was a dramatic increase in 1997 followed by a dramatic drop in 1998, followed by another increase in 1999 (Figure 21). Snow crab larvae, which were relatively low in abundance compared to the dominant species were vastly underestimated by either set of lines in both years. Discontinuous distributions with sporadic high catches, and high abundances in areas other than the lines, (Figure 22) attributed to the low estimates of abundance from the lines.

Estimated abundances of *Limacina* sp. were similar using the lines and using all stations in 1994 and slightly higher using all stations in 1997 (Figure 23). Abundance was higher in 1997 compared to 1994, but the peak of abundance occurred in 1996. Distribution of pteropods was discontinuous both years with null catches on the central portion of the Northeast Newfoundland Shelf and the Grand Banks in 1994 (Figure 24). Highest abundances occurred to the north and near the shelf break in 1994 whereas in 1997 highest abundances occurred on the Grand Banks.

Estimates of abundance of large hyperid amphipods were similar using any method (Figure 25) although in 1994 and 1997 abundance was relatively low in comparison to other years. In the case of hyperids, a mostly northern species, highest abundances, which were not on the lines (Figure 26), appear to be compensated by null catches which would lower the estimate.

Discussion

The results demonstrate that over the period of the surveys, 1991- 99, abundance of total zooplankton, was low during the first part of the decade. Abundance increased beginning in 1995 or 1996 and remained high, particularly during the last three years of the surveys from 1997–1999. This result is consistent with the observation that over the same period, 1996 to 1999, there was an increase in total nekton during the same surveys, 1994-99, (Dalley et al. 2000). Most nekton species are juvenile planktivorous fish including Atlantic cod, American plaice, sand lance and redfish, all of which increased in abundance by 1 to 2 orders of magnitude from 1996-7 to 1999. Although most investigators have historically believed that fish recruitment is tied to the timing and magnitude of the annual production cycle, direct causal links have been difficult to establish. A pelagic survey of the type carried out here that simultaneously examines the invertebrate zooplankton community and the nekton community preying upon it provides a unique opportunity to make the links between production and fish recruitment.

Since larger mesh sizes were used in earlier years, abundance of smaller zooplankton must be interpreted with caution. During the 1991 and 1992 surveys 505-micron mesh nets were used which would permit escapement of the smaller zooplankton, particularly earlier life history stages of the smaller copepods as *Oithona* and *Temora*. However, the result here that zooplankton biomass is dominated by *Calanus finmarchicus* is consistent with observations from the Scotian Shelf (McLaren et al. 2001) to Flemish Cap (Anderson 1990). This calanoid copepod dominates in terms of biomass not as much as a function of it large numbers as its large individual size, which is a significant consideration here. Anderson and Warren (1991) found that stages CI and CII of *C. finmarchicus* were under-sampled in a 333-micron mesh, and stages CI-CIII were under-sampled in the 505 mesh. Since time of the pelagic surveys here was late summer and a high proportion of the *C. finmarchicus* were the later larger stages we conclude that undersampling of this dominant copepod would be minimal. It is also worthy of note that other larger zooplankton that would not be under-sampled by the larger mesh were also much more abundant during the more recent years. *C. hyperboreous,* which was restricted to the northern portion of the survey area, was an exception to this and had highs in abundance in 1994, 1996 and 1997

For most species the mean abundance calculated from all stations sampled in 1994 and 1997 indicated that the two or 4 lines were poor estimators of abundance from the large area and in most cases underestimated abundance. This is probably to be expected given the large size of the area and the non-uniformity distributions. This is particularly true of a species like crab, which although it has a wide distribution has abundance estimates that are driven by one or two very large catches.

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Table 1. Summary of pelagic surveys conducted from 1991 to 1999 indicating the dates of surveys, number of bongo samples collected each year and the mesh size used. DoY refers to calendar day for start, end and midday of each survey.

Year	Ship-Trip	Dates	DoY Start	DoY End	DoY Mid	Number of sets	Mesh size
1991	DAWS 046	11 Oct.-22 Oct.	281	296	289	86	505
1992	TEM127	30 Sept.-15 Oct.	274	289	281	54	505
1993	TEM 143	27 Sept.-20 Oct.	270	293	281	87	333
1994	TEM 157/GAD 247	22 Aug.-3 Sept.	234	246	241	99	333
1995	TEM 175/TEL 018	5 Sept.-22 Sept.	248	264	257	139	333
1996	TEM 193/TEL 034	19 Aug.-6 Sept.	231	249	241	147	232
1997	TEM 210/TEL 050	11 Aug.-29 Aug.	233	241	233	148	232
1998	TEM 226/TEL 069	24 Aug.-10 Sept.	236	253	244	132	232
1999	TEM 242/TEL 081	23 Aug.-19 Sept.	234	261	248	127	232

Table 2 A list of taxonomic groupings for invertebrate zooplankton collected during pelagic surveys carried out in the Newfoundland region, 1991-1999.

Phylum: Coelenterata
- **Class: Hydrozoa**
  - *Aglantha digitale*
  - *Cyanea capillata*

Phylum: Ctenophora

Phylum: Chaetognatha
- *Eukrohnia hamata*
- *Sagitta elegans*
- *S. maxima*
- *S. sp.*

Phylum: Mollusca
- **Class: Gastropoda**
  - *Limacina helicina*
  - *L. retroversa*
  - *L. sp*
  - *Clione limacina*
- **Class: Bivalvia**
- **Class: Cephalopoda**
  - *Illex illecebrosus*
  - *Loligo pealii*

Phylum: Annelida
- **Class: Polychaeta**
  - *Tomopteris*
  - *T. helgolandica*
  - *T. septentrionalis*

Phylum: Arthropoda
- **Class: Crustacea**
  - **Order: Cladocera**
    - *Evadne nordmanni*
    - *E. spinifera*
    - *E. sp.*
    - *Podon leuckarti*
    - *P. sp.*
  - **Subclass: Ostracoda**
    - *Conchoecia sp.*
  - **Subclass: Copepoda**
    - Calanoida
      - *Acartia danae*
      - *Acartia longiremis*
      - *Acartia sp.*
      - *Anomalocera patersoni*
      - *Calanus finmarchicus*
      - *Calanus glacialis*
      - *Calanus hyperboreus*
      - *Centropages hamatus*
      - *Centropages minor*
      - *Centropages sp.*
      - *Centropages typicus*
      - *Clausocalanus sp.*
      - *Euchaeta norvegica*
      - *Eurytemora herdmanni*
      - *Eurytemora sp.*
      - *Heterorhabdus norvegicus*
      - *Mecynocera clausi*
      - *Metridia longa*
      - *Metridia lucens*
      - *Microcalanus sp.*
      - *Paracalanus*
      - *Paracalanus sp*
      - *Pseudocalanus sp*
      - *Scolecithricella minor*
      - *Scolecithricella ovata*
      - *Scolicithrix danae*
      - *Spinocalanus sp*
      - *Temora longicornis*
    - Cyclopoida
      - *Oithona atlantica*
      - *Oithona similis*
      - *Oithona sp*
      - *Oncaea borealis*
      - *Oncaea conifera*
      - *Oncaea sp*
    - Harpacticoida
      - Harpacticoid
      - *Microsetella norvegica*
  - **Subclass: Cirripedia**
    - *Balanus sp.*
  - **Subclass: Malacostraca**
    - **Order: Mysidacea (mysids))**
    - **Order: Cumacea**
    - **Order: Amphipoda**
      - **Suborder: Gammaridae**
      - **Suborder: Hyperidae**
      - *Parathemisto abyssorum*
      - *P. gracilipes*
      - *P. libellula*
      - *P. sp.*
    - **Order: Euphausiacea**
      - *Meganyctiphane norvegica*
      - *Thysanoessa longicaudata*
      - *T. raschii*
    - **Order: Decapoda**
      - *Eulas fabricii*
      - *Spirontocaris spinus*
      - *Pandalus borealis*
      - *P. montaguii*
      - *Chionoectes opilio*
      - *Hyas sp.*

Phylum: Echinodermata

Phylum: Chordata
- **Class: Thaliacea**
- **Class: Larvacea**
  - *Fritillaria*
  - *Oikopleura sp.*

Table 3. Annual percentages of *Calanus finmarchicus* at each developmental stage, used in the estimation of biomass each year of the pelagic surveys, 1991-1999.

	Life Stage						
Year	C1	C2	C3	C4	C5	Female	Male
1991			18.8	41.6	34.6	1.1	3.9
1992		0.1	9.6	46.1	37.3	6.1	0.9
1993	0.3	5.7	33.5	37.5	19.8	3.1	0.2
1994	0.3	7	28.8	36.4	17.1	3.7	6.6
1995	0.1	6.5	37	39.6	15.7	1	0.1
1996	2.2	21.5	29.7	26.2	15.5	2.3	2.7
1997	3.8	10.1	29.7	31.1	18.2	2.4	4.8
1998	5.9	13.9	26.8	30.8	18.8	1.7	2.1
1999	9.4	11.9	21.2	30.9	23.1	2.8	0.7

Table 4. Summary of mean abundance estimates of 20 invertebrate zooplankton taxa using stations positioned on the two central and four biomomitoring lines for the 1994 and 1997 pelagic surveys.

