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Temperature Conditions in the Gulf of St. Lawrence and on the Scotian Shelf during 1996 Relevant to Snow Crab

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ABSTRACT

Near-bottom temperatures during 1996 for areas inhabited by snow crab are presented, specifically for the southern Gulf of St. Lawrence, Sydney Bight and the northeastern Scotian Shelf. Data were available from groundfish surveys in the Laurentian Channel area in January, on the Scotian Shelf in July, and in the Gulf in September. Bottom temperatures in the regions of interest were generally <3°C, conditions ideal for snow crab. Relative to the long-term means, the present temperatures are generally below normal. Time series of the area of the southern Gulf covered by temperatures <0°C and <1°C indicate that cold conditions have persisted there since the late 1980s. On Sydney Bight and on the northeastern Scotian Shelf around Misaine Bank, temperature time series at 100 m show colder-than-normal conditions since the mid-1980s. These 100 m measurements are representative of conditions for depths from 50 m to approximately 200 m.

RÉSUMÉ

L'étude porte sur les températures de l'eau, près du fond en 1996, dans les zones habitées par le crabe des neiges, en particulier dans le sud du golfe du Saint-Laurent, dans la baie de Sydney et dans la partie nord-est du plateau néo-écossais. Les données ont été tirées de levés effectués sur le poisson de fond dans le secteur du chenal Laurentien en janvier, sur le plateau néo-écossais en juillet et dans le golfe en septembre. Les températures de fond dans les régions visées étaient en général inférieures à 3 °C, soit des conditions idéales pour le crabe des neiges. Comparativement aux moyennes à long terme, les températures actuelles sont généralement sous la normale. Les séries chronologiques de la région du sud du golfe correspondant à des températures <0 °C et <1 °C indiquent que les conditions d'eau froide persistent dans cette région depuis la fin des années 1980. Dans la baie de Sydney et sur la partie nord-est du plateau néo-écossais aux environs du banc de Misaine, les séries chronologiques des températures à 100 m de profondeur indiquent des températures inférieures à la normale depuis le milieu des années 1980. Ces relevés à 100 m sont représentatifs des conditions en vigueur à des profondeurs variant entre 50 et 200 m environ.

Introduction

Snow crab (*Chionoecetes opilio*) is a cold-water species typically inhabiting bottom depths of 80-200 m in water temperatures < 3°C. An active and very lucrative fishery presently exists in the Gulf of St. Lawrence, on Sydney Bight and on the northeastern Scotian Shelf. Annual assessments of the stock abundance, fishing effort, biological characteristics and the environment of the snow crab are undertaken by the Maritimes Region of the Department of Fisheries and Oceans (DFO). The purpose of this paper is to provide information on the temperature conditions during 1996 in areas occupied by snow crab and to compare these temperatures to their long-term means. A similar exercise was undertaken last year (Drinkwater and Pettipas, 1996). We begin with a description of the temperature data, then provide details of the methods used to analyze the temperature fields and finally present the results.

Data

Extensive near-bottom temperatures in our areas of interest were available from three DFO groundfish surveys. All data were collected with a conductivity-temperature-depth (CTD) instrument. The first was undertaken in the Laurentian Channel and adjacent shelf regions during January. For this study, only stations from the western side of the Channel and on the Magdalen Shallows, Sydney Bight and the northeast Scotian Shelf were used (Fig. 1a). The second CTD dataset covered Sydney Bight and the northeastern Scotian Shelf and was part of the annual summer groundfish survey of the Scotian Shelf during July (Fig. 1b). The final dataset was the Gulf of St. Lawrence annual groundfish survey in September that covered the Magdalen Shallows (Fig. 1c). Additional temperature data from 1996 were obtained from the Marine Environmental Data Service (MEDS) in Ottawa, Canada's national oceanographic data archive, and from other regional DFO fisheries surveys (J. McRuer, BIO, personal communication). Pre-1996 data used to estimate long-term means were obtained from the historical hydrographic database maintained at the Bedford Institute of Oceanography (BIO) that contains an edited version of the MEDS holdings in our area of interest.

Methods

The near-bottom temperatures from each of the hydrographic surveys were interpolated onto a specified grid using an objective analysis procedure known as optimal estimation, as was described last year (Drinkwater and Pettipas, 1996). This method is similar to other objective techniques such as kriging but offers the advantage that interpolation is 4-dimensional; three space dimensions, two horizontal and one vertical, and the time dimension. In this study the surveys were treated as synoptic and no interpolation in time was carried out. The interpolation used the 15 nearest neighbours within a radius of up to 30 km in the horizontal (x,y) direction and within 15 m of the bottom between 0-50 m and 25 m at depths > 50 m. The maximum profile depth for each station was assumed to be the bottom depth and checked against bathymetric charts. The temperature grid for the Scotian Shelf in July and for the Laurentian Channel area in January was 0.2x0.2° latitude-longitude and the grid boundaries were selected to match the survey areas. For the Gulf of St. Lawrence in September the grid was 0.1x0.1° latitude-longitude. The data were then smoothed and the bottom temperatures contoured. There was, however, no smoothing of the January data. This was because the computer contouring package, through its smoothing routine, produced an unrealistic (weak) temperature gradient over the steep slope of the Laurentian Channel. Instead, the raw optimally-estimated temperatures were hand-contoured. The Gulf of St. Lawrence data collected in September were restricted to depths ≥ 30 m for plotting purposes. High temperatures at shallower depths led to strong bottom-temperature gradients towards the coasts which were incorrectly contoured. Also, snow crab do not usually occupy these depths.

Long-term monthly climatological means of the near-bottom temperatures were estimated at each grid point based upon optimal estimations using all available data in the historical temperature, salinity database at the Bedford Institute for the years 1961-1990. The thirty-year period was chosen to coincide with that used by the meteorologists and recommended by the Northwest Atlantic Fisheries Organization (NAFO). The climatological means were then subtracted from the 1996 survey data to produce temperature differences from the long-term means, hereafter referred to as anomalies. For the January survey, we used the long-term means determined last year (Drinkwater and Pettipas, 1996). This meant that no means were available for the region north of Cabot Strait. For the January and July surveys, we also examined the change in temperature since last year by subtracting the 1995 optimally estimated temperatures from the 1996 estimates.

