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State of Zooplankton on the Scotian Shelf, 1997

by

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Abstract

There were no significant differences in the mesozooplankton biomass levels between the Louisbourg and Halifax lines in either April or October, 1997. This result was different from that reported for 1996 when there were higher levels of zooplankton biomass on the Halifax Line. The krill index showed a significant increase in Emerald Basin over the values of 1996. Highest estimated concentrations of krill were found on the western half of the Shelf in the region of Roseway Basin. During April, 1997, the *C. finmarchicus* biomass in the top 100m was higher on the western half of the Shelf than on the eastern half, *C. hyperboreus* biomass was higher on the eastern half and *C. Glacialis* showed a relative uniform biomass distribution. In October higher concentrations of young copepodite stages of *C. finmarchicus* were found on the Louisbourg Line than on Western Bank or the Halifax Line, suggesting that reproduction of *C. finmarch*icus extended longer into the fall on the eastern Shelf region than the central region represented by the Halifax Line. An intrusion of very cold fresh water on the slope at the shelf break was observed in October extending from the Louisbourg Line to midway between the Halifax Line and the Browns Bank Line. This cold water had flooded Emerald Basin by April, 1998.

Résumé

Les valeurs de la biomasse du mésozooplancton entre les transects de Louisbourg et de Halifax ne présentaient aucun écart significatif tant en avril qu'en octobre 1997. Cela diffère des résultats signalés pour 1996 où la biomasse du zooplancton était supérieure pour le transect de Halifax. L'indice du krill indiquait une augmentation appréciable dans le bassin Emerald par rapport à 1996. Les concentrations estimées les plus élevées ont été notées dans la demie ouest du plateau, dans la région du bassin Roseway. En avril 1997, la biomasse de *C. finmarchicus* dans les 100 m supérieurs était plus élevée dans la demie ouest du plateau, comparativement à la partie est. Celle de *C. hyperboreus* était plus élevée dans la demie est et celle de *C. glacialis* présentait une distribution uniforme. En octobre, des concentrations plus élevées de *C. finmarchicus* de stade copépodite jeune ont été décelées sur le transect de Louisbourg, comparativement à celles du banc Western ou du transect de Halifax, ce qui porte à croire que la reproduction de *C. finmarchicus* s'étendait plus avant à l'automne dans la partie est du plateau que dans la partie centrale, correspondant au transect de Halifax. Une intrusion d'eau très froide au point de rupture de pente du plateau a été observée en octobre; elle s'étendait du transect de Louisbourg à mi-chemin entre le transect de Halifax et le transect du banc Browns. Cette eau froide a envahi le bassin Emerald en avril 1998.

Introduction

Historical bottom temperature data for the Nova Scotian shelf show a seasonal pattern of consistently colder water on the eastern end of the shelf compared to the central or western regions (Sameoto et al. 1997). The growth rate of cod is known to be slower on eastern regions of the shelf than on western regions and in the Gulf of Maine (Campana et al. 1995). This may be a consequence of the lower temperature and or lower food levels on the eastern region of the shelf.

The purpose of this study was to measure biological and physical differences among, the eastern, central and the western regions of Scotian Shelf. These regions are characterized by different TS properties and different biological characteristics. Earlier studies showed the eastern region had a lower zooplankton biomass as well as lower temperatures than the other two regions of the shelf (Sameoto et al 1997). Results from a 1997 April and October study of biological and physical characteristics of the water column along a series of transects on the Scotian Shelf and Cabot Strait are presented.

Methods

The Browns Bank (BBL), Halifax (HL), Louisbourg (LL), Cabot Strait (CS) and Laurentian Channel (LC) lines were sampled during April and late October to early November, 1997 using 0.75 m and 0.2 m diameter vertically towed 200 µm plankton nets, the BIONESS, OPC/CTD and multifrequency acoustics (Sameoto and Herman 1990, Sameoto 1990b, 1993, Herman et al. 1993). In October, in addition to the above sampling methods, BATFISH profiles were taken to collect data from the CTD, optical zooplankton counter (OPC), and fluorometer on the HL, LL, and CS lines. Nets tows and OPC/CTD samples were taken across Western Bank (WB) in October. Temperature was continuously measured at a depth of 6m using the ship's intake seawater system. The cruise tracks and stations for the studies are shown in Fig. 1.

The TS characteristics of representative stations along each of the lines, except Cabot Strait line, were compared to all the TS data in the AFAP data base. AFAP data from the Cabot Strait West area, the Central Nova Scotia Slope and the Newfoundland Slope areas for the months of April and October were plotted and a polygon box drawn around each of the plotted data sets. The 1997 TS profiles from different stations on the lines were superimposed on these boxes to indicate a possible source for the water on the different stations.

Acoustic backscattering data were collected at 3 frequencies (12, 153 and 200 kHz) along each transect to map the distribution and estimate the concentration of macrozooplankton (> 1 cm) and micronekton.

Acoustic backscattering levels at 153 kHz were recorded throughout the water column along the Halifax transect in May and October using a RDI ADCP (Cochrane et al. 1994, Zhou et al. 1994, RD Instruments 1990). Data from a May 1997 transect of the HL were used in place of April's data because the April data were of poor quality due to severe weather. The acoustic backscattering at 153 and 200 kHz were primarily from macrozooplankton and micronekton in the size range of 0.5 - 4 cm length. On the Shelf the principal acoustic scatterers at this frequency are juvenile and adult euphausiids (Cochrane et al. 1991, 1994). Therefore these acoustic data are good indicators of changes in euphausiid biomass both across the shelf and between different seasons and years. The changes in volume backscattering strength from euphausiid backscattering are roughly equivalent to changes in their biomass concentration or density, i.e. a 10 dB change in backscattering corresponds to a 10 fold change in biomass density (Cochrane et al. 1991).

Simultaneously with the recording of the RDI data, acoustic backscattering data at 12, and 200 kHz were also recorded using conventional echosounders. The 12 kHz frequency provided information on the relative abundance and distribution of juvenile and adult fish throughout the water column. The data from 12 kHz were used to verify that the scattering at 153 and 200 kHz were from macrozooplankton and not from fish.

Wet biomass measurements were made by the method described in Sameoto and Herman (1990). The concentration estimates for species numbers represent the total number of each species in the entire water column under 1 m^2. A cubic spline smoother was fitted by the least squares method to the species concentration data along each of the lines using the program S-Plus 4.

Dry weight biomass concentrations of the three springtime dominant species (*Calanus finmarchicus, C. glacialis* and *C. hyperboreus*) were estimated for samples from net tows collected in the top 100 m (or the entire water column if the depth was < 100 m), by determining the dry weight of individuals of each stage of each species (after drying groups of individuals at 60° C overnight) and by summing these according to the estimates of abundance of the different stages and species.

Results

Temperature and Salinity Structure

April

The April temperature contours, taken from the flow through system at 6 m depth (Fig. 2) reflected three zones of the shelf, the eastern zone influenced by the cold fresh outflow from the Gulf of St. Lawrence, the central region affected by the warmer and more saline slope water and the western region which is a mixture of the slope and Gulf water.

The entire water column at the near shore station (Stn. 1) on the Louisbourg Line (LL) was < 0° C (Fig. 3). The LL basin station (Stn. 5) was slightly warmer with the cold intermediate water (CIL) above 0° C and the bottom temperature close to 3° C, which was about 1.5° C warmer than in June , 1996. The thickness of the upper cold layer on the LL slope station (Stn. 7) was about 180 m, which was 30 m deeper than in June, 1996. The climatological seasonal bottom temperatures show the Shelf east of Sable Island is colder during all seasons (Sameoto et al. 1997). The TS profiles of Stn. 1 to 13 on the LL fell within the polygon of the Cabot Strait West water. At the deep slope Stn. 14, water in the top 100m was within the Cabot Strait West box, but below 100 m it was more chararctisitic of Newfoundland Slope water (Fig. 4).

The HL Stn. 1 (not shown) TS was within the Cabot Strait West polygon. Stn. 2 water was a mixture of Cabot Strait West (the top 40 m) and Nova Scotia Slope water, whereas, all the other stations on the HL had TS profiles that were within the Nova Scotia Slope polygon (Fig. 4). The CIL in April at the near shore station (Stn. 1) on the HL was < 0° C to a depth of 50 m. The CIL was confined to only the first two inshore stations (Fig. 3). On the HL slope station (Stn. 6) the layer below 50 m was about 2° C warmer than in June, 1996.

On BBL and the Eastern Shelf station the TS profiles were similar to the stations on the HL with the profiles falling within the Nova Scotia Shelf polygon (Fig. 5).

October

In October the top 50 m of water at the LL shelf stations was about 8° C (Fig. 3), and this was 2° C warmer than in November, 1996. At the LL slope station (Stn, LL 7) the entire water column to a depth of 300 m was colder by about 1°C than it was in November, 1996 (Fig. 6). The TS profiles (Fig. 5) showed all the water on the shelf fell within the Cabot Strait West polygon, but the TS for Stn 14 on the slope was within both the Cabot Strait West and Newfoundland polygons.

The top 50 m of water at the HL shelf stations was about 12° C, and that was 4° C warmer than the same water layer in November, 1996. The HL slope station (Stn. HL 6) top layer was 12° C and this was 2° C colder and much thinner than it was November, 1996. The CIL on the slope in 1997 was much colder (~0.5° C) and thicker (150 m) than it was in 1996 (Fig. 6). The TS profiles for Stn. 2 and 3 showed the top 50 m was Cabot Strait water whereas the deeper water (> 50 m) fell within the polygon for Newfoundland Slope water and the colder region of the Nova Scotia Slope polygon. The Stn. 6 TS profile was completely within the Newfoundland Slope polygon (Fig. 4).

The TS profiles of Stn. 1 to 3 on BBL were within the Cabot Strait West polygon, whereas, Stn. 5 and 6 were completely within the Nova Scotia Slope polygon. The TS of the eastern slope station 2 was totally different than the BBL slope station Stn. 6, with the values all falling within the Newfoundland Slope polygon (Fig. 5).

A BATFISH transect across Emerald Basin in early December, 1997, found a tongue of this cold Newfoundland Slope water between 50 and 100 m on the Emerald Bank side of Emerald Basin, suggesting this cold water flowed on to the shelf by way of the deep troughs and was replacing the deep warmer water in the Emerald and LaHave basins.