	Mean Abundance Estimate					
	1994			1997		
Taxon	2-line(10)	4-line(26)	All-(98)	2-line(10)	4-line(26)	All-(147)
All Zooplankton	125.45	143	490.45	4561.34	3773.7	6213.22
Copepods	110.1	125.74	433.52	3567.26	3046.47	5390.22
Other Zoo	15.35	17.26	56.93	994.08	727.23	823.19
O. similis	1.52	2	13.41	1931.51	1649.57	3084.44
Pseudocalanus	10.34	10.46	59.94	540.26	385.82	736.07
C. finmarchicus	40.3	189.11	181.06	442.48	271.08	300.42
C. hyperboreus	7.03	7.4	16.79	8.99	6.86	17.2
T. longicornis	34.78	307.2	61.78	28.52	74.34	282.12
C. hamatus	6.2	13.5	51.4	4.8	183.8	419.2
Copsbc	8.25	40.13	30.77	454.1	389.25	472.21
Cladocerans	4.48	37.2	19.34	534.97	312.5	321.16
Limacina	4.21	27.73	4.87	213.06	154.21	189.03
Bivalve Larvae	0	0.35	0.1	8.14	25.99	71.09
Larvaveans	1.14	13.51	11.89	212.37	132.11	140.56
Cnidaria	0	0.9	4.26	1.39	14.75	14.34
Tomopterus	0.01	2.21	1.25	6.45	12.2	26.5
Chaetognaths	0.55	6.4	7.57	5.84	4.72	8.97
Hyperids	0.28	6.58	0.94	0.08	1.01	1.32
Euphausids	1.09	6.4	1.47	10.36	5.56	11.5
Mysids	0.12	1.16	0.3	0	0	0.52
Snow Crab	0.07	1.42	0.74	1.21	0.7	3.46

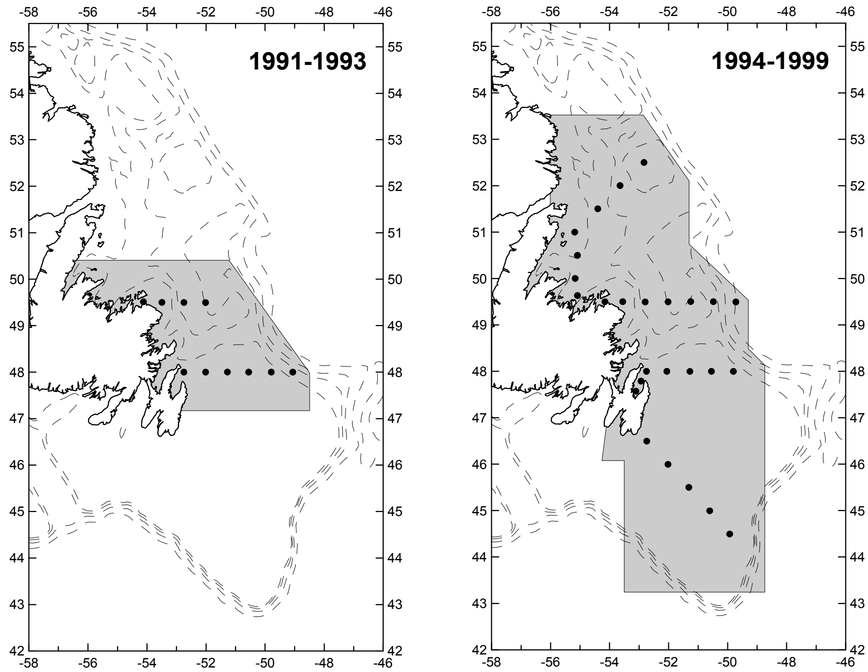


Figure 1. Map showing positions of stations on 2 central lines and 4 more widespread lines that were examined for invertebrate zooplankton from 1991 to 1999. The shaded portions indicate the approximate area of the pelagic surveys for the years indicated.

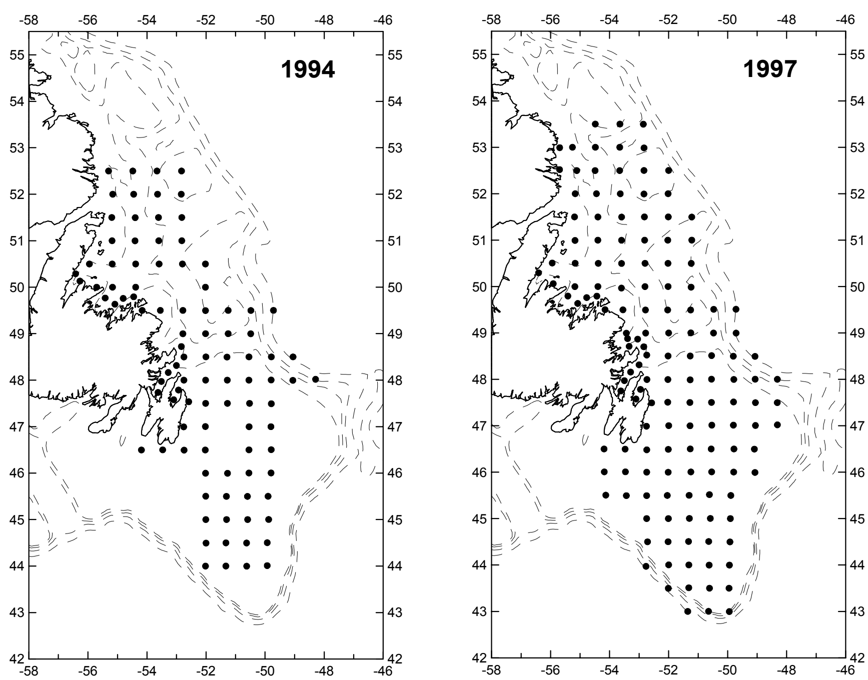


Figure 2. Map showing positions of all stations that were examined for invertebrate zooplankton during the 1994 and 1997 pelagic surveys.

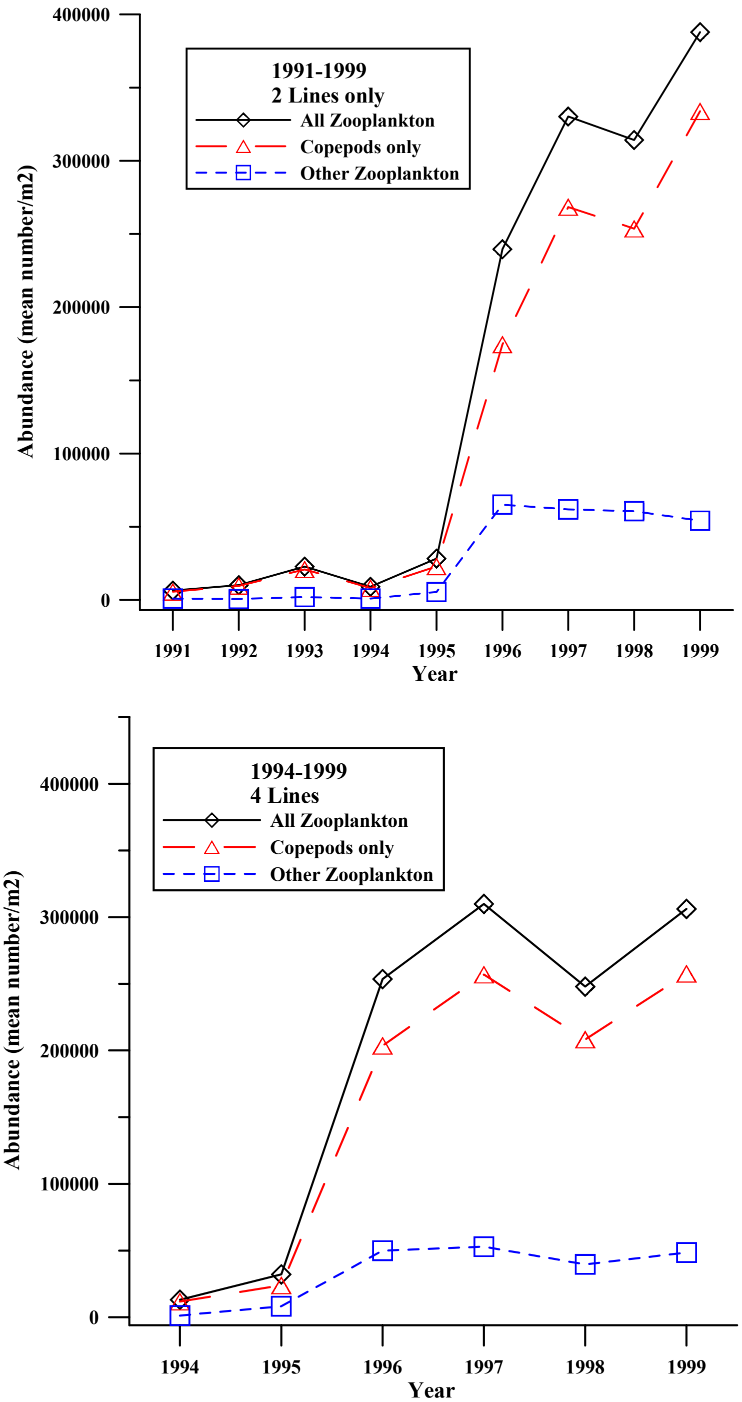


Figure 3. Estimated mean abundance of all zooplankton, copepods only, and all zooplankton except copepods, using two central lines over nine years (top) and 4 lines over 6 years (bottom) derived from pelagic surveys carried out from 1991 to 1999 in the Newfoundland region.