In addition to the optimally-estimated bottom temperatures, monthly mean temperature profiles were determined for Sydney Bight (area 1 of Drinkwater and Trites (1987); Fig. 2) and Misaine Bank on the northeastern Scotian Shelf (area 5; Fig. 2). All available data within each of these areas were averaged by month at standard depths (0, 10, 20, 30, 50, 75, 100, 125, 150, 175, 200, 250, 300 m). We also present the area of the Magdalen Shallows covered by waters <0°C and <1°C. For this analysis depths were restricted to ≤ 155 m. These depth limitations were imposed for interannual comparisons because no depths greater than 155 m were sampled during the years 1984-1988.

Results

Near-bottom Temperatures

Near-bottom temperatures during the January survey of the Laurentian Channel and vicinity ranged from < 1°C in shallow waters on the Magdalens, Sydney Bight and northeastern Scotian Shelf to over 6°C in the deep Laurentian Channel (Fig. 3). The temperature pattern reflects the topography with a very sharp temperature gradient along the steep slope of the Laurentian Channel. The colder shelf waters (<2°C) are relatively low in salinity, whereas the warmer waters in the deeper Channel are higher in salinity and of offshore (Labrador slope water) origin. Subtracting the long-term means show that the bottom temperature anomalies in January were near normal, generally being < ± 1°C over the region (Fig. 3). Exceptions were the colder-than-normal temperatures on northern Sydney Bight and in the southern region of the survey, with the lowest anomalies centred near the 200 m isobath. Relative to last year's January survey, temperatures changed little (Fig. 4). The largest differences lay along the 200 m isobath where temperatures generally decreased by 1-3°C. This may be explained by a deepening of the cold upper layers waters in this area.

In July, near-bottom temperatures were estimated for the entire Scotian Shelf although for this study we were only interested in the northeastern region and Sydney Bight. The data show that in these areas, bottom waters were primarily <3°C with significant sections <2°C (Fig. 5). Temperatures there were almost exclusively below their long term means by upwards of 2°C (Fig. 5), however, they did warm relative to July 1995 over most of this region (Fig. 6). Exceptions were on the outer banks of the Scotian Shelf, such as Banquereau, and on the northeastern edge of the shelf where bottom temperatures decreased from 1995 to 1996.

On the Magdalen Shallows, bottom temperatures below 30 m show a range of < 0°C to over 10°C (Fig. 7). The coldest waters extend over a large region north of Prince Edward Island in depths of 50-80 m. From there, bottom temperatures tend to increase towards the shallower, near shore regions and towards the deeper Laurentian Channel. This is because during summer in the Gulf of St. Lawrence the coldest temperatures are found at intermediate depths (50-150 m). These cold intermediate layer (CIL) waters are sandwiched between the warm solar-heated upper layer waters and the relatively warm, salty deep waters of the Laurentian Channel. In winter, the CIL layer merges with the upper layer as the latter cools. The origin of the waters in the CIL is thought to be by advection of cold Labrador Shelf water through the Strait of Belle Isle and atmospheric cooling of the water within the Gulf of St. Lawrence in winter. The warmest, near-bottom waters are in the shallowest regions, in particular around the Magdalen Islands. The waters were generally below normal by 0 to 1°C except around the Magdalen Islands and the southern regions of the Magdalen Shallows (Fig. 7).

Areal Index of Cold Water on the Magdalen Shallows

One measure of the temperature conditions on the Magdalen Shallows is the areal index of the bottom covered by waters < 0°C and <1°C during the September groundfish survey (Swain, 1993). In 1996, these areas were 15350 km^2 and 36965 km^2, respectively, both down slightly from 1995 (Fig. 8). They still remain relatively high, however, indicating that much more cold water covers the Magdalen Shallows than normal. This large amount area of cold water has persisted since approximately 1989. It is also consistent with the very cold CIL waters throughout the Gulf of St. Lawrence since the mid-1980s as first revealed by Gilbert and Pettigrew (1997) and updated in Drinkwater et al. (1996).

Monthly Mean Temperature Anomaly Profiles

On Sydney Bight (area 1 in Fig. 2) vertical profiles of the monthly mean temperatures were available for 7 months in 1996. Expressed as temperature anomalies, they exhibit high variability in the upper 100 m of the water column and especially in the near surface (< 50 m) waters (Fig. 9). Between 100 and 200 m there is a tendency towards negative temperature anomalies but in January anomalies were positive. At depths > 250 m, which were restricted to the Laurentian Channel or along its slope, temperatures were above their long-term means but by less than 1°C. Temperature variability throughout the water column was not as high as last year (Drinkwater and Pettipas, 1996). The time series of the temperature anomalies at 100 m show that in the years since the mid-1980s, temperatures have been as low as 1.5°C below the long-term mean. During 1995 and 1996 temperatures have primarily remained below normal but are suggestive of a slight warming with some positive monthly temperature anomalies.

Monthly mean temperature profiles for Misaine Bank (area 5 in Fig. 2) were available for 6 months during 1996. They too show variable upper layer temperatures with the most prominent anomalies during June when near surface anomalies were approximately 4°C above normal (Fig. 10). During most months, temperatures in the top 50 m of the water column were at or below normal. The most consistent temperature feature was the relatively cold water at depths >50 m. Temperature anomalies there were typically between 0 and -2°C. The time series of the temperature anomalies at 100 m shows that these negative values have persisted since approximately the mid-1980s (Fig. 10). Recent years have been the coldest or near coldest since the 1950s and match the cold period of the 1960s. This pattern is indicative of the water column below 50 m. Absolute temperatures at 100 m are typically 1-2.5°C depending upon the time of the year.

Summary

Near-bottom temperatures collected during groundfish surveys in January in Cabot Strait and Sydney Bight, in July on the northeastern Scotian Shelf and in September on the Magdalen Shallows have been compared to their long term means. Additional temperature data on Sydney Bight and the Scotian Shelf were also examined. There was a tendency for colder-than-normal conditions throughout the region at bottom depths from approximately 50 m to 250 m. Such cold conditions that have persisted since the mid- to late-1980s. On Sydney Bight, temperatures were generally the same as observed in 1995 whereas on the northeastern Scotian Shelf they have warmed, perhaps signifying the beginning of a moderating trend. The near-bottom temperatures on the Magdalen Shallows, Sydney Bight and the northeastern Scotian Shelf are believed to be formed from a combination of local winter cooling plus advection, from the Labrador Shelf in the case of the Gulf of St. Lawrence and from the Gulf in the case of the bottom waters on Sydney Bight and the northeastern Scotian Shelf. Given that snow crab prefer temperatures <3°C, the relatively cold temperatures would appear to be favourable for snow crab.