Zooplankton Abundance and Distribution

There were no significant statistical differences (using an unpair t test) between the mean total wet weight biomass of mesozooplankton on the HL and LL in April or October (Table 1). However, there were large differences between stations on each of the lines (Fig. 7). On the HL in April the lowest biomass level was found at the near shore station (Stn. 1). There was little difference in biomass between stations across the shelf, but levels increased on the slope stations. On the LL the lowest biomass was found on the Banquereau Bank station (Stn. LL 6) and the highest biomass in a basin (Stn. LL 5) just north of the Banquereau Bank.

Table 1. Mean and standard deviation (S.D.) of total wet weight biomass on the Halifax and Louisbourg lines.

	April		**October**	
	Mean	S.D.	Mean	S.D.
Halifax Line	32	16	21	15
Louisbourg Line	31	13	17	14

In October the HL biomass was again very low at the near shore Stn. HL 1 and was also low on Emerald Bank (HL Stn. 4) and at the slope stations, (Stn. 6 and 7), but the biomass was higher in Emerald Basin (Stn. HL 3) and Stn. HL 2. On the LL, the biomass was generally lower in October than in April. The Banquereau Bank Stn. LL 6 again had the lowest biomass of all the stations on the line (Fig. 7).

The April and October 1997 biomass levels on the HL stations were significant lower than in June and November, 1996, whereas at the LL stations they were similar to those in June and November of 1996 (Sameoto et al. 1997).

Total *Calanus* spp. dry weight biomass in April was more-or-less evenly distributed over the Scotian Shelf, with 80 % of the values being between 1.5 and 5 g m^{-2} (Fig. 8). The highest biomass (> 16 g m^{-2}) occurred on the CSL. *C. finmarchicus* biomass levels were highest at shelf and slope stations on the HL and further west. *C. hyperboreus* levels were highest on the LL and CSL, and much lower at stations further west. The biomass of *C. glacialis* was substantially lower than that of either of the other two species, with highest values occurring on the CSL and at stations on the Western Scotian Shelf and lowest values on the HL.

In October the total number of *C. finmarchicus* m^{-2} in Emerald Basin was slightly lower than that observed in November, 1996, and was the lowest recorded in the fourteen year series. The arctic species *C. glacialis* and *C. hyperboreus* also had very low concentrations in the Basin (Fig. 9).

The concentrations of the dominant species of copepods were compared on the different stations on the HL, LL and across Western Bank (WB) for October. The numbers m^{-2} of the dominant species and the development stages of *C. finmarchicus* are shown (Fig. 10 to 12), plus the cubic spline smoothers fitted to the data for each species on three lines.

The highest concentrations of total copepods m^{-2} were found on the LL, with Banquereau Bank having the highest concentrations of all the stations (Fig. 10). The numbers m^{-2} on the HL and WB were similar. The dominant species on all lines was *Oithona similis,* a small omnivore. There were differences in the dominant species of copepods on the three lines, with *Centropages typicus* most abundant on the HL and WB and *Oithona similis* and *Psuedocalanus spp.* most abundant on the LL. The highest numbers of copepod nauplii were found on the LL (Fig. 11).

The copepodite stage structure of *C. finmarchicus* was different between HL and LL (Fig. 12). The LL had higher numbers of young stages and lower numbers of stage VI females than the HL. This indicated that reproduction of *C. finmarchicus* continued in the late fall on the LL whereas it stopped earlier on the HL. The highest concentrations of stages IV to VI on the HL were found in Emerald Basin.

BATFISH Estimates of Zooplankton Concentration

In October the concentrations of large and small size zooplankton, measured with an OPC mounted on the BATFISH, across the Shelf along the LL and HL showed that the two lines had distinctly different distribution patterns (Fig. 13). The patterns agreed with those suggested from net samples. There were much higher concentrations of small zooplankton on the Cape Breton side of the Cabot Strait and on the Banqereau Bank end of the LL than there were anywhere on the HL. The highest concentrations of large zooplankton (mainly *C. finmarchicus* stages IV) were located in Emerald Basin. The BATFISH data are consistent with an outflow of zooplankton from the Gulf of St. Lawrence. A HL transect with the OPC in December showed the concentrations of large zooplankton in the Emerald Basin had decreased from the levels in October.

Krill Distribution and Abundance

The April distribution of krill based on acoustical measurements, at 200 kHz, showed higher concentrations on the western half of the shelf than on the eastern half, with the highest concentrations found in Roseway Basin (Fig. 14). The high levels recorded on the edge of the Shelf break were probably due to a combination of scattering from euphausiids and mesopelagic fish, primarily myctophiids (Sameoto, 1988). The acoustic index of krill biomass in Emerald Basin showed a slight decrease from the values recorded in June, 1996. The 1997 acoustic index was near the mean for the index over the data series (Fig. 15).

An error due to faulty equipment was found in the 1995 acoustic data . These acoustic levels were too low and subsequently have been corrected in the Acoustic Index figure in this report.

The backscattering volume in dBs calculated from the ADCP data (Fig. 16) along the LL had a similar pattern and similar mean values to those measured in 1996. The HL mean volume backscattering was higher than that of the LL during the spring and fall. The mean level of backscattering in the spring on the HL has showed a downward trend since 1995 (Table 2).

Table 2. Mean volume backscattering levels (dB) for the entire water column along the Halifax and Louisbourg lines measured by the RDI ADCP.

YEAR	MONTH	HALIFAX LINE	LOUISBOURG LINE
1995	APRIL	-61.18	no data
1995	OCTOBER	-66.47	no data
1996	JUNE	-63.58	-71.47
1996	NOVEMBER	-64.53	-71.78
1997	MAY	-66	-71.59
1997	OCTOBER	-68.63	-72.52

Conclusions

The general pattern of zooplankton and krill biomass concentrations and geographic distributions were similar to those seen in 1996, with the western half of the shelf having a higher biomass of krill. The main difference in 1997 compared to 1996 was that the total zooplankton biomass was not significantly different between the HL and LL. In June, 1996, the biomass was higher on the HL than on the LL. The similarity in the biomass values on the two lines in 1997 was due to the unexpected low biomass levels of *C. finmarchicus* in Emerald Basin in April.

On the HL, total *Calanus* spp. dry weight biomass (0-100m) in April 1997 was similar to that found in April 1995, except at HL2, where *C. finmarchicus* biomass was ca. 5 times higher in 1997. On the LL, total *Calanus* spp. dry weight biomass (0-100 m) in April 1997 was similar to that found in April 1995, except at LL2, where C. hyperboreus biomass was ca. 3 times higher in 1997. For both years, however, total *Calanus* spp. dry weight biomass (0-100 m) was slightly higher at shelf stations on the LL than on the HL.

The October composition of the dominant copepod species on the two lines suggested that the two regions may have different trophic interactions in the fall. The LL was dominated by an omnivore and the HL was dominated by a herbivore. The region of Banquereau Bank appears to be unique from other banks we have sampled with high chlorophyll levels and large populations of small copepods on the Bank from March to November. A cursory look at the samples as they were collected in April and October indicated there were few fish larvae collected and those that were captured were sand lance and herring. Few if any gadoid larvae or eggs were seen.

The large mass of cold water seen at the slope stations in October was an unusual feature never observed in the years that we have been sampled these lines in the fall. By April, 1998 this influx of cold water had reduced the temperature of the deep water in Emerald Basin to approximately 6° C (Drinkwater et al. 1998).

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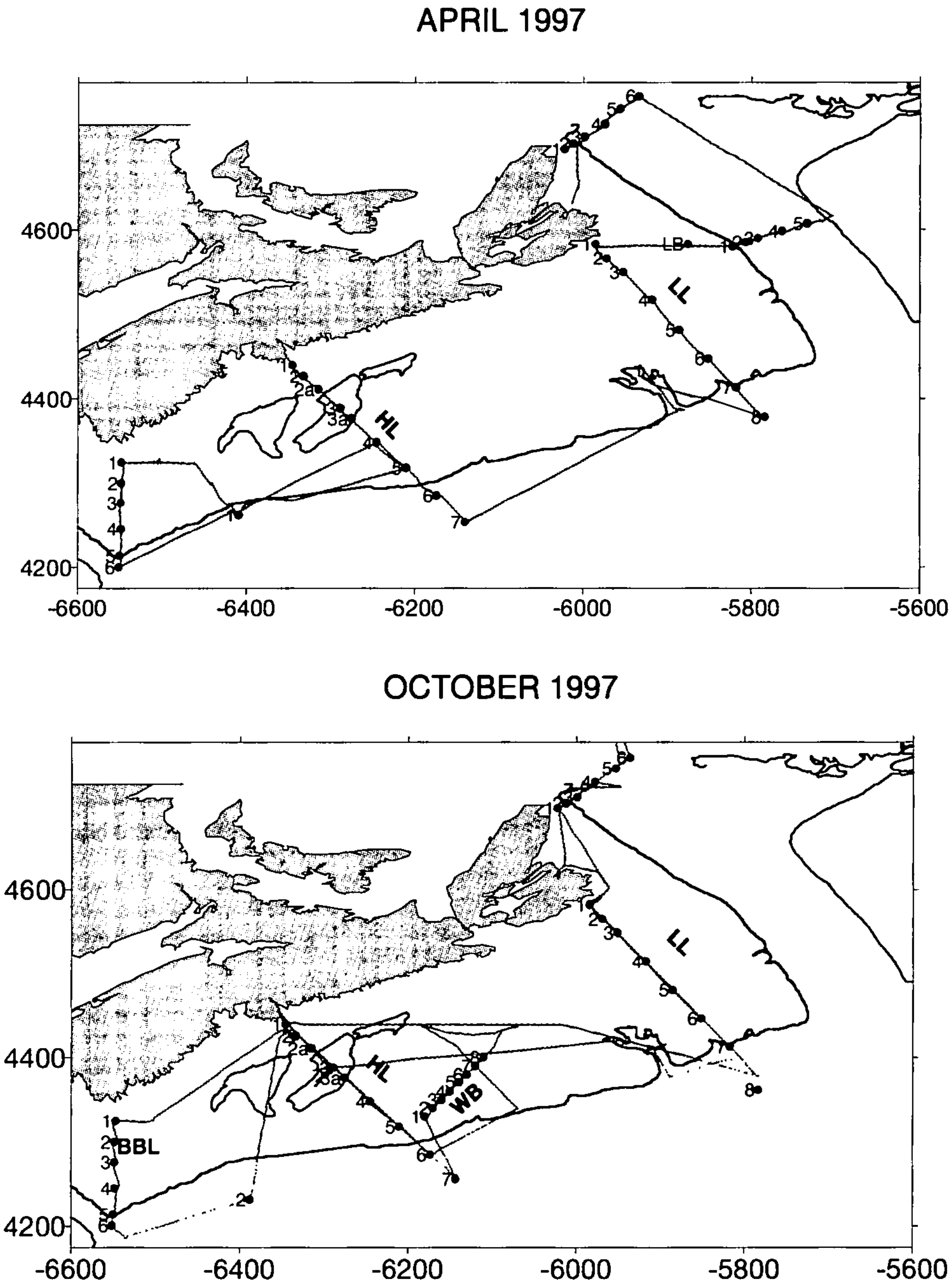


Fig. 1. Cruise tracks and station positions for April and October. HL - Halifax Line, LL - Louisbourg Line, WB - Western Bank Line, BBL - Browns Bank Line.