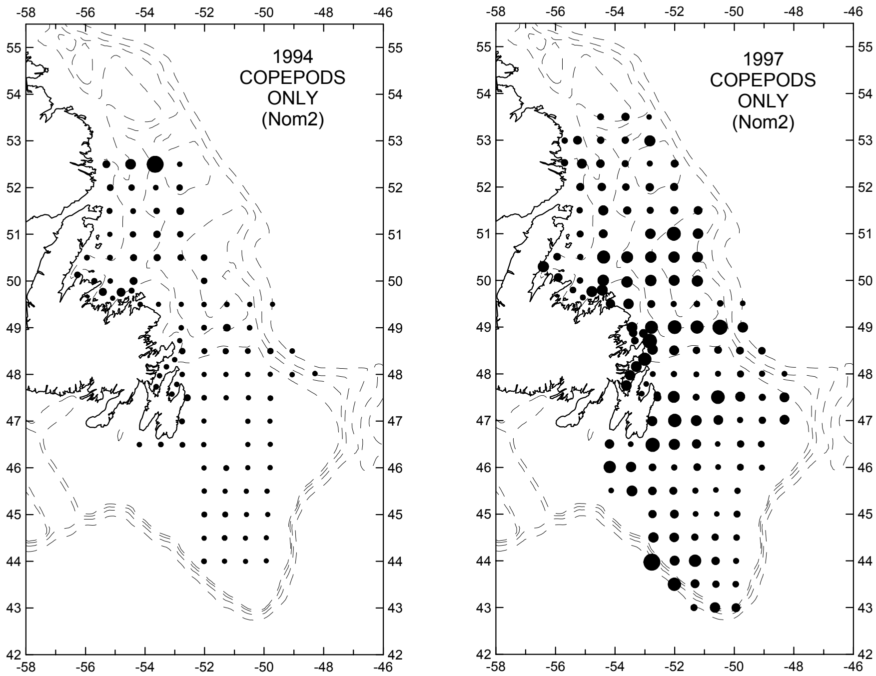


Figure 4. Distribution all copepod species combined of determined from all stations occupied during pelagic surveys carried out in Newfoundland region in 1994 and 1997.

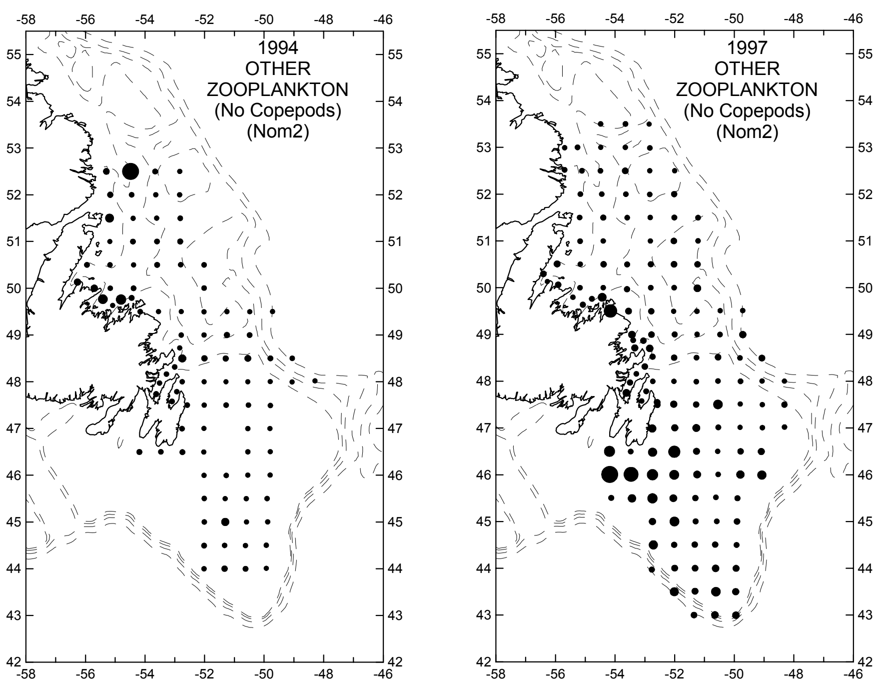


Figure 5. Distribution of all zooplankton species (excluding copepods) combined, determined from all stations occupied during pelagic surveys carried out in Newfoundland region in 1994 and 1997.

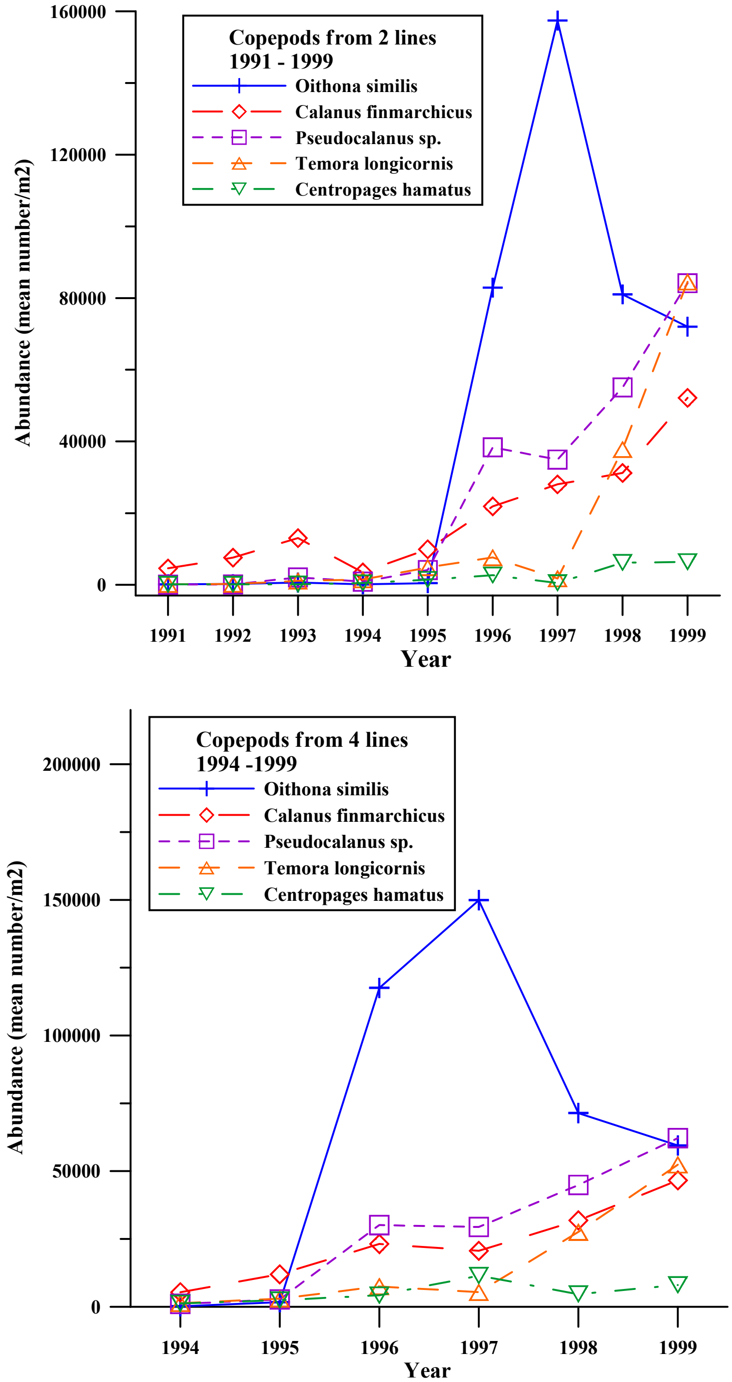


Figure 6. Estimated mean abundance of numerically dominant copepods, using two central lines over nine years (top) and 4 lines over 6 years (bottom) derived from pelagic surveys carried out from 1991 to 1999 in the Newfoundland region.