Acknowledgements

We would like to thank G. Chouinard for providing us with the January survey CTD data and F. Page and R. Losier for the September survey data. Also we acknowledge the help of J. McRuer in securing these and additional data. Finally, we acknowledge T. Lambert and S. Wilson who provided CTD data collected during the sentinal surveys in the Sydney Bight region.

References

Drinkwater, K.F. and R. Pettipas. 1996. Near-bottom temperatures on Sydney Bight and the northeastern Scotian Shelf during 1995. DFO Atlan. Fish. Res. Doc. 96/136, 14 p.

Drinkwater, K.F. and R.W. Trites. 1987. Monthly means of temperature and salinity in the Scotian Shelf. Can. Tech. Rep. Fish. Aquat. Sci. 1539: 101 p.

Drinkwater, K.F., E. Colbourne and D. Gilbert. 1996. Overview of environmental conditions in the Northwest Atlantic in 1995. NAFO Sci. Coun. Studies 27: 1-37.

Gilbert, D. and B. Pettigrew. 1997. Interannual variability (1948-1994) of the CIL core temperature in the Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. Vol. 54 (Suppl. 1): 57-67.

Swain, D.P. 1993. Variation in September near-bottom temperatures in the southern Gulf of St. Lawrence, 1971-1992. DFO Atl. Fish. Res. Doc. 93/48, 17 p.

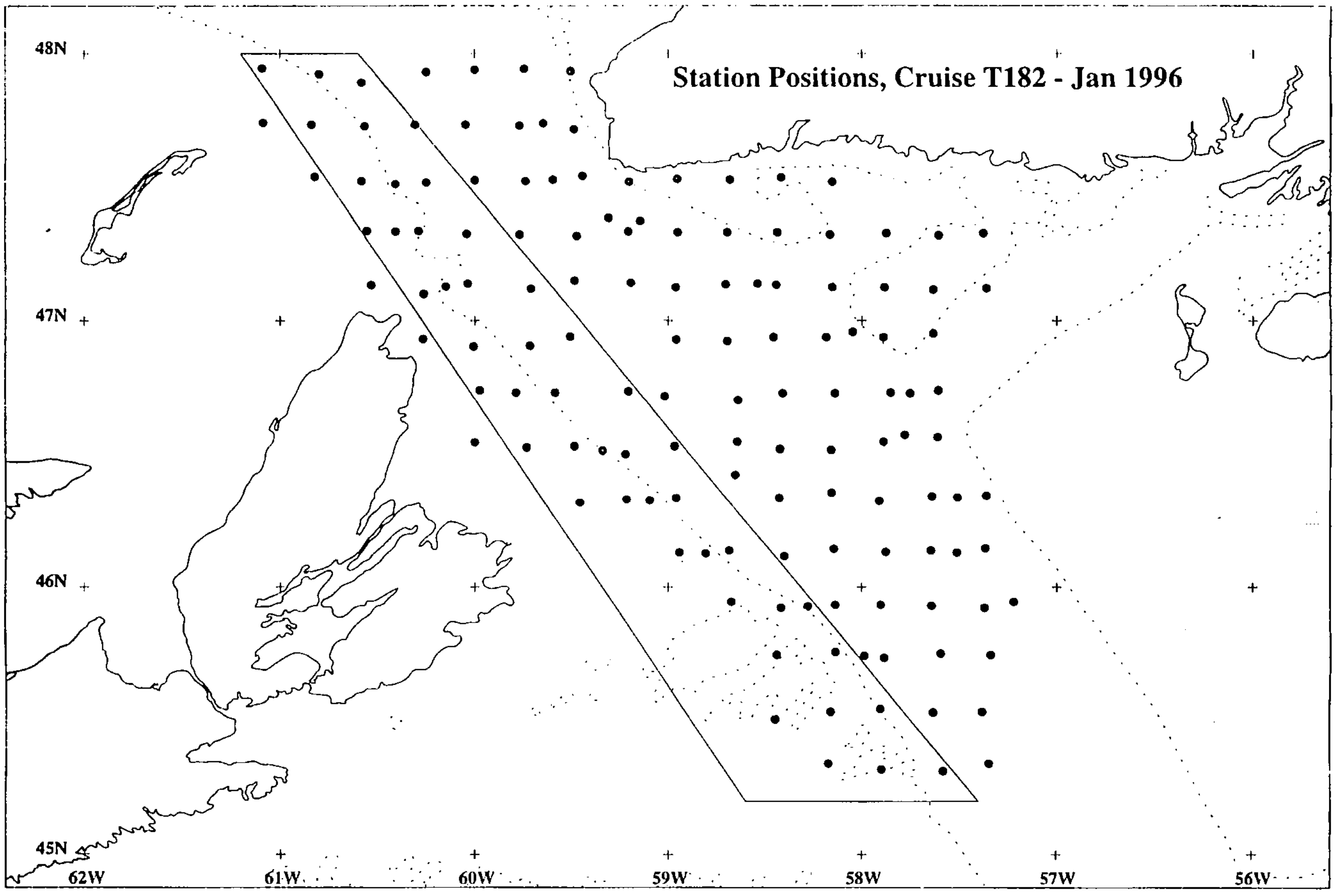


Fig. 1a The CTD stations during the January 1996 survey. The box indicates the area in which the bottom temperatures were optimally estimated.