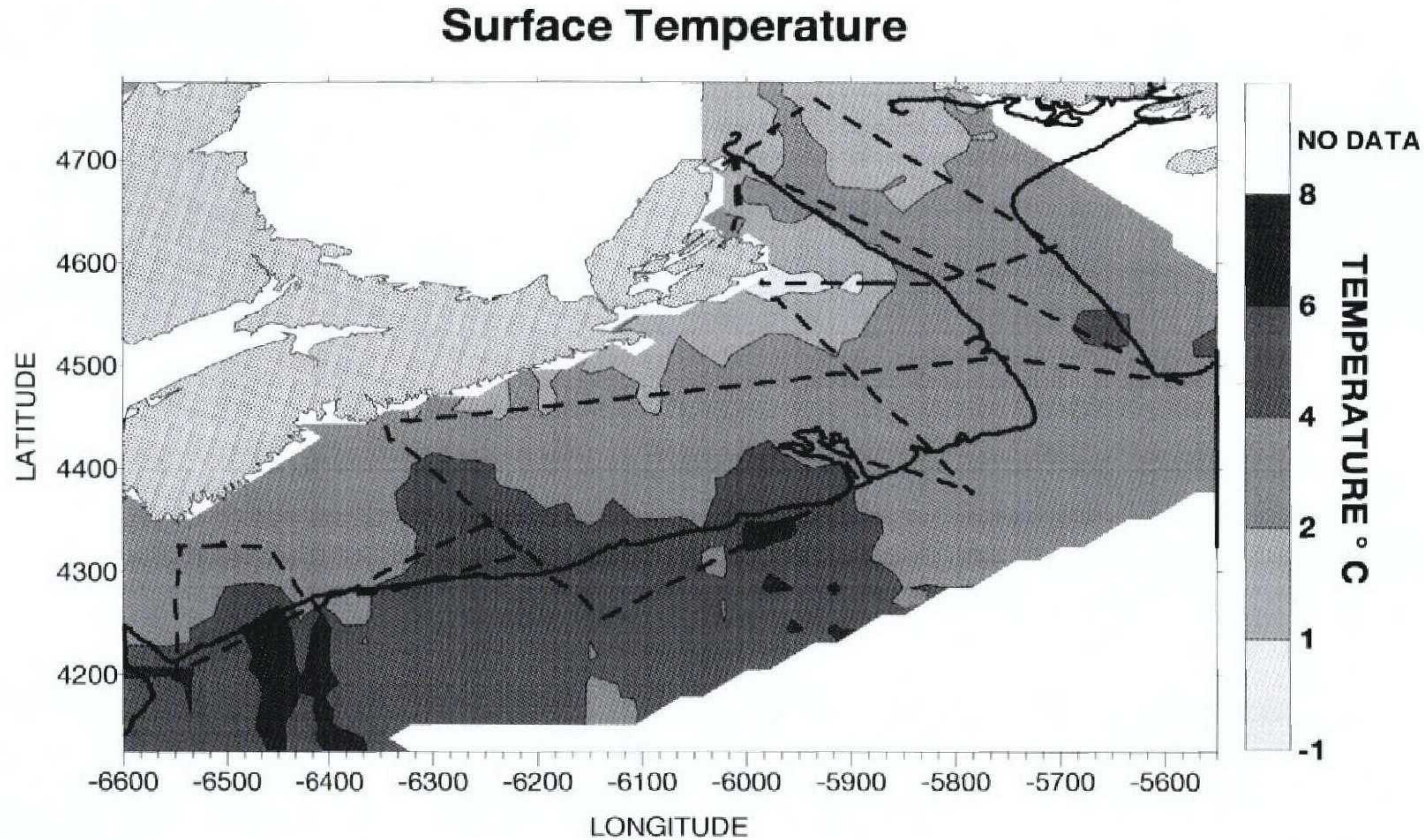


Fig. 2. April, 1997, temperature contours at 6m measured by the continuous flow through system

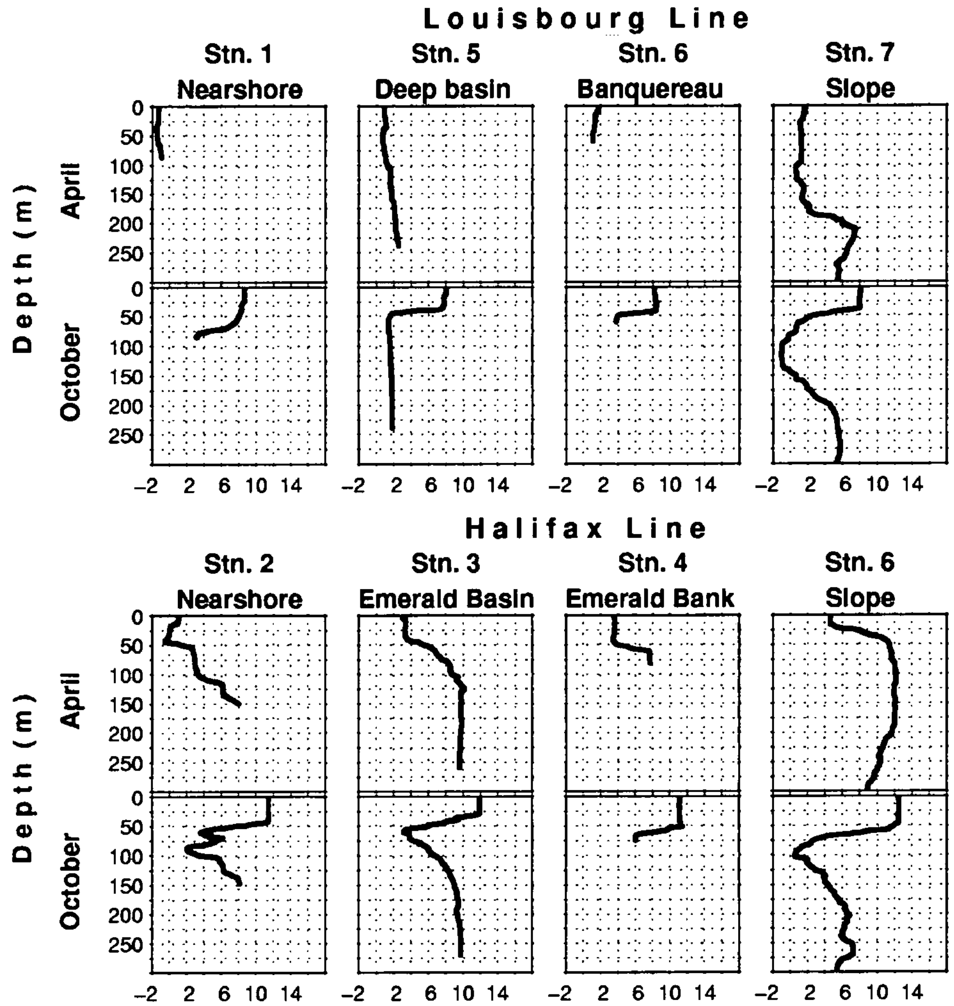


Fig. 3. Temperature profiles for selected stations on the Louisbourg and Halifax lines for April and October 1997.