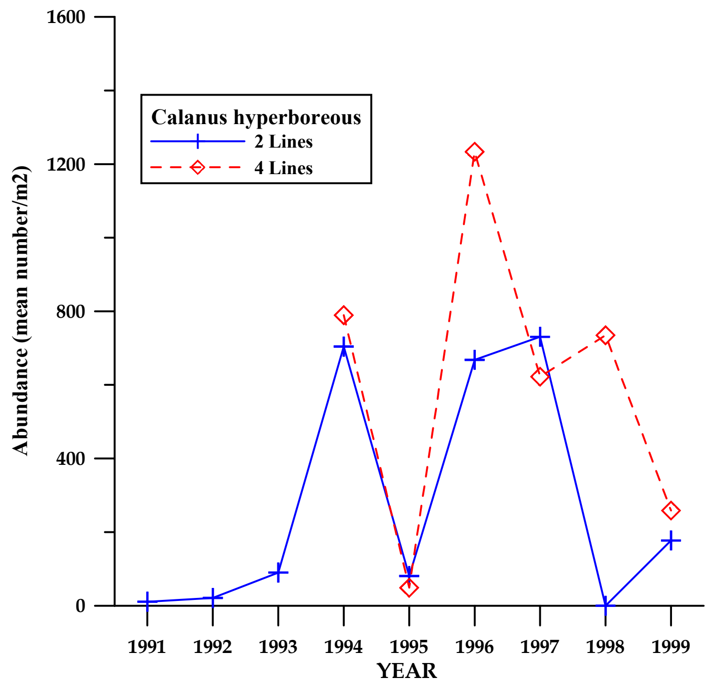


Figure 7. Estimated mean abundance of Calanus hyperboreus using two central lines over nine years (top) and 4 biomonitoring lines over 6 years (bottom) derived from pelagic surveys carried out from 1991 to 1999 in the Newfoundland region.

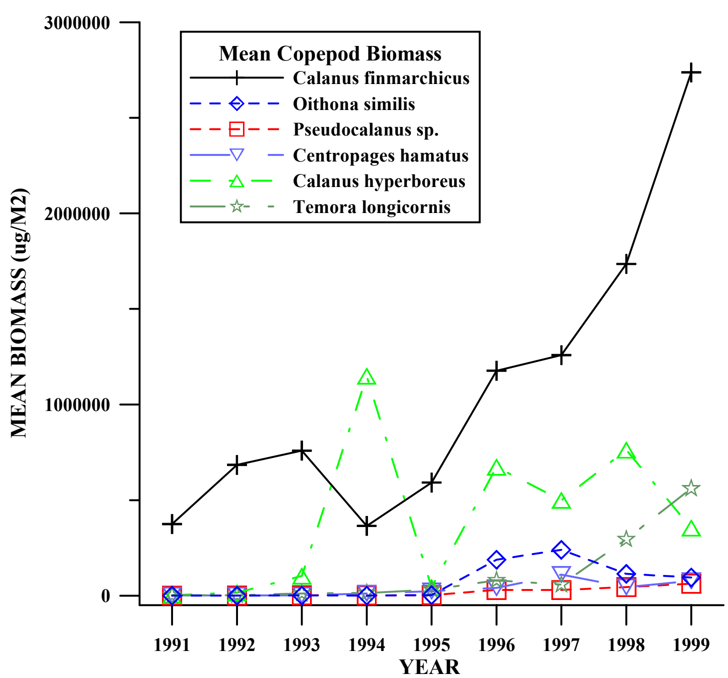


Figure 8. Estimated mean biomass for numerically dominant copepods and C. hyperboreus from pelagic surveys carried out in the Newfoundland Region, 1991-1999.

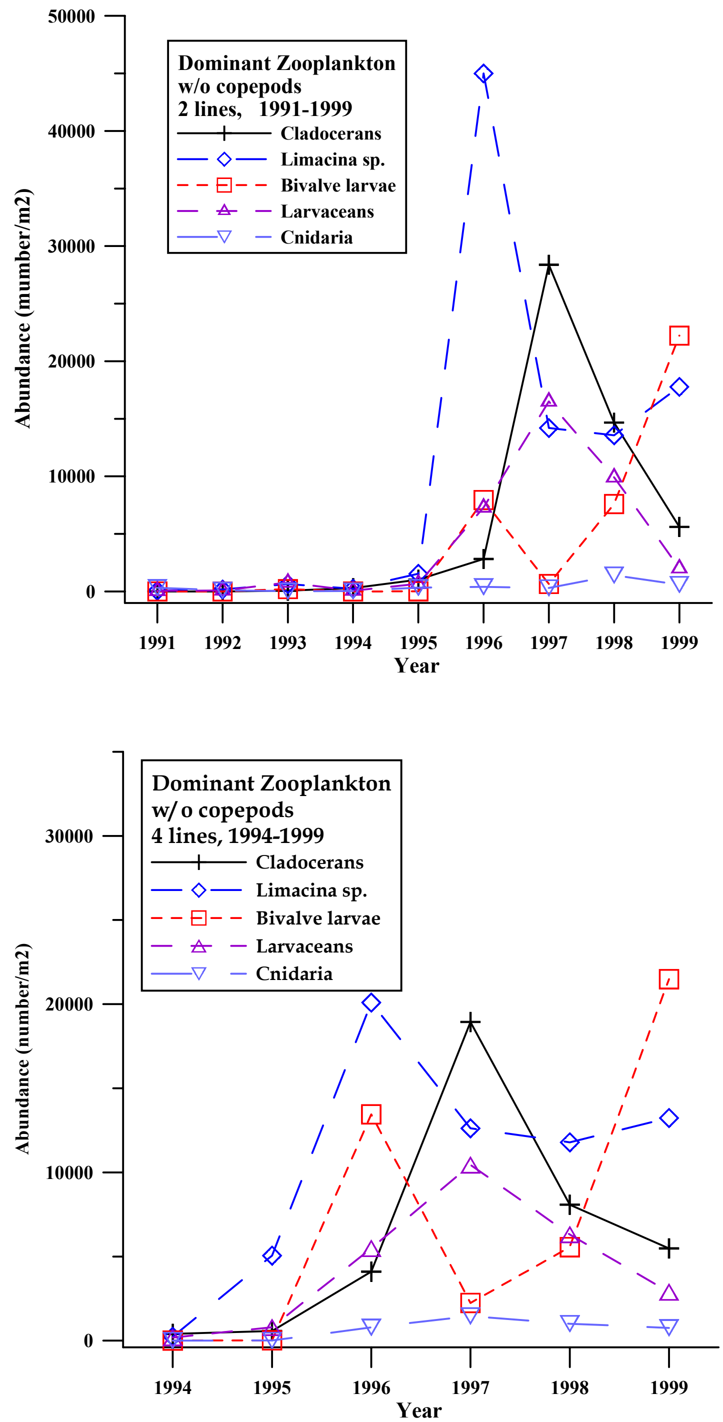
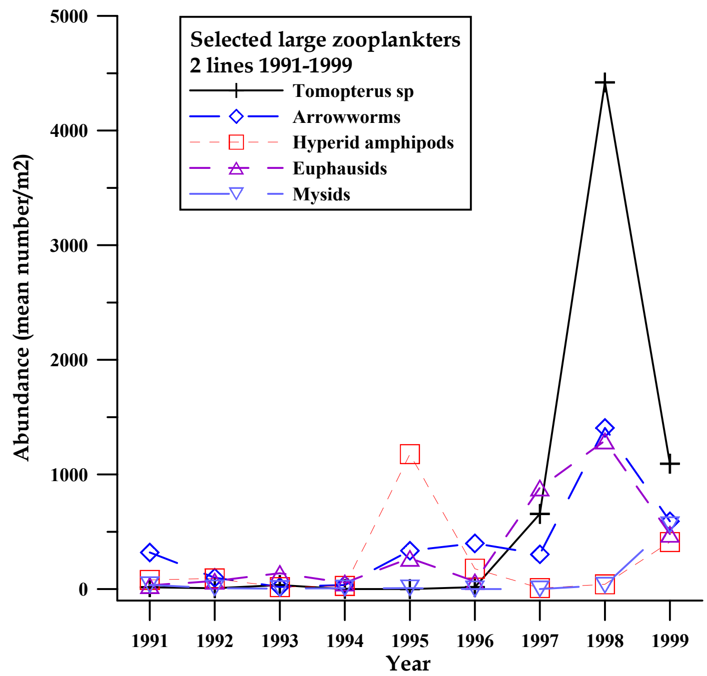


Figure 9. Estimated mean abundance of numerically dominant zooplankton groups, using two central lines over nine years (top) and 4 lines over 6 years (bottom) derived from pelagic surveys carried out from 1991 to 1999 in the Newfoundland region.



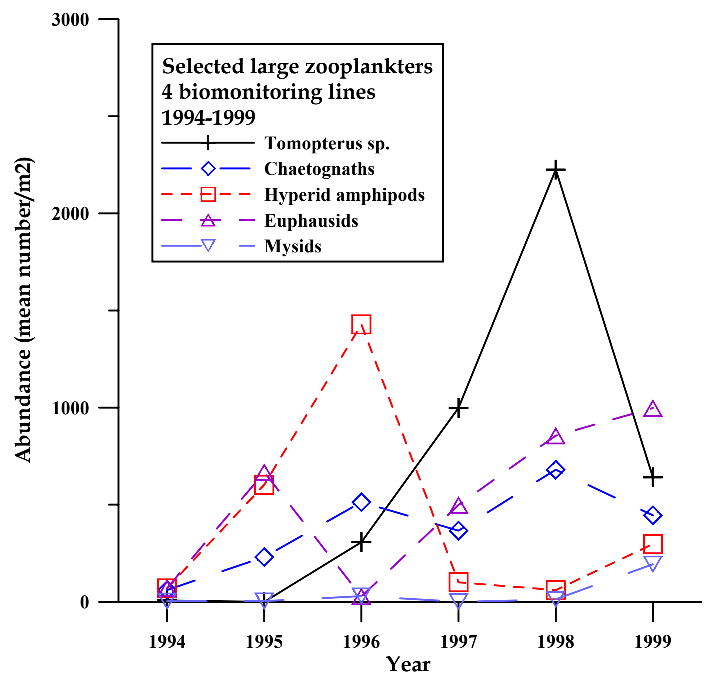


Figure 10. Estimated mean abundance of all selected zooplankton using two central lines over nine years (top) and 4 lines over 6 years (bottom) derived from pelagic surveys carried out from 1991 to 1999 in the Newfoundland region.