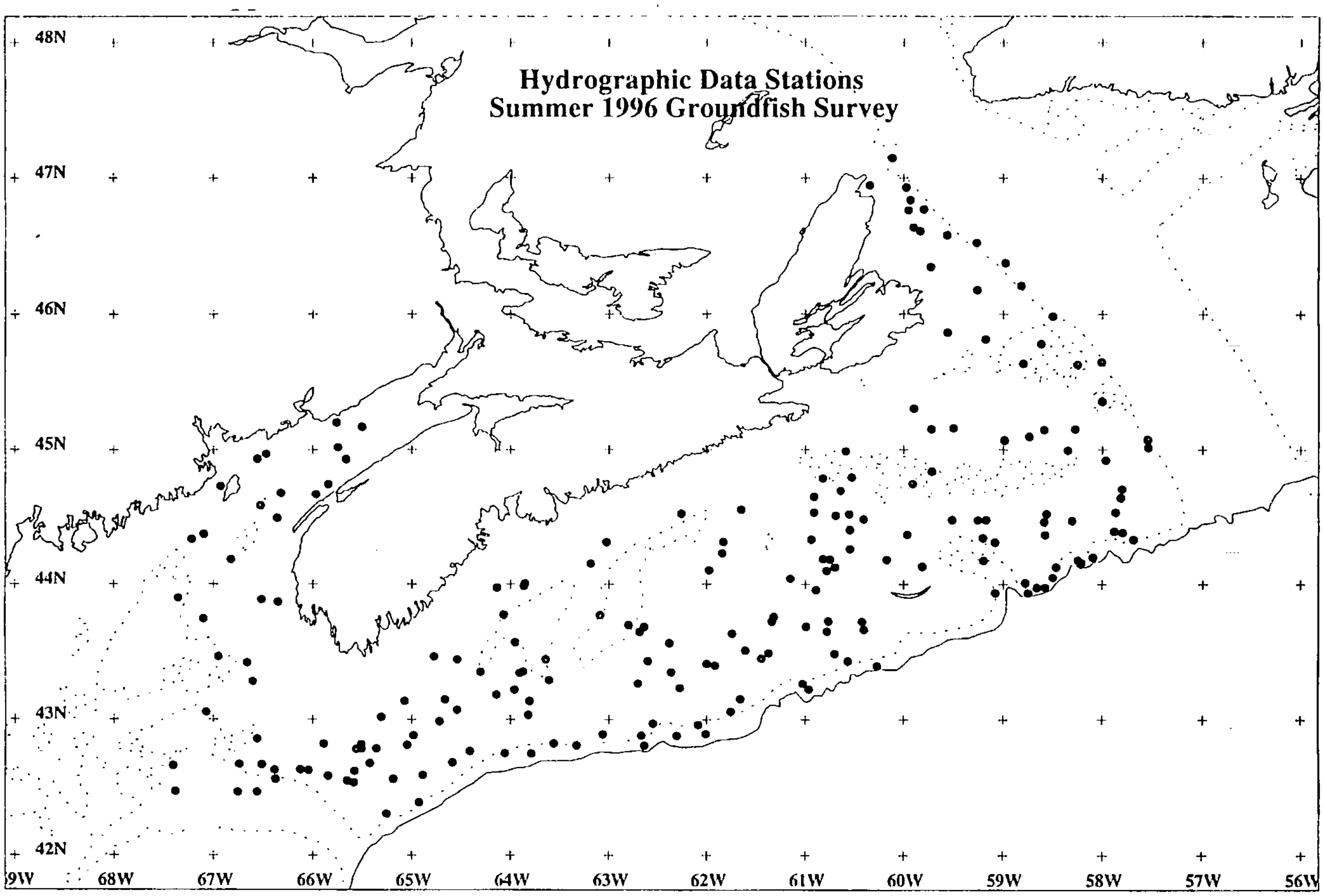


Fig. 1b The CTD stations during the July 1996 survey.