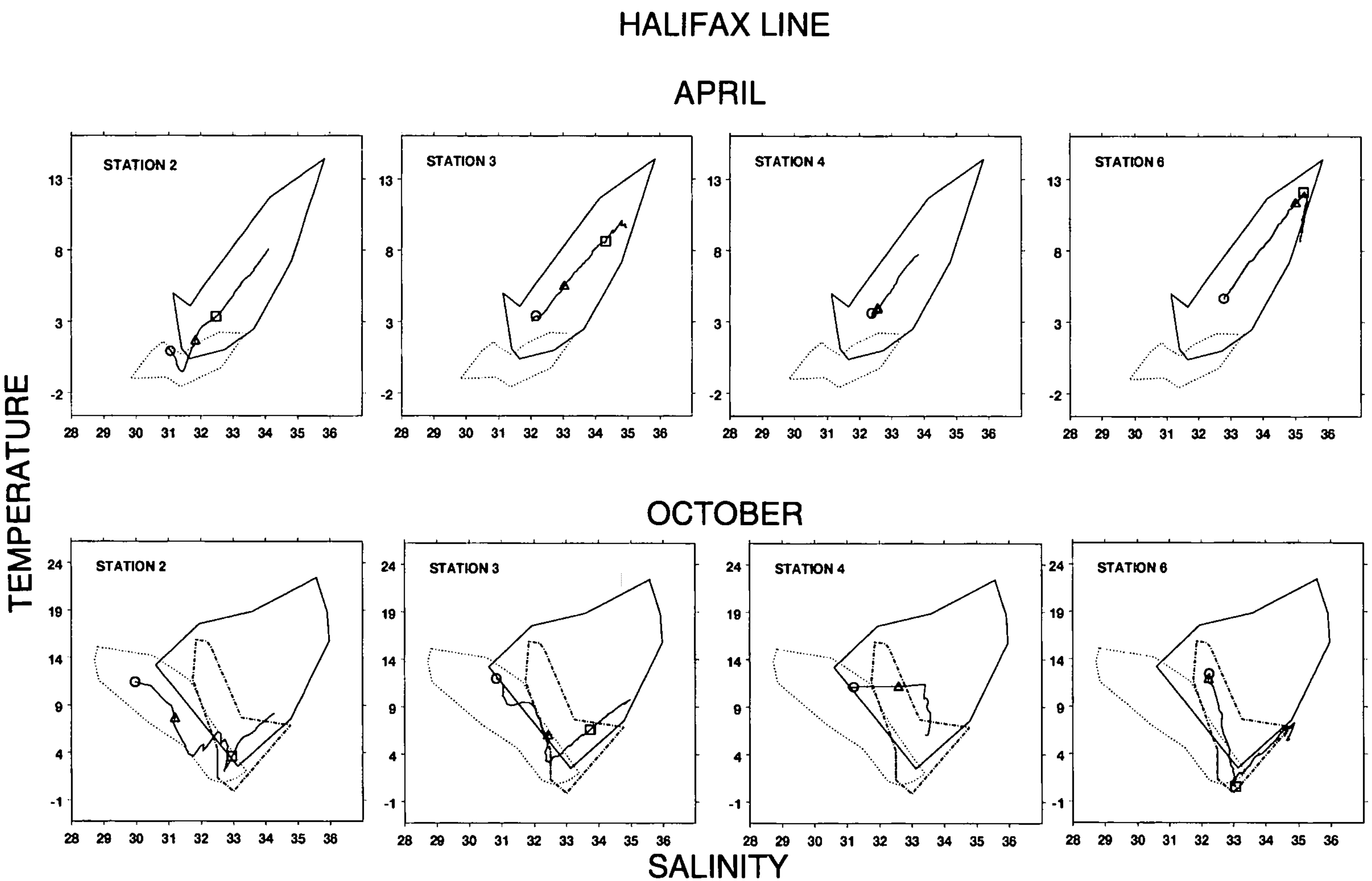


Fig. 4. TS plots for the Halifax and Louisbourg lines for April and October, 1997. The polygons represent the boundaries of TS data in the AFAP TS data base. Dotted line encloses data from the western end of Cabot Strait, the dashed line encloses data from the Newfoundland slope and the solid line polygon enclosed data from the Nova Scotia Slope. Data within the polygons are for April and October. Circle represents TS at 10 m, triangle TS at 50 m and square TS at 100m.

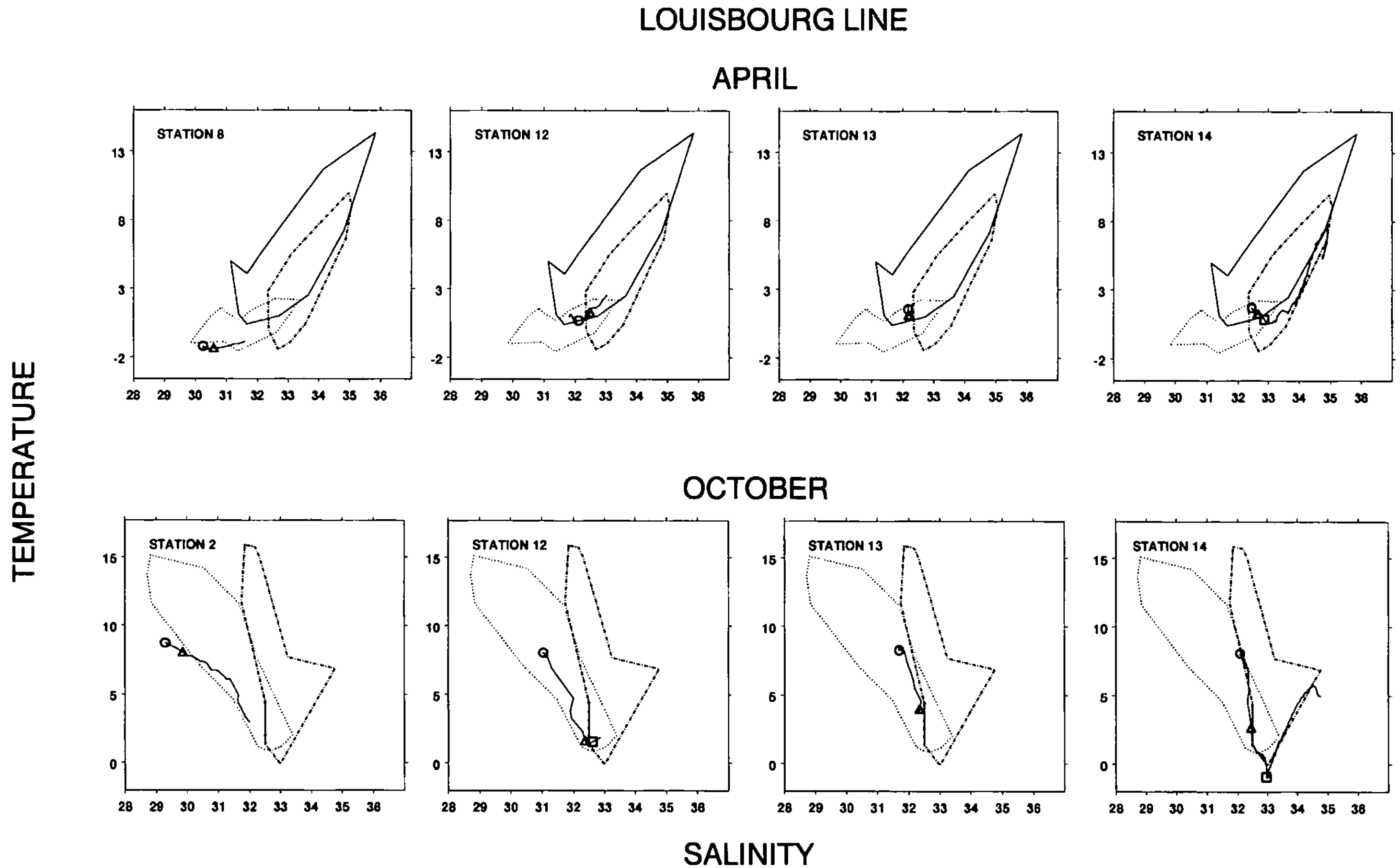


Fig. 4. Continued.

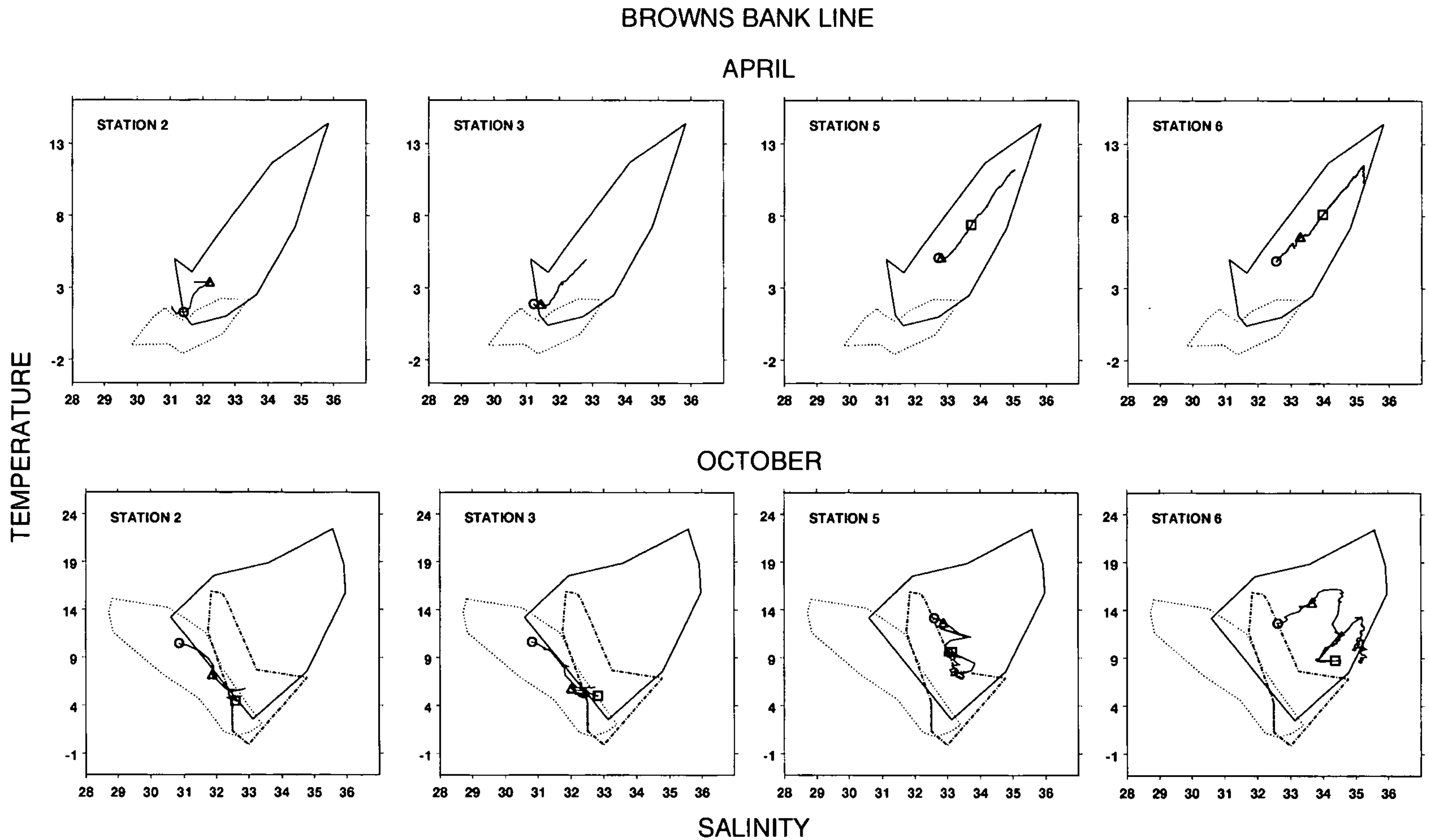
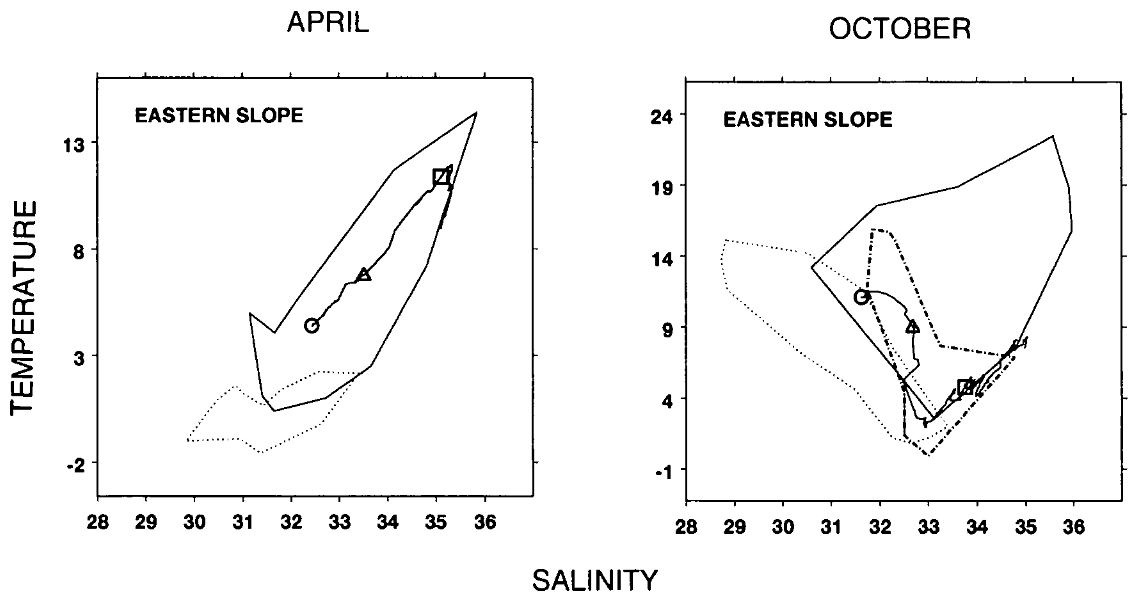