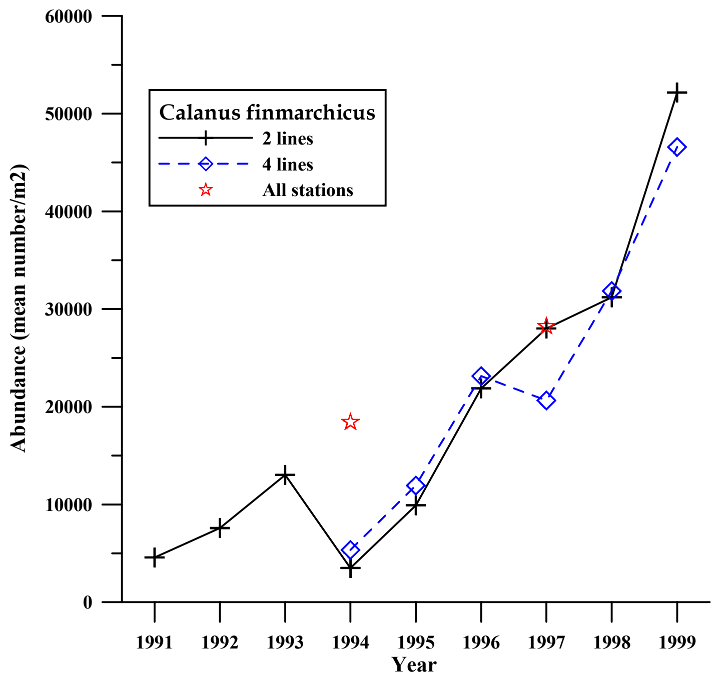


Figure 11. Comparison of mean abundance of *Calanus finmarchicus* estimated using 2 central lines for 9 years, 4 lines for 6 years, and all stations in 1994 and 1997.

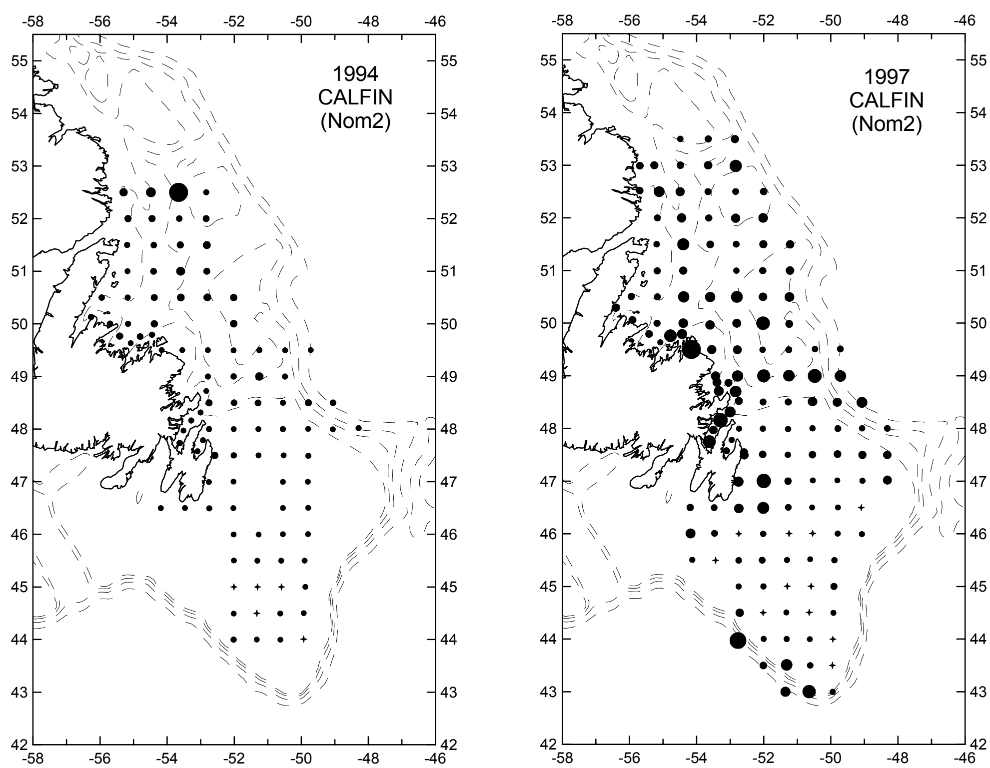


Figure 12. Distribution of *Calanus finmarchicus* determined from all stations occupied during pelagic surveys carried out in Newfoundland region in 1994 and 1997.

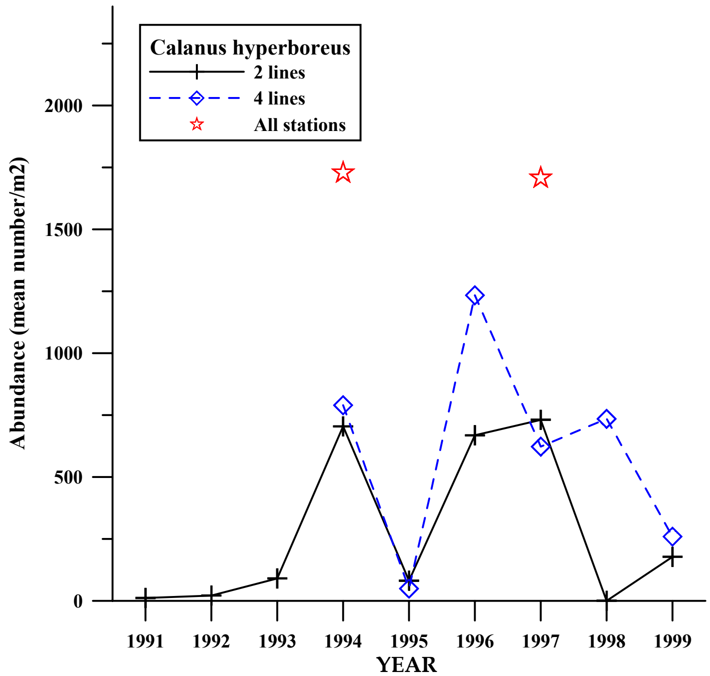


Figure 13. Comparison of mean abundance of *Calanus hyperboreus* estimated using 2 lines for 9 years, 4 lines for 6 years and all stations in 1994 and 1997.

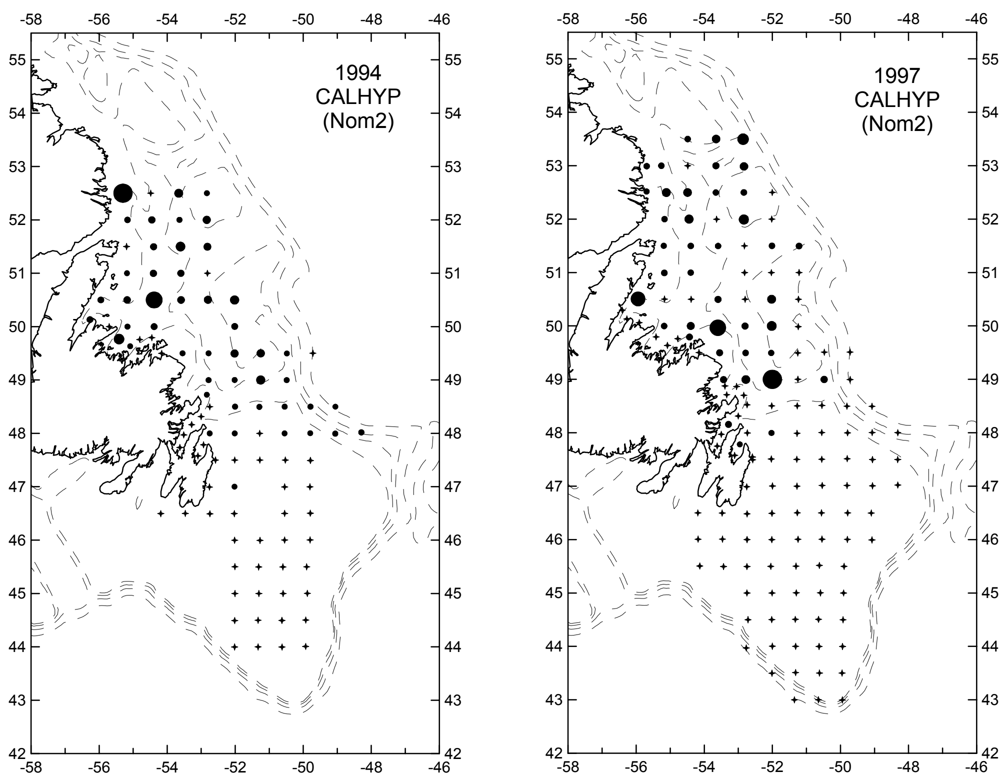


Figure 14. Distribution of *Calanus hyperboreus* determined from all stations occupied during pelagic surveys carried out in Newfoundland region in 1994 and 1997.