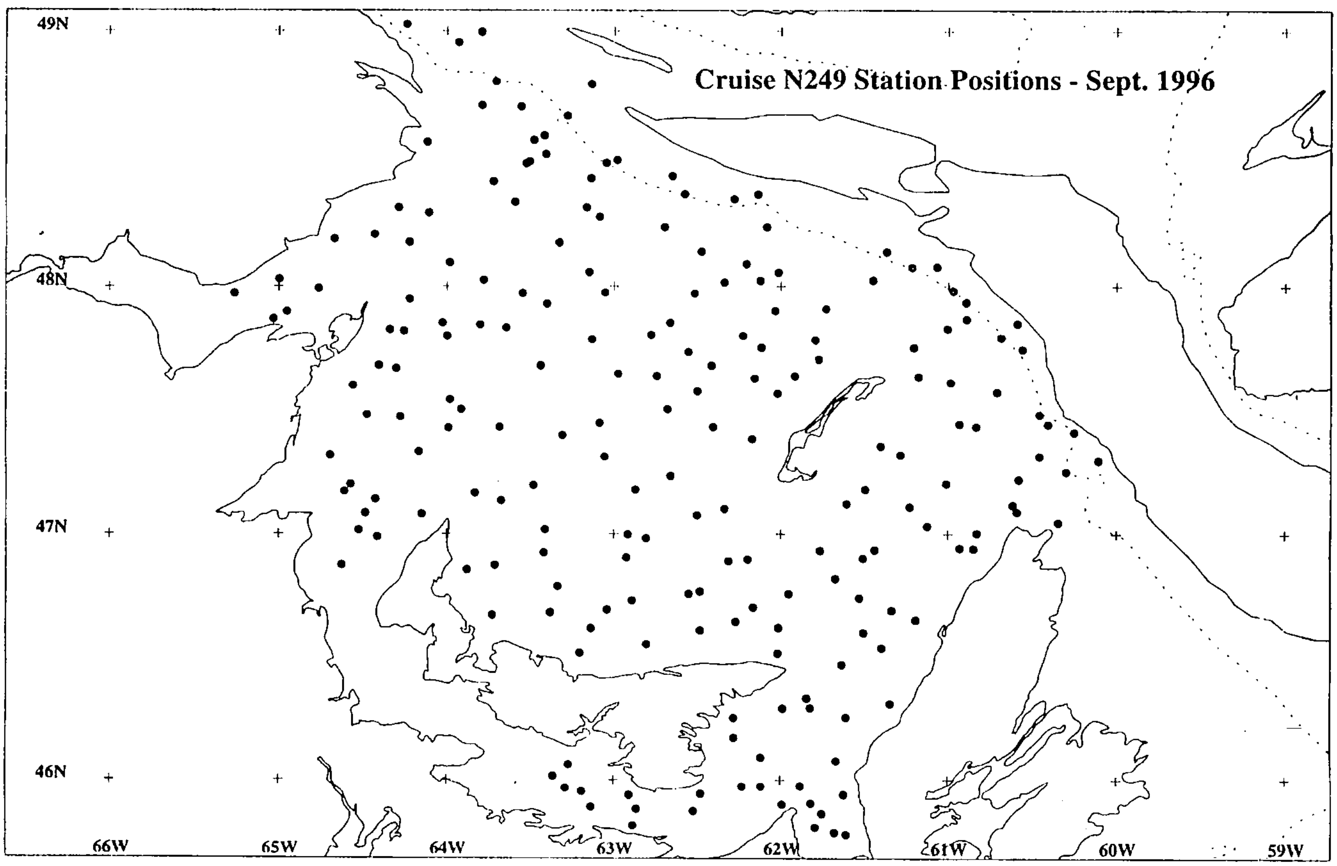
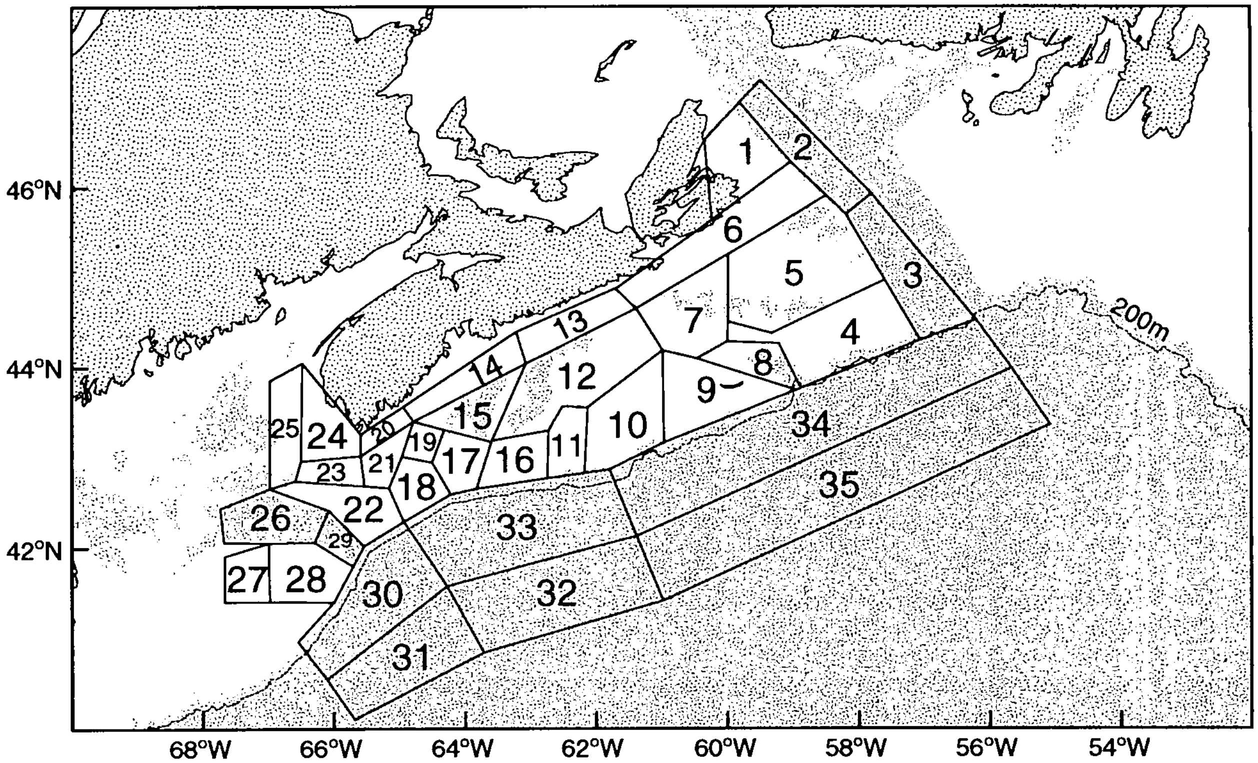


Fig. 1c The CTD stations during the September 1996 survey.



1. Sydney Bight
2. N. Laurentian Channel
3. S. Laurentian Channel
4. Banquereau
5. Misaine Bank
6. Canso
7. Middle Bank
8. The Gully
9. Sable Island
10. Western Bank
11. Emerald Bank
12. Emerald Basin
13. Eastern Shore
14. South Shore
15. Lahave Basin
16. Saddle
17. Lahave Bank
18. Baccaro Bank
19. Roseway Bank
20. Shelburne
21. Roseway Basin
22. Browns Bank
23. Roseway Channel
24. Lurcher Shoals
25. E. Gulf of Maine
26. Georges Basin
27. Georges Shoal
28. E. Georges Bank
29. N.E. Channel
30. Southern Slope
31. Southern Offshore
32. Central Offshore
33. Central Slope
34. Northern Slope
35. Northern Offshore

Fig. 2 The areas defined by Drinkwater and Trites (1987) for the Scotian Shelf.