Fig. 5. TS plots for the Browns Bank line and the eastern Slope station for April and October, 1997. The polygons represent the boundaries of TS data in the AFAP TS data base. Dotted line encloses data from the western end of Cabot Strait, the dashed line encloses data from the Newfoundland slope and the solid line polygon enclosed data from the Nova Scotia Slope. Data within the polygons are for April and October. Circle represents TS at 10 m, triangle TS at 50 m and square TS at 100m.



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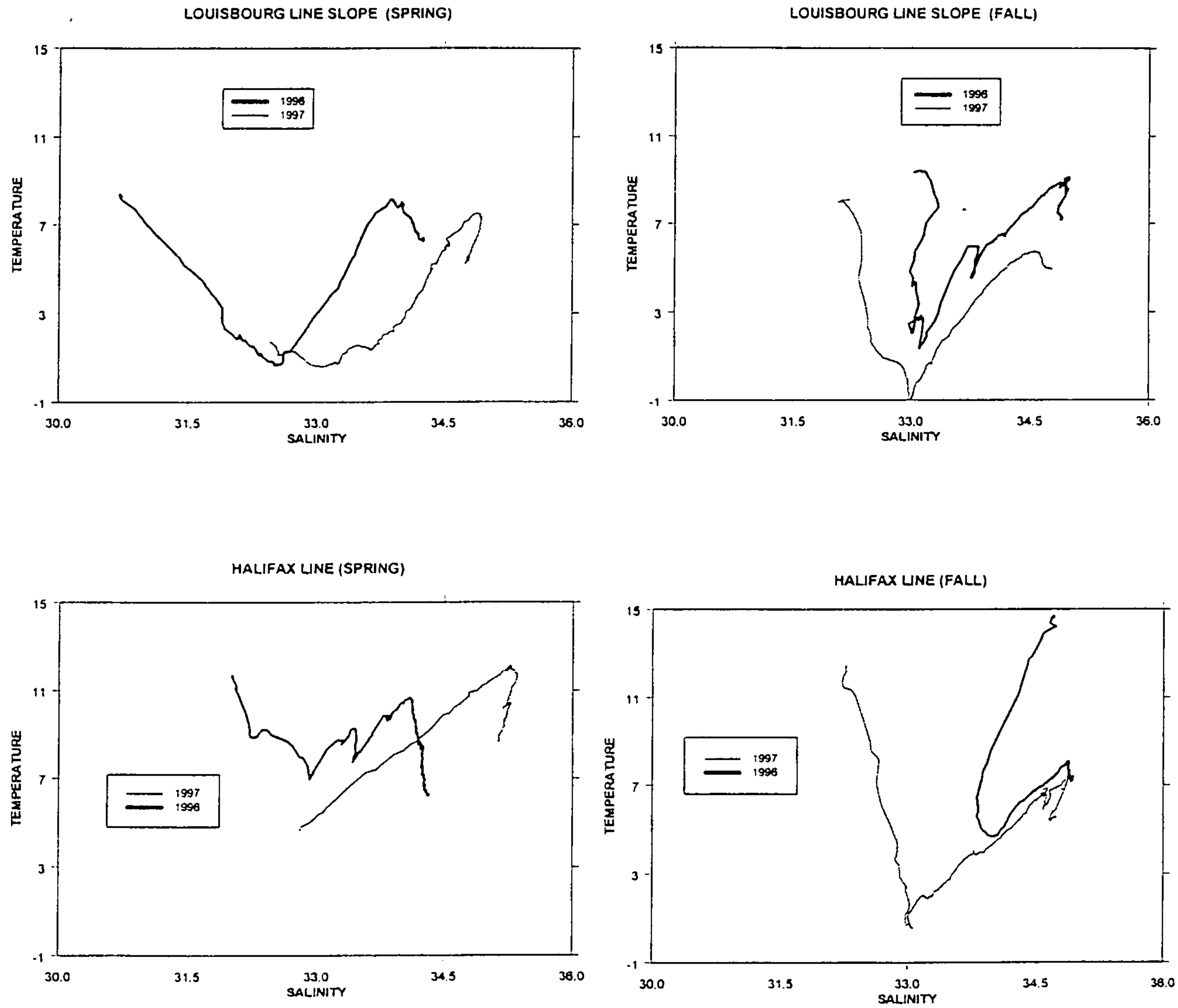

Fig. 6. TS plots for the slope stations on the Louisbourg and Halifax lines for spring and fall 1996 and 1997.

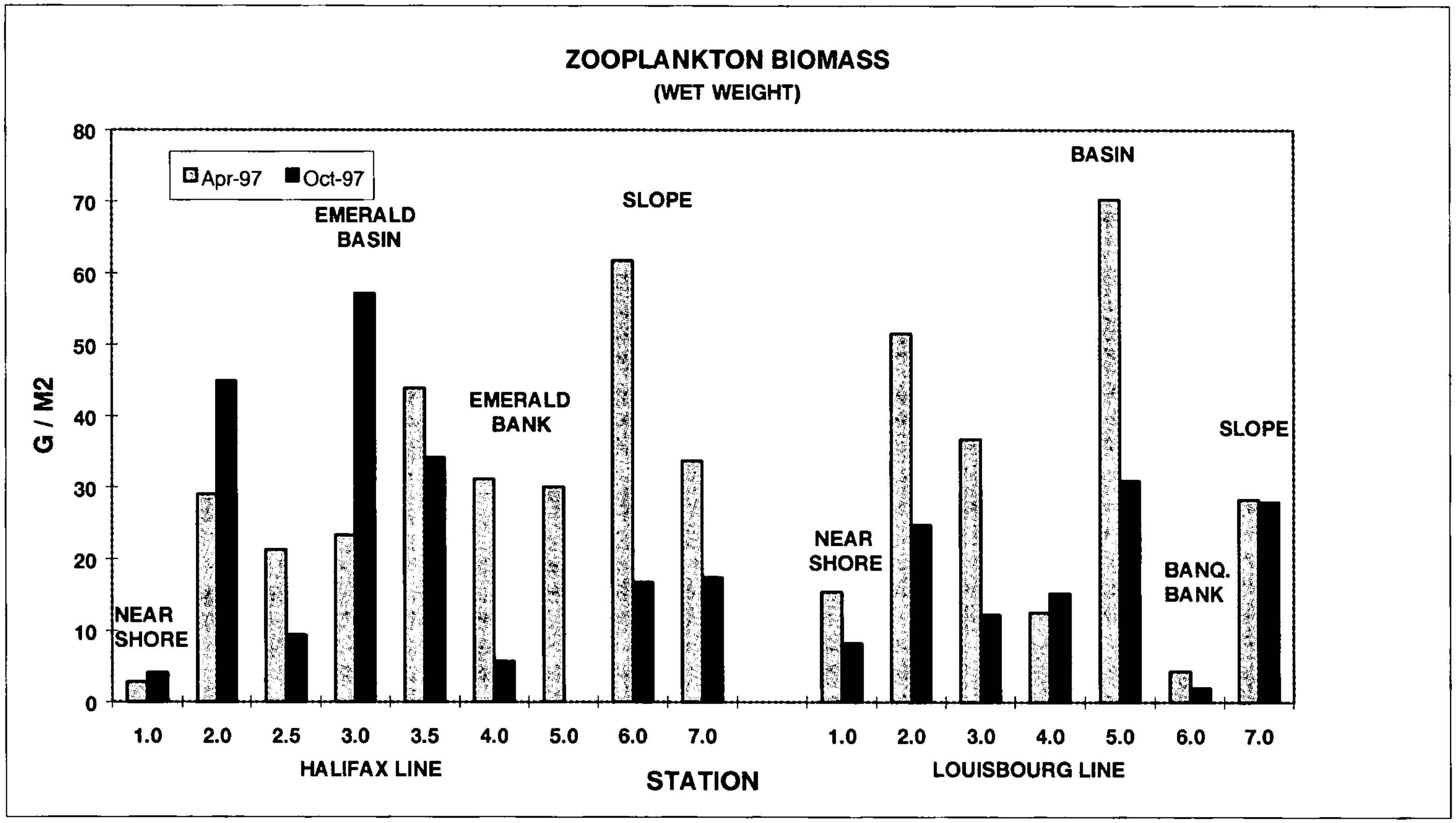

Fig. 7. Wet biomass of zooplankton per m2 for stations on the Halifax and Louisbourg lines for April and October, 1997.