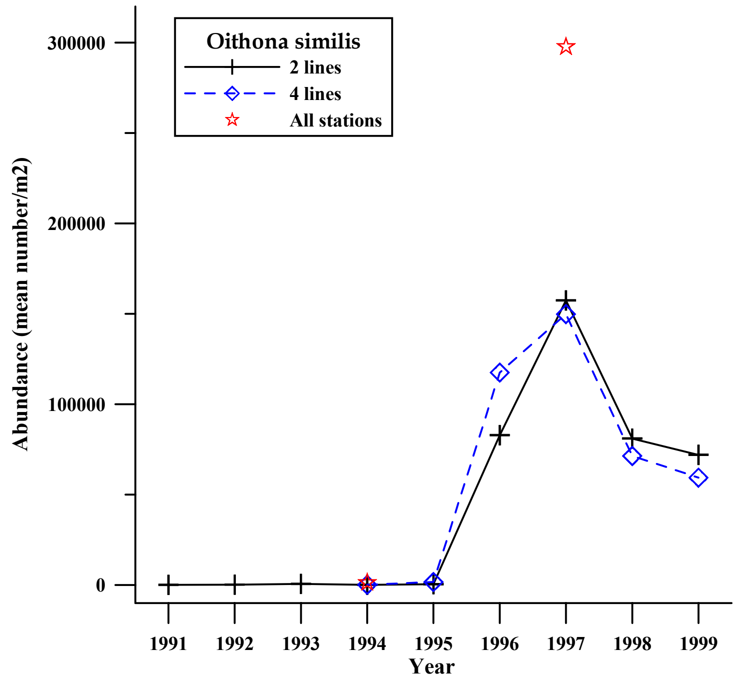


Figure 15. Comparison of mean abundance of *Oithona similis* estimated using 2 central lines for 9 years, 4 lines for 6 years and all stations in 1994 and 1997.

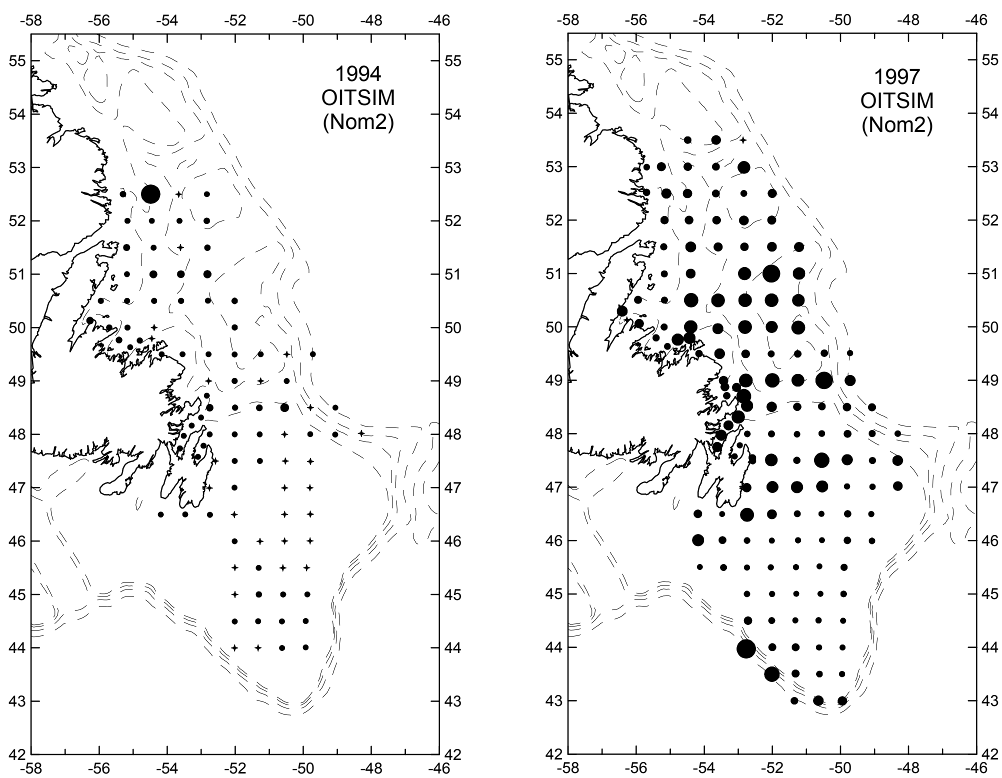


Figure 16. Distribution of *Oithona similis* determined from all stations occupied during pelagic surveys carried out in Newfoundland region in 1994 and 1997.

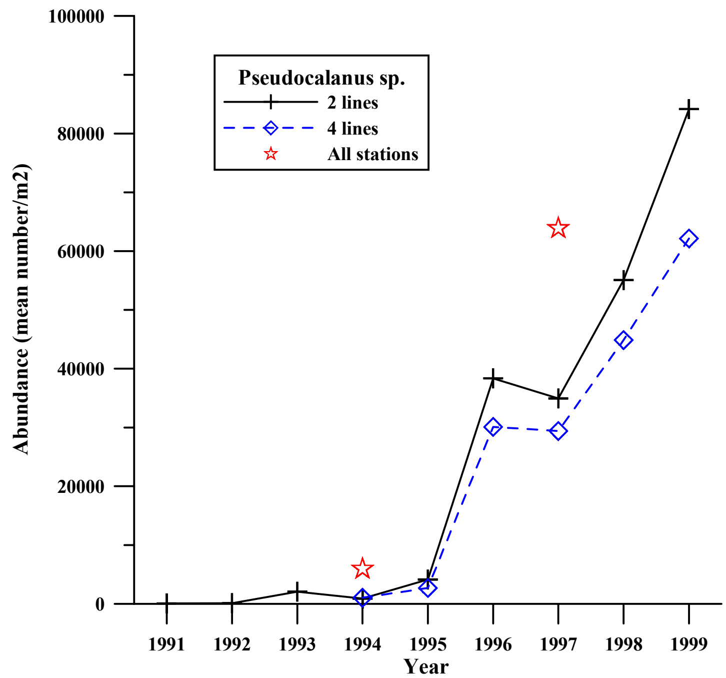


Figure 17. Comparison of mean abundance of *Pseudocalanus sp.* estimated using 2 lines for 9 years, 4 lines for 6 years, and all stations in 1994 and 1997.

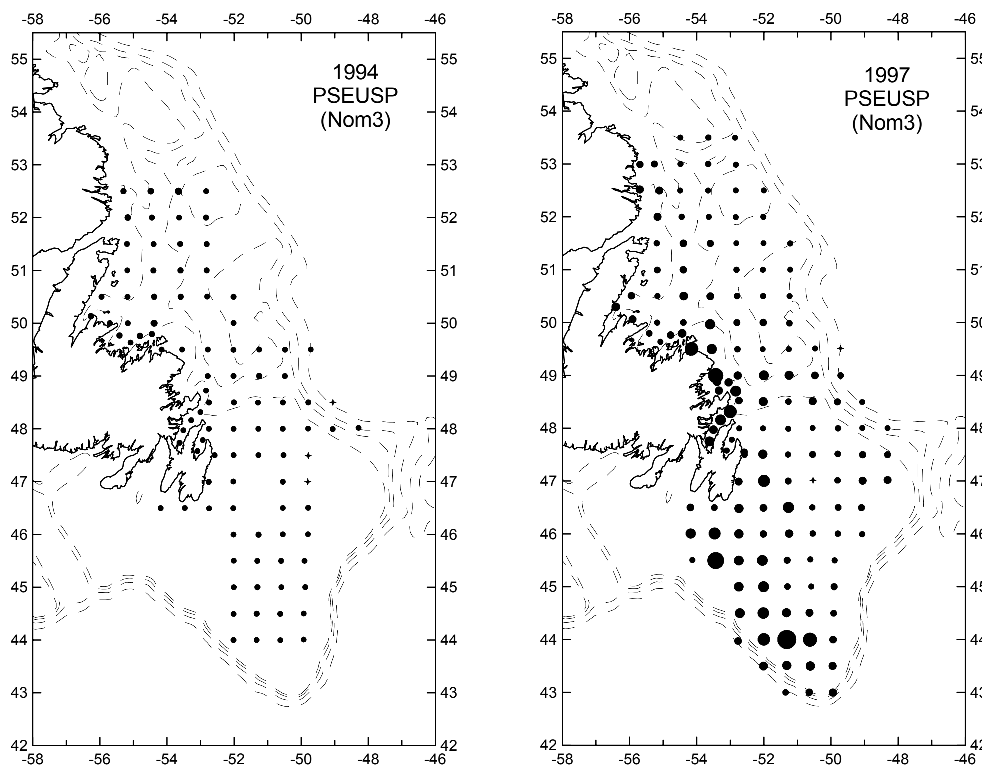


Figure 18. Distribution of *Pseudocalanus sp.* determined from all stations occupied during pelagic surveys carried out in Newfoundland region in 1994 and 1997.