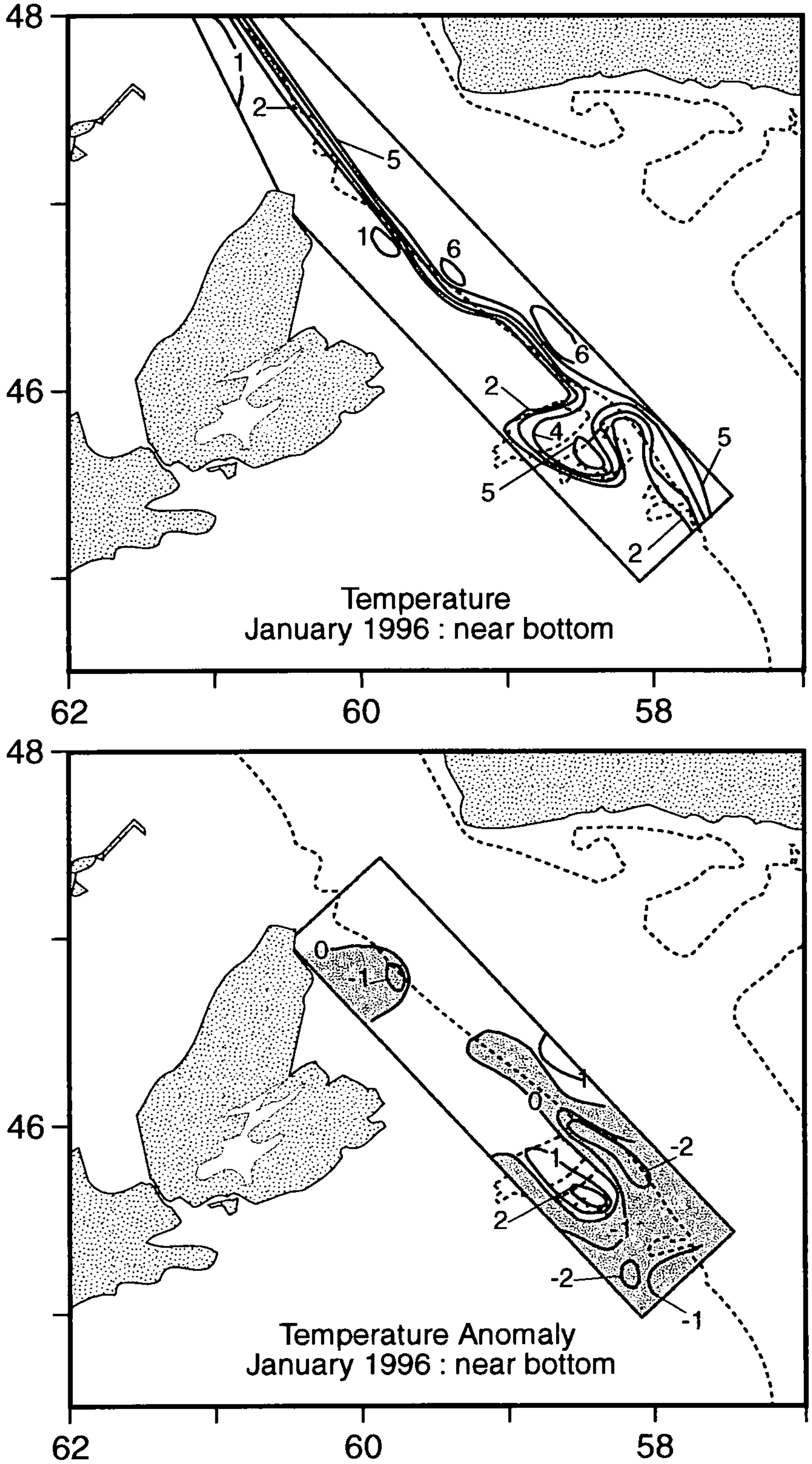


Fig. 3 The near-bottom temperatures (top panel) and their anomalies from the long-term (1961-90) means (bottom panel) during the January survey. Negative anomalies are shaded.

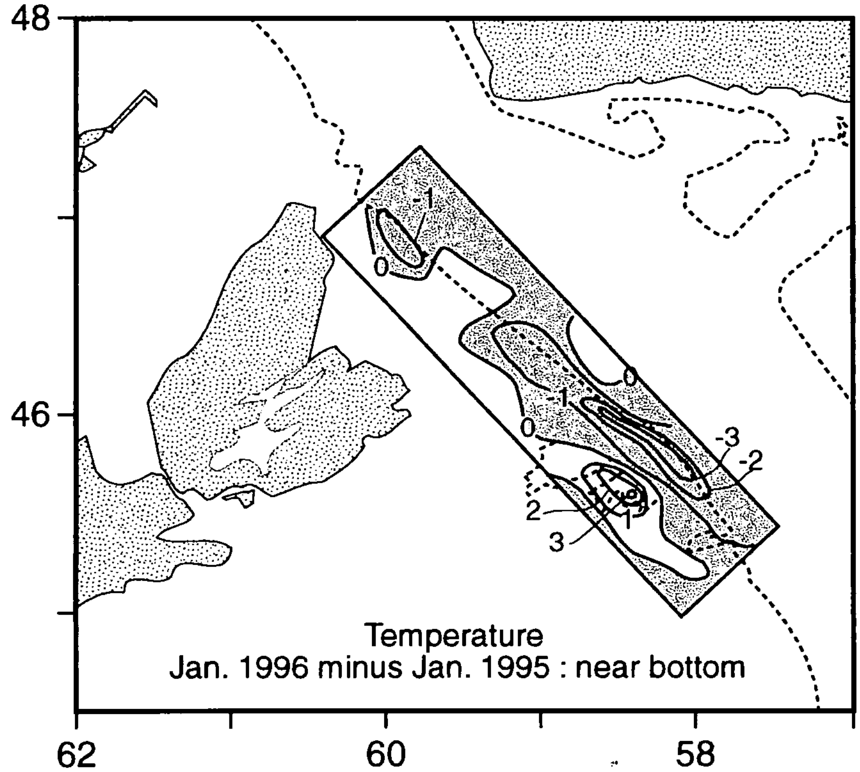
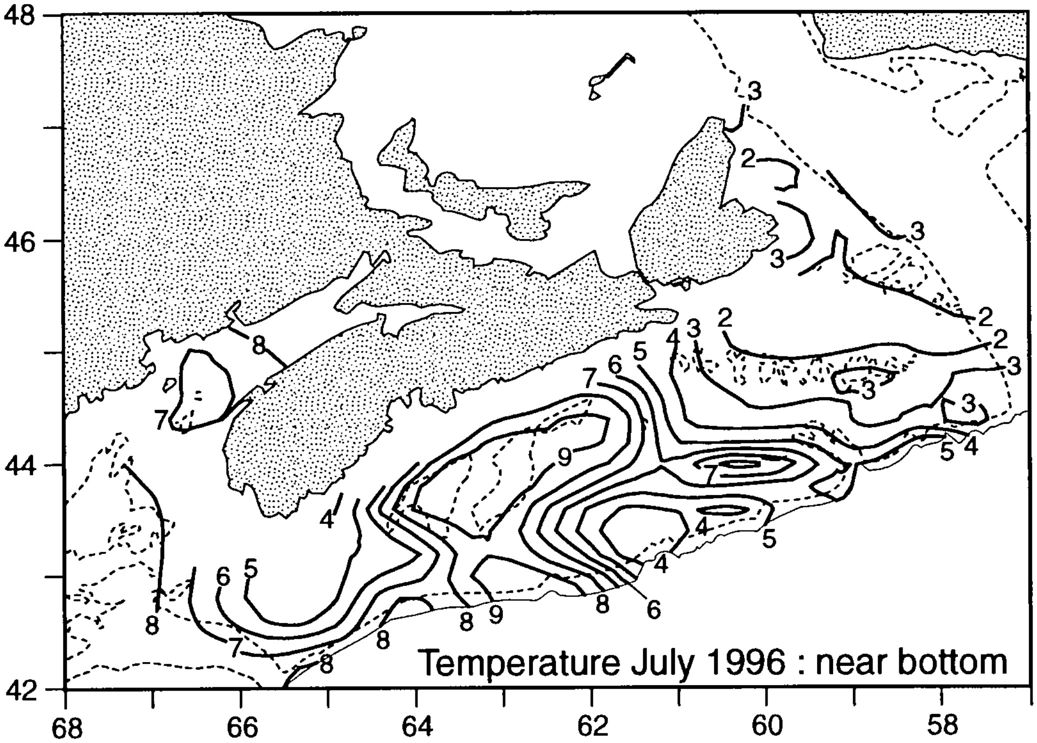