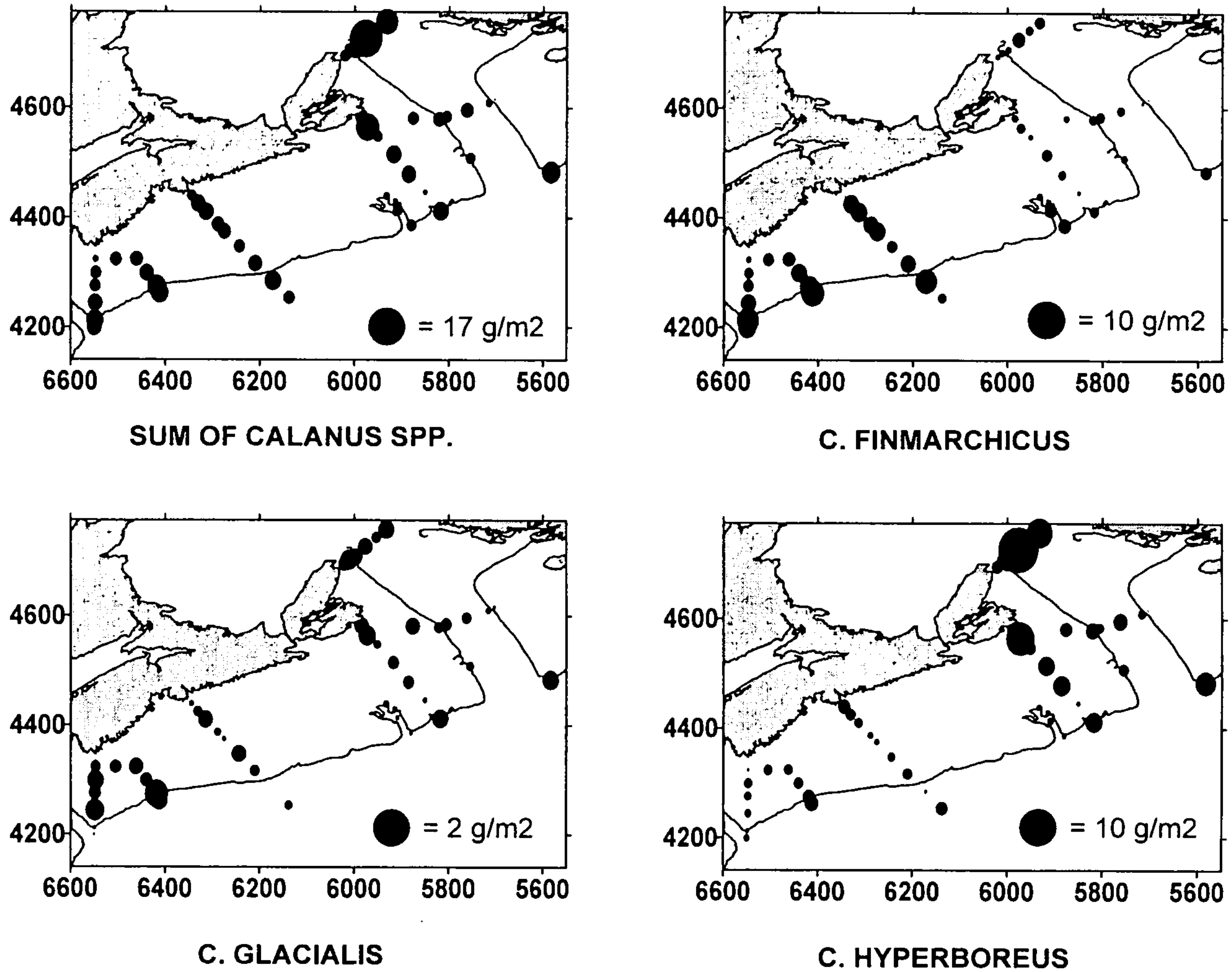

Fig. 8. Biomass (g dry weight per m2) of Calanus spp. on and around the Scotian Shelf in April 1997

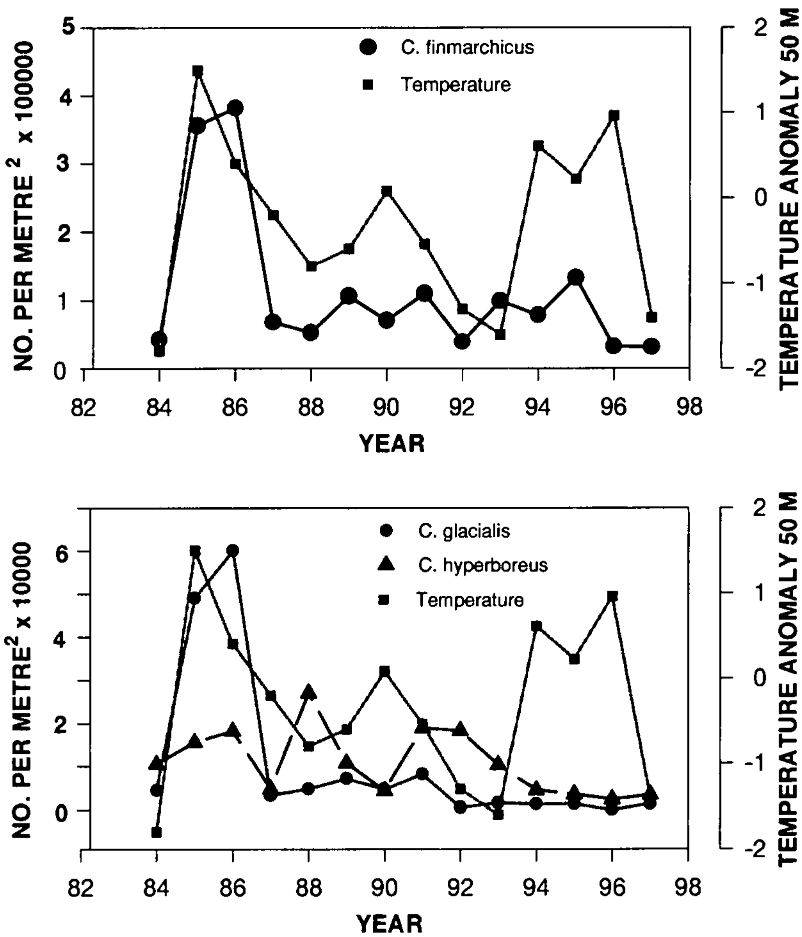

Fig. 9. Concentrations of Calanus species in Emerald Basin and the June temperature anomaly between 1984 and 1997.

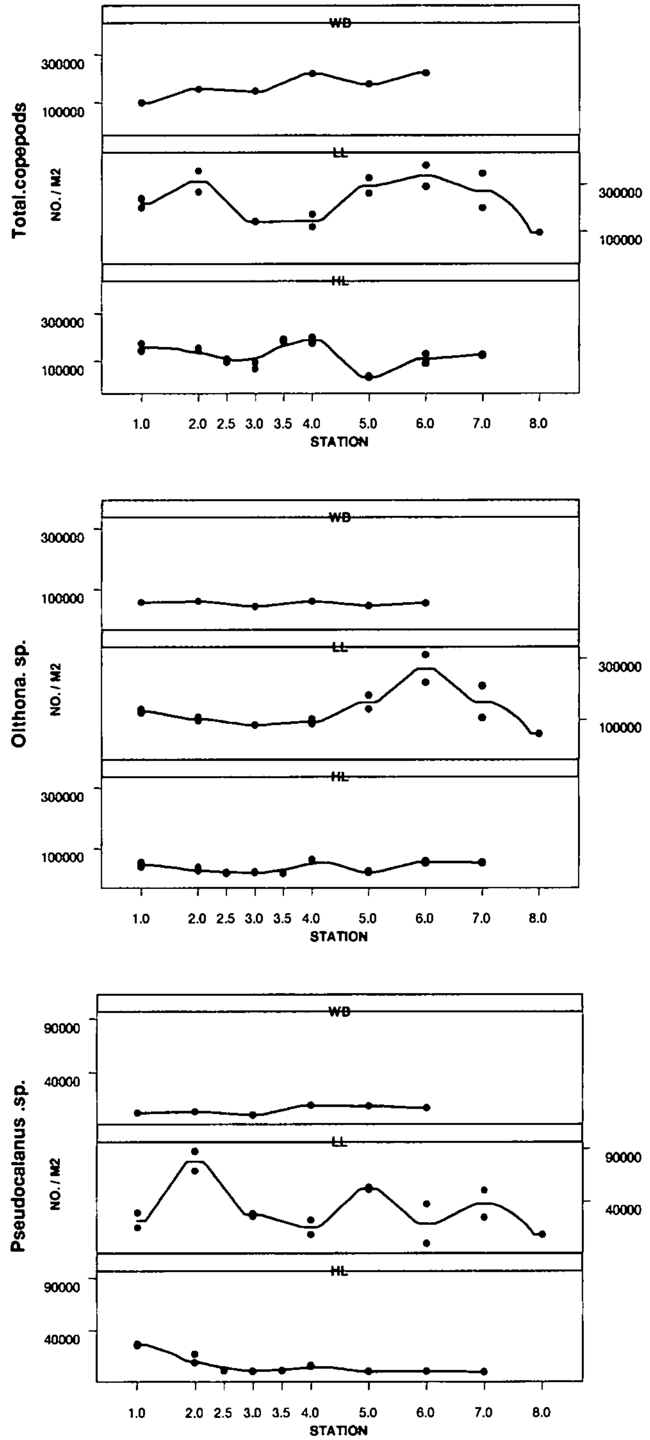

Fig. 10. Total copepods, Oithona similis and Pseudocalanus sp. per m2 collected with 0.2 m dia. bongo nets on the HL , LL and WB lines. Both replicates are shown for HL and LL but only one replicate is shown for WB. Lines are least squares fitted cubic spline smoothers.