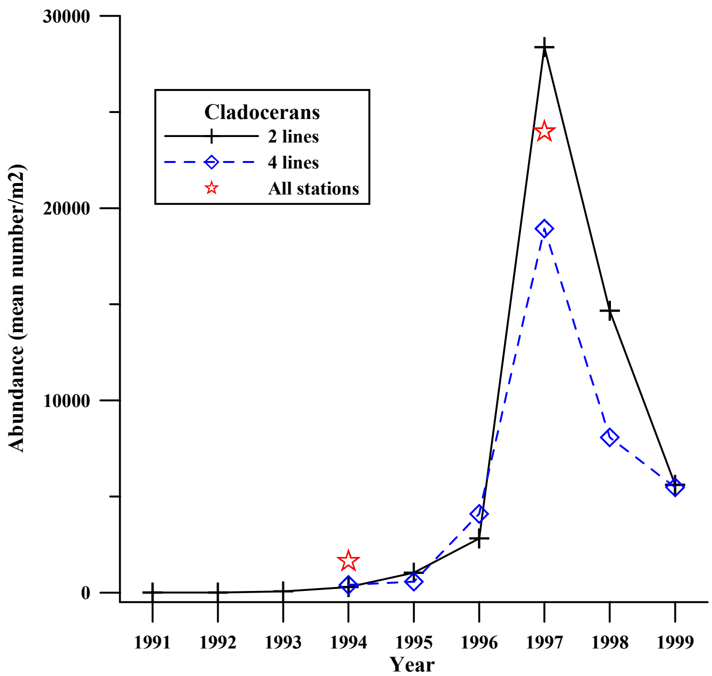


Figure 19. Comparison of mean abundance of Cladocerans estimated using 2 central lines for 9 years, 4 lines for 6 years, and all stations in 1994 and 1997.

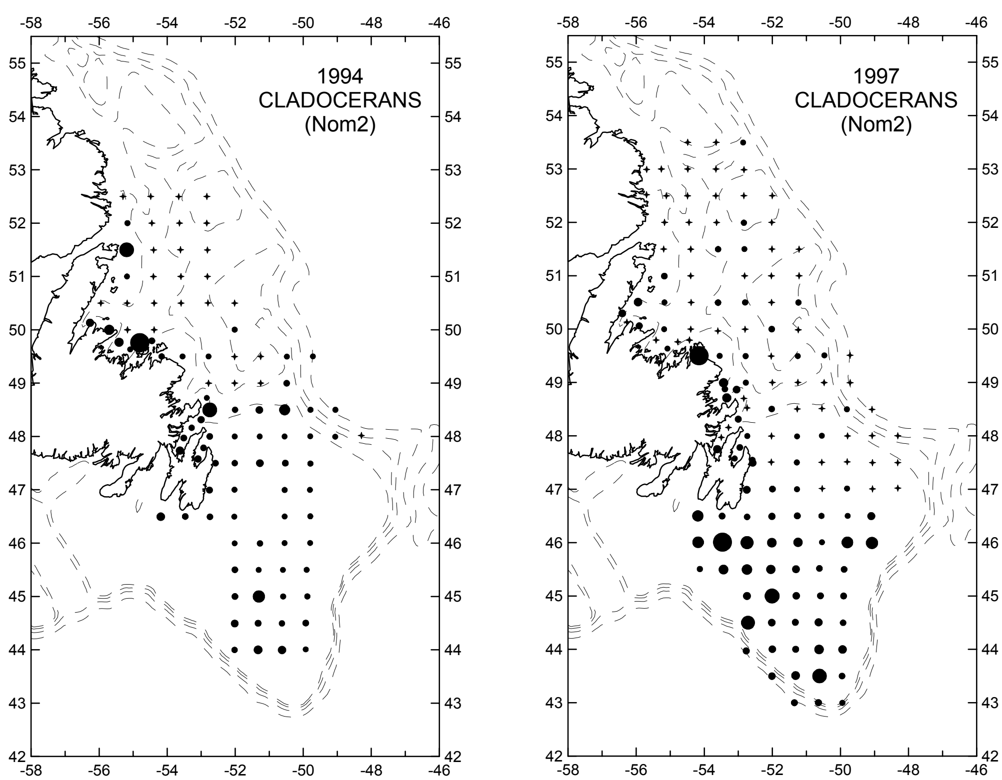


Figure 20. Distribution of cladocerans determined from all stations occupied during pelagic surveys carried out in Newfoundland region in 1994 and 1997.

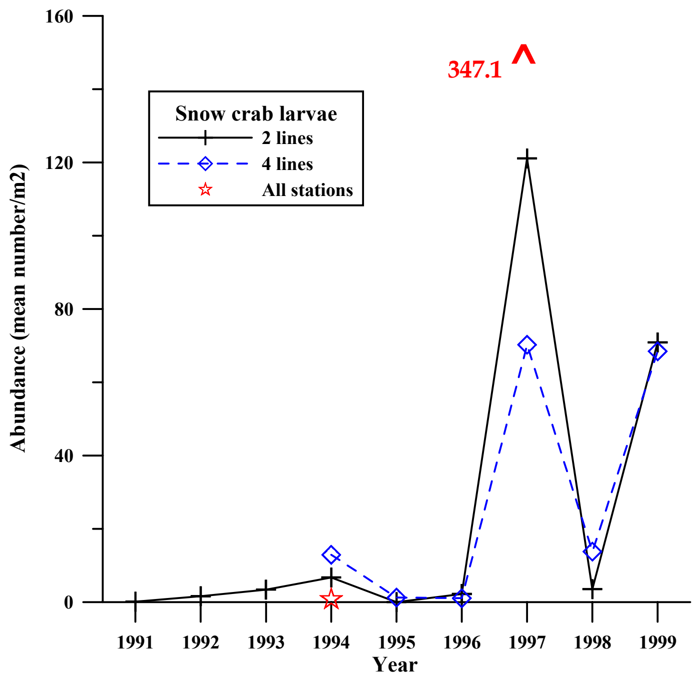


Figure 21. Comparison of mean abundance of snow crab larvae estimated using 2 lines for 9 years, 4 lines for 6 years, and all stations in 1994 and 1997

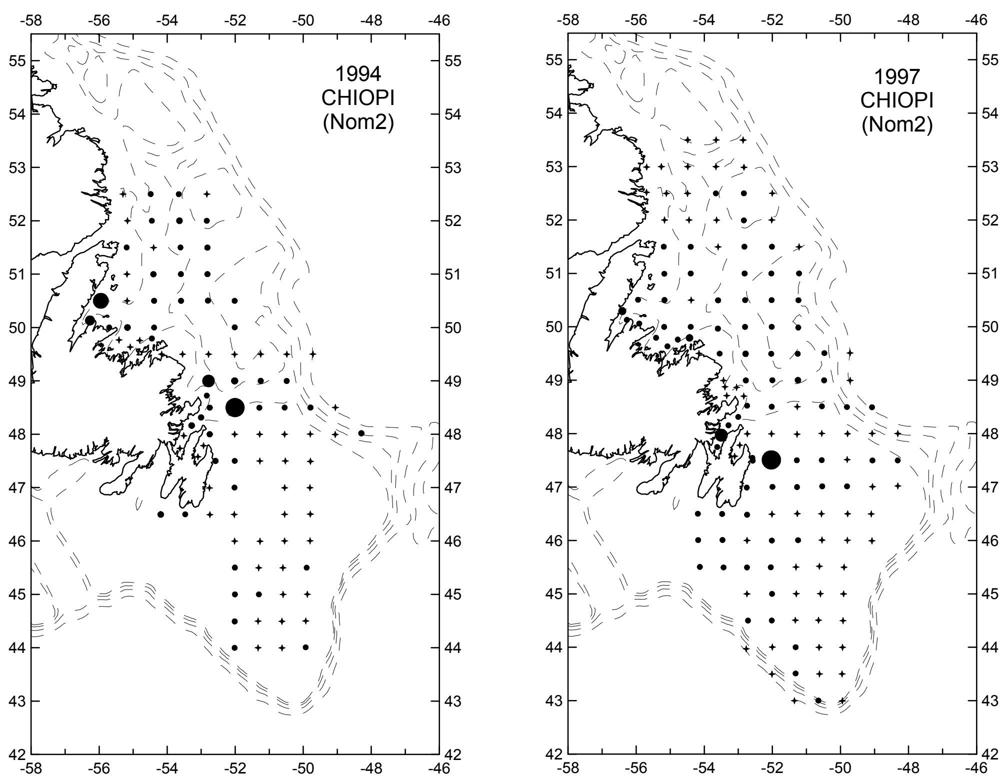


Figure 22. Distribution of snow crab larvae determined from all stations occupied during pelagic surveys carried out in Newfoundland region in 1994 and 1997.