Fig. 4 The difference between the 1996 and 1995 temperature fields for the January survey. Positive values indicate warming and negative a cooling. Negative differences are shaded



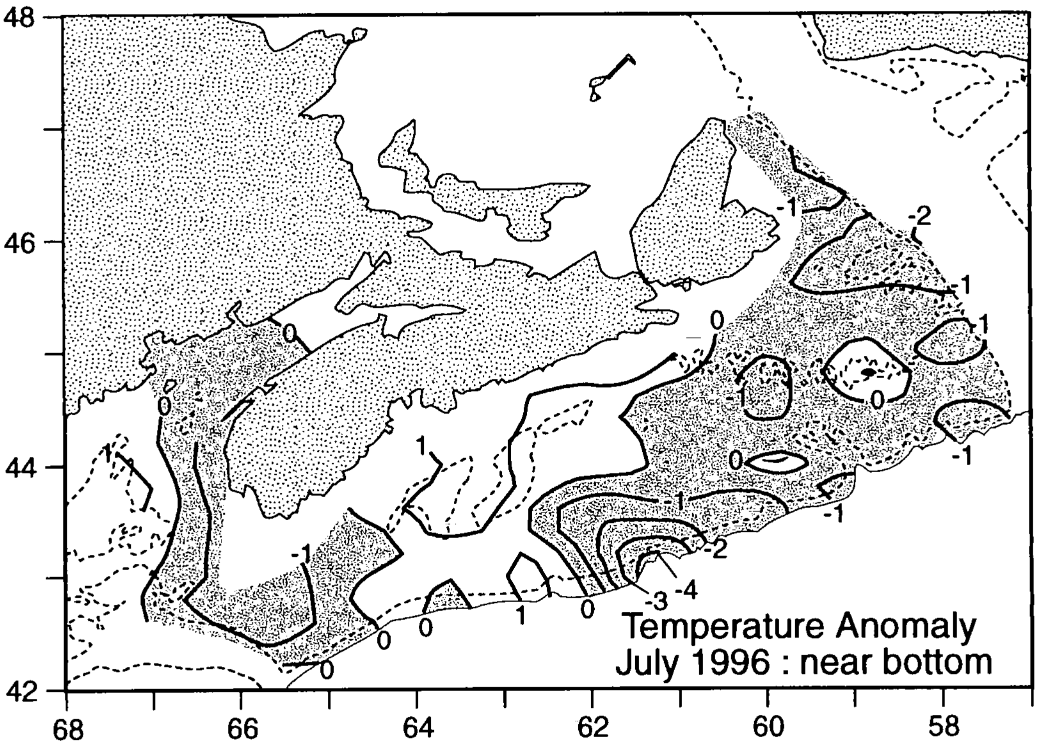


Fig. 5 The near-bottom temperatures (top panel) and their anomalies from the long-term (1961-90) means (bottom panel) during the July survey. Negative anomalies are shaded.

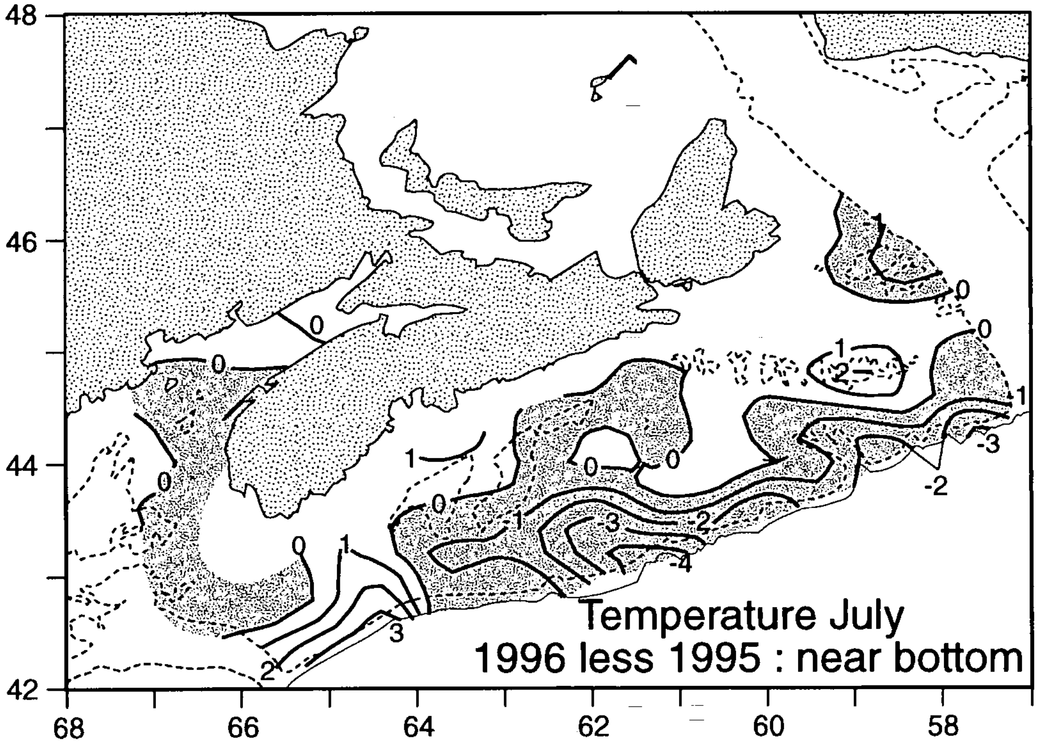


Fig. 6 The difference between the 1996 and 1995 temperature fields for the July survey. Positive values indicate warming and negative a cooling. Negative differences are shaded.