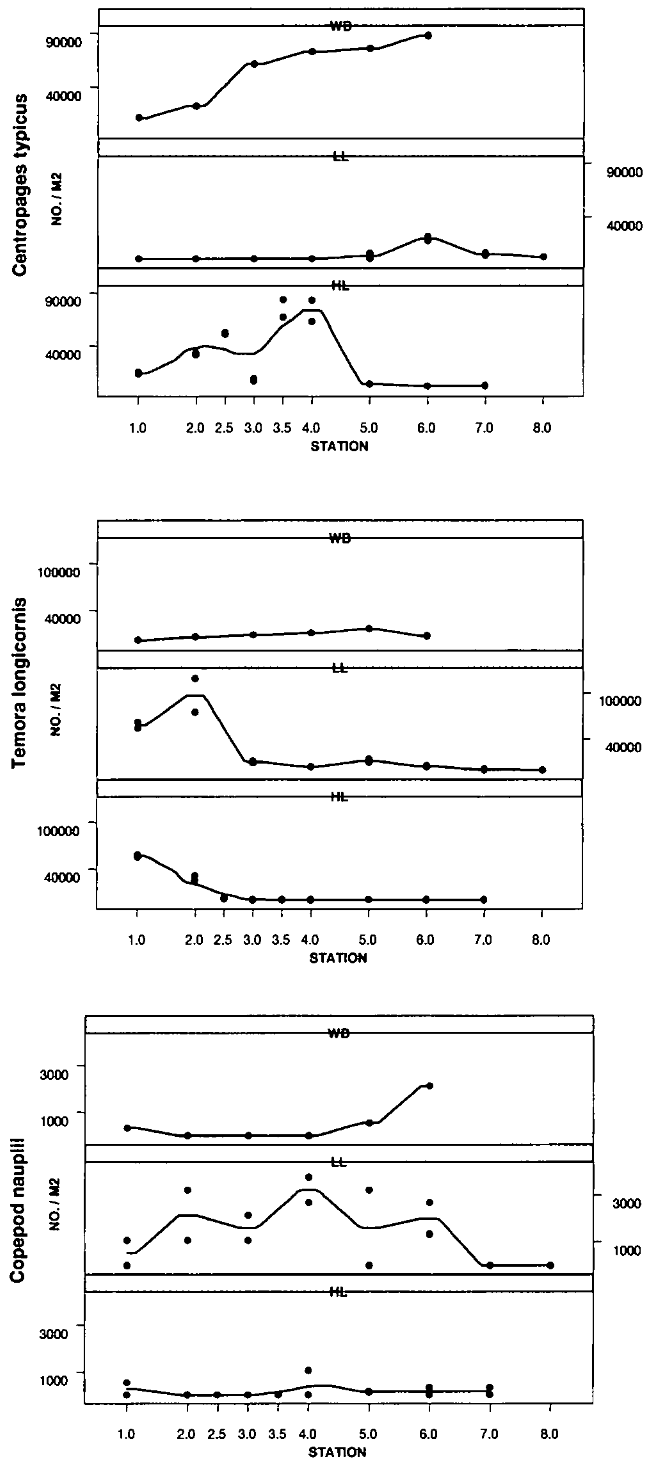

Fig. 11. Total numbers of Centropages typicus, Temora longicornis and copepod nauplii at stations along the Halifax (HL), Louisbourg (LL) and Western Bank (WB) lines. See Fig. 10 for more details.

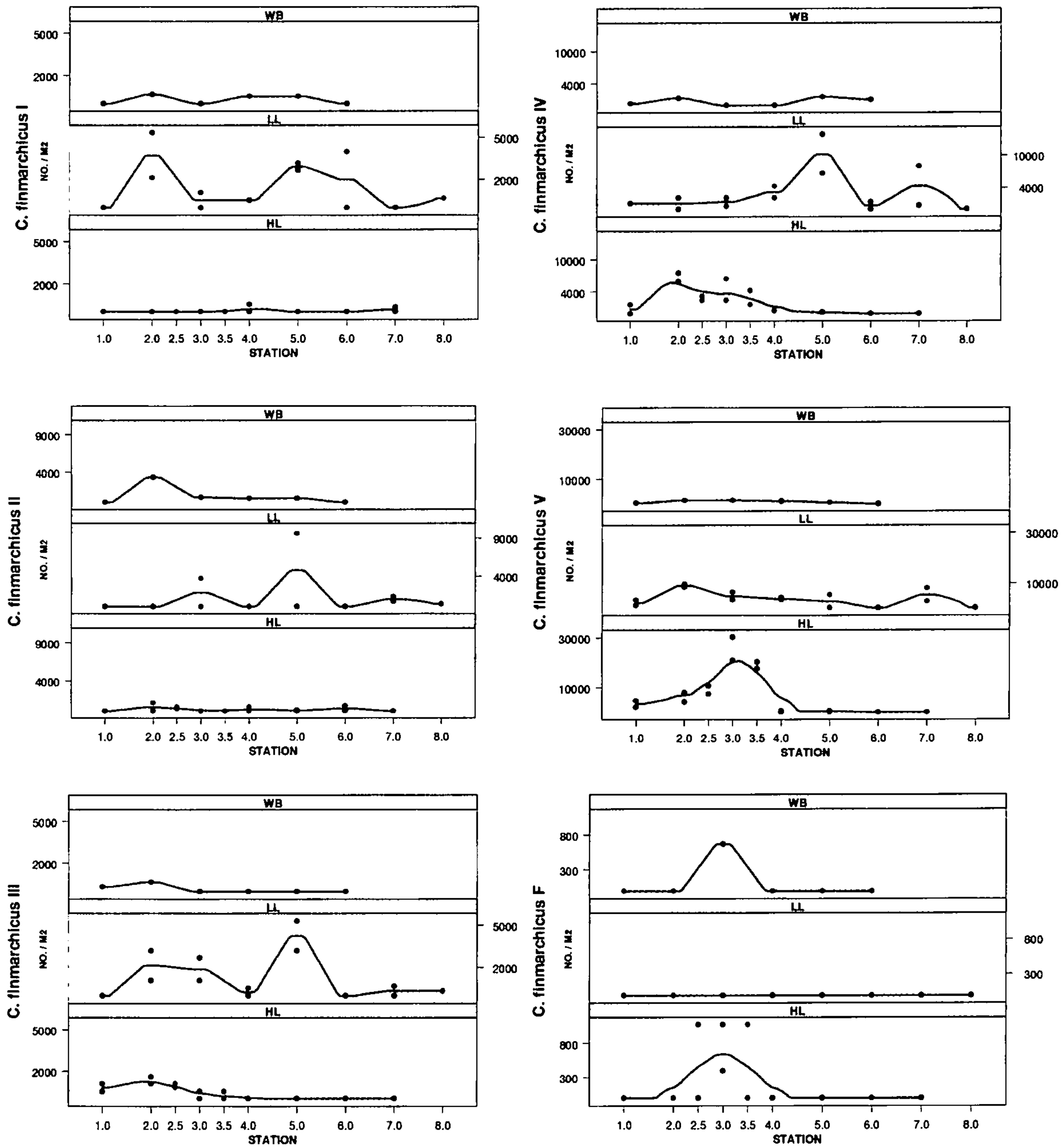

Fig. 12. C. finmarchicus copepodite stage concentrations per m2 for HL, LL and WB. See Fig. 10 for details.

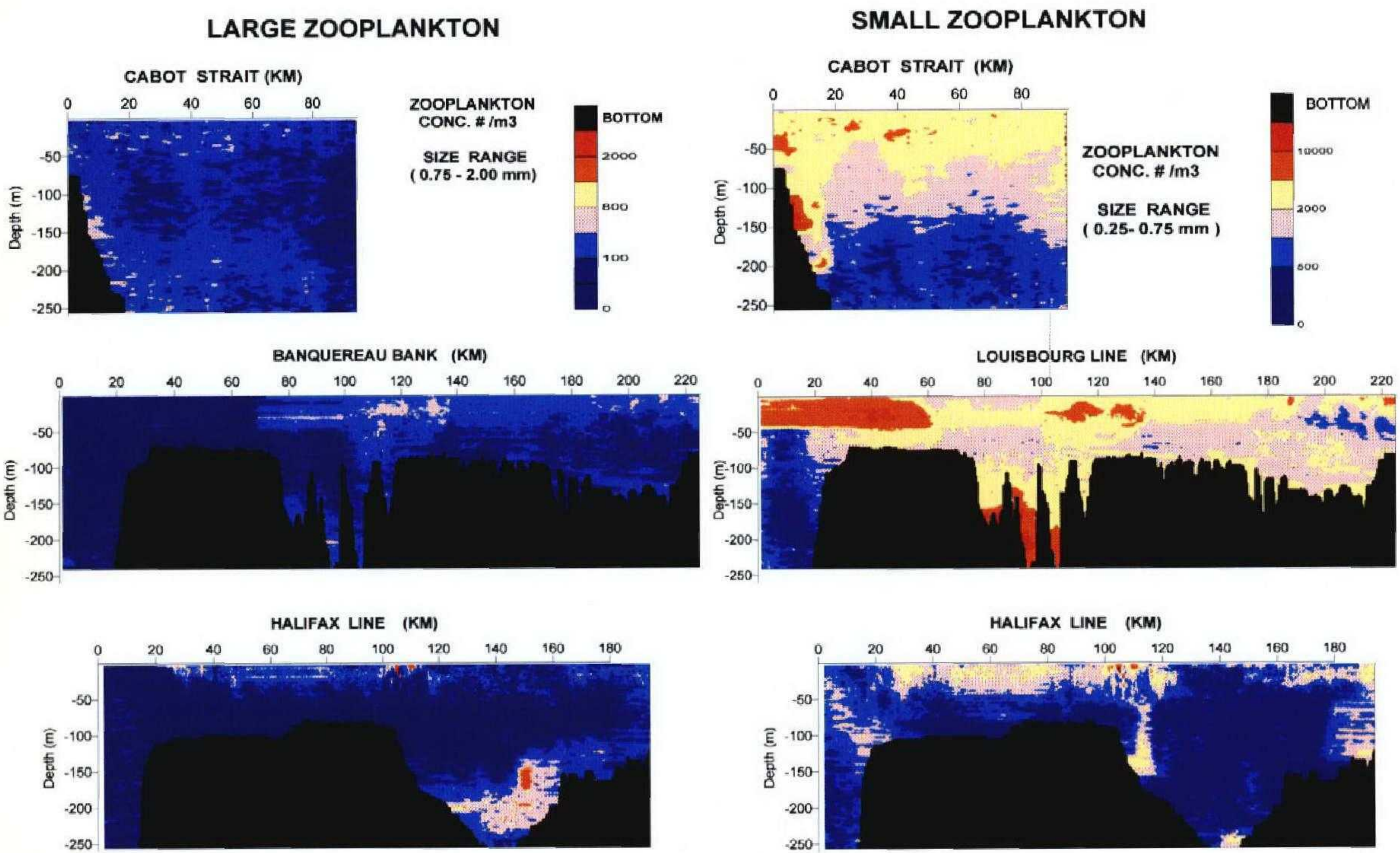

Fig. 13. Concentrations of large (0.75 - 2.00 mm)and small (0.25 - 0.75 mm) zooplankton measured by the OPC mounted on the BATFISH.