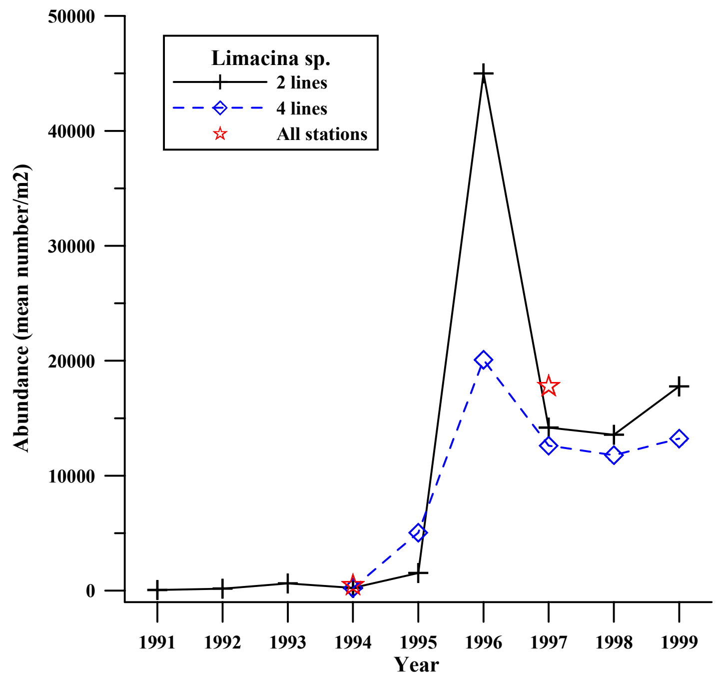


Figure 23. Comparison of mean abundance of *Limacina spp.* estimated using 2 central lines for 9 years, 4 lines for 6 years and all stations in 1994 and 1997.

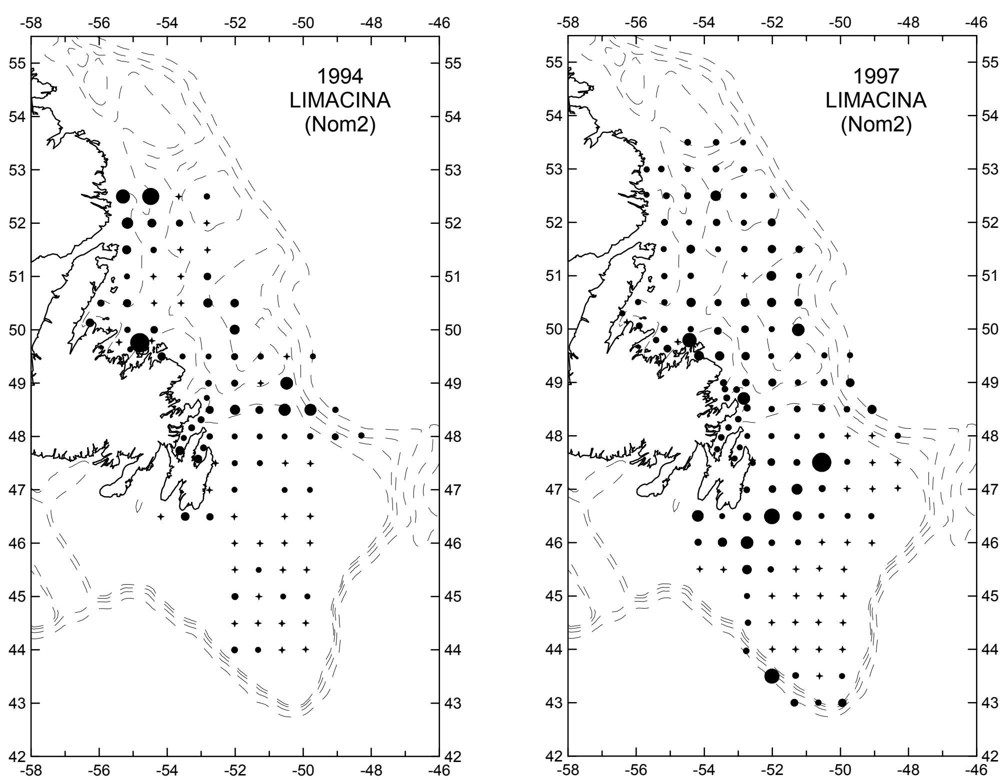


Figure 24. Distribution of *Limacina spp.* determined from all stations occupied during pelagic surveys carried out in Newfoundland region in 1994 and 1997.

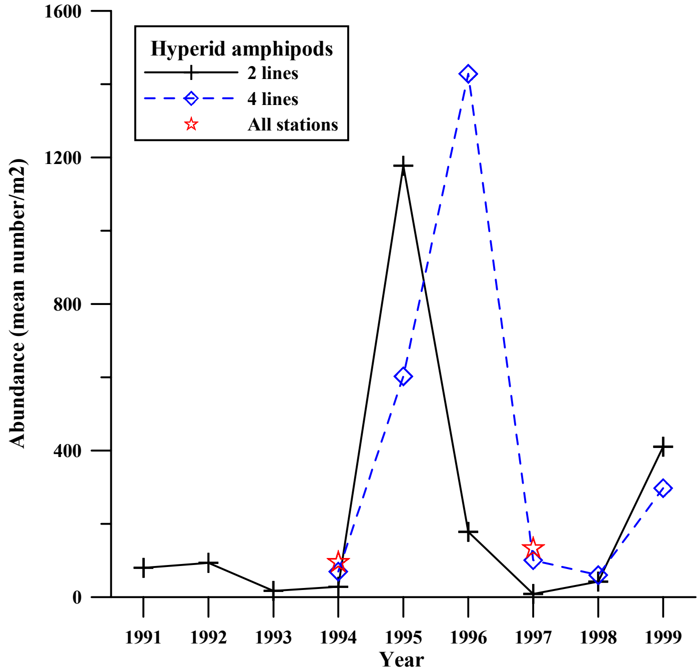


Figure 25. Comparison of mean abundance of hyperid amphipods estimated using 2 central lines for 9 years, 4 lines for 6 years and all stations in 1994 and 1997.

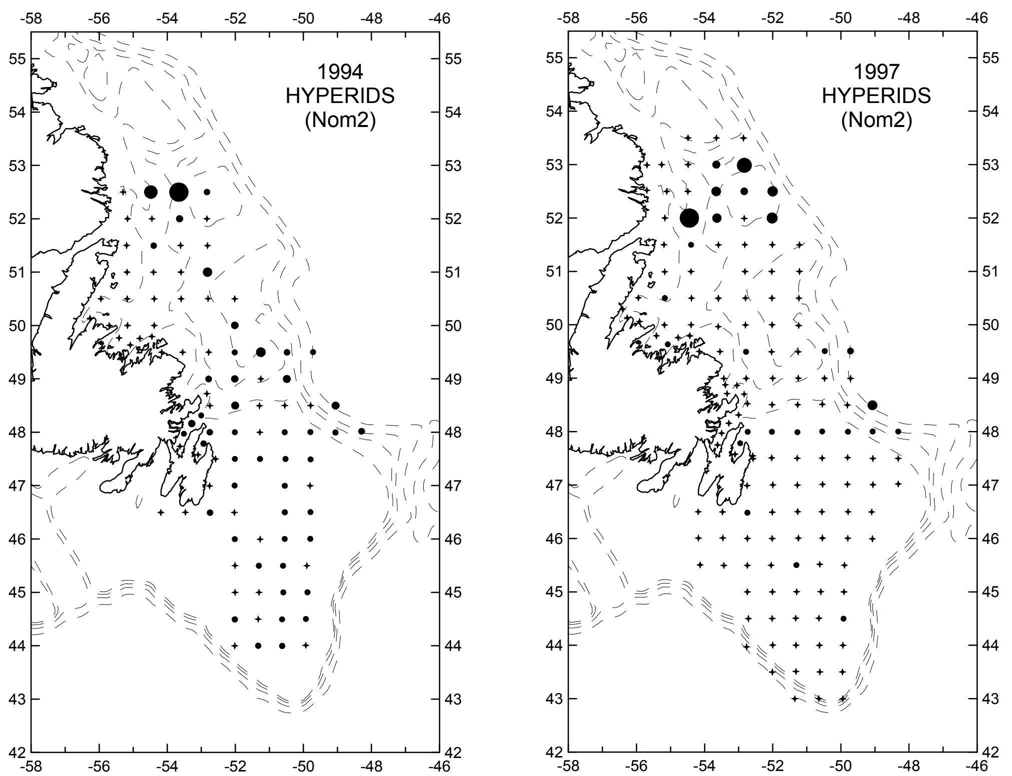


Figure 26. Distribution of hyperid amphipods determined from all stations occupied during pelagic surveys carried out in Newfoundland region in 1994 and 1997.