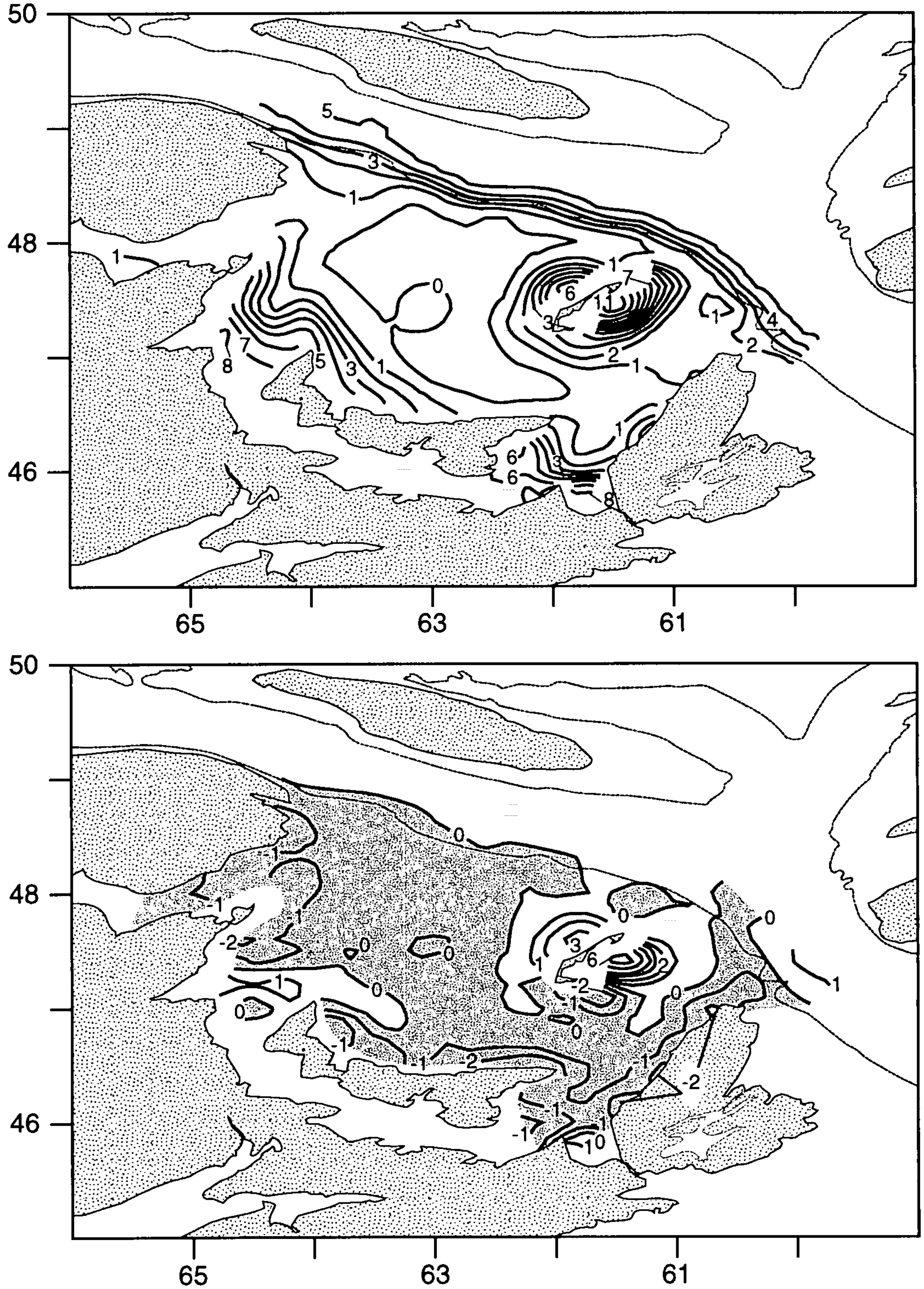


Fig. 7 The near-bottom temperatures (top panel) and their anomalies from the long-term (1961-90) means (bottom panel) during the September survey. Negative anomalies are shaded.

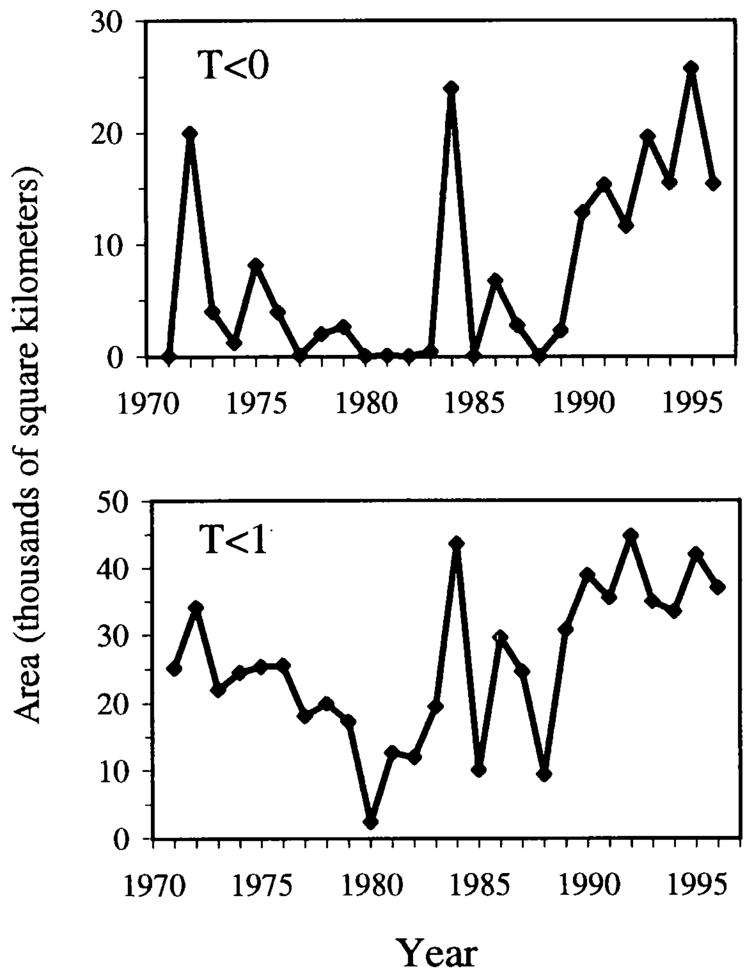


Fig. 8 The area of Magdalen