200 kHz BACKSCATTERING LEVELS APRIL 1997

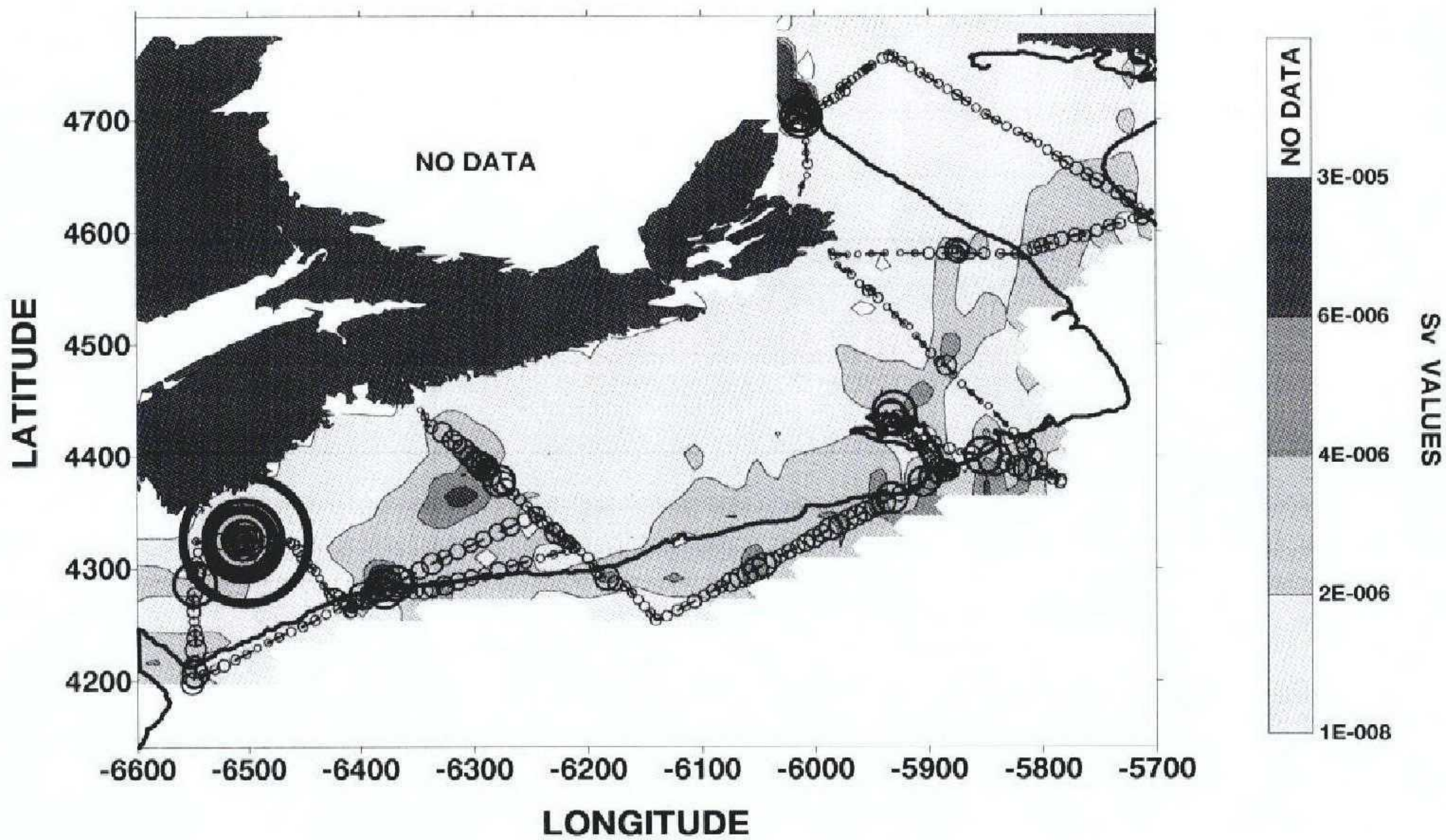

Fig. 14. Acoustic estimates of krill biomass per m2. The larger the circle diameter the higher the biomass. Calculated contours are also shown for the Sv values.

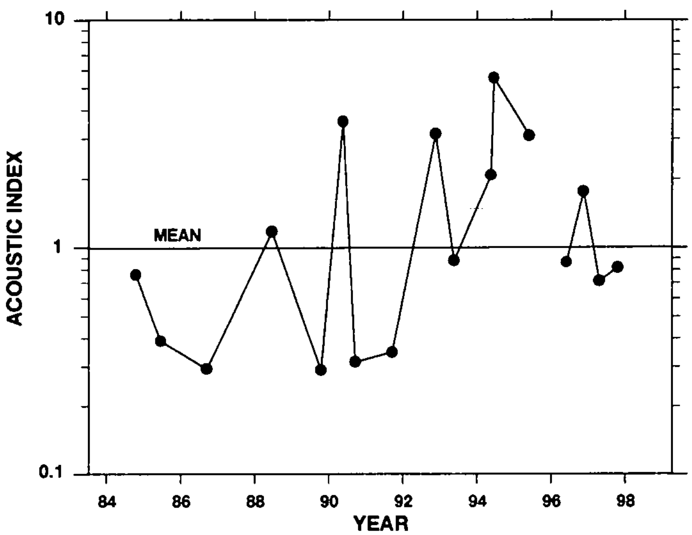

Fig. 15. Acoustic index of krill Emerald Basin.

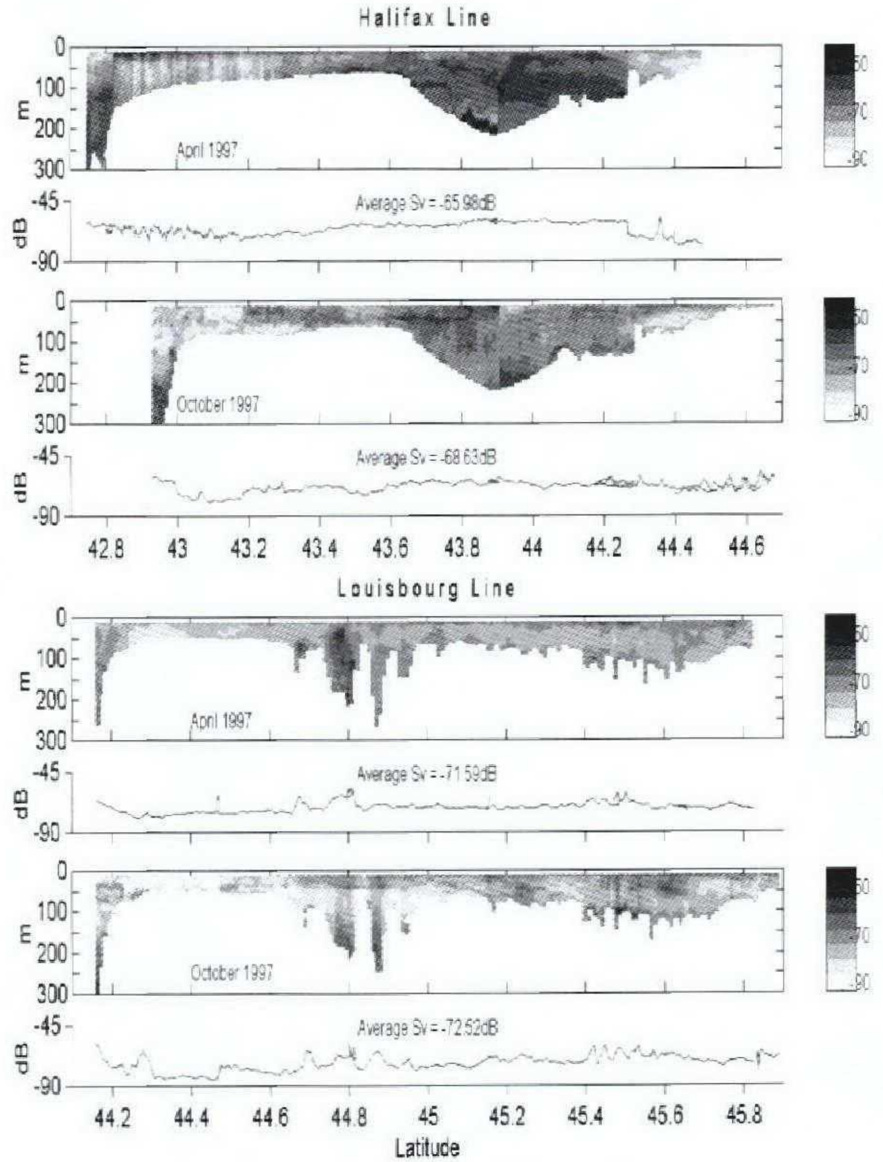

Fig. 16. Echograms from the RDI ADCP along the Halifax and Louisbourg Lines in April and October 1997 and the average volume backscattering in dBs for each line.

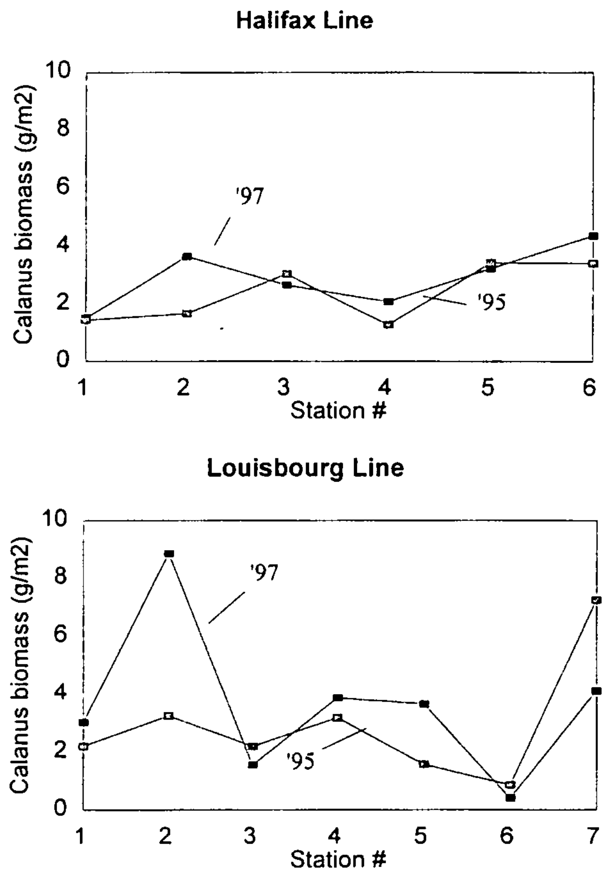

Fig. 17. Sum of the biomasses (g dry weight per m2) of Calanus spp. along the Halifax and Louisbourg Lines in April 1995 and 1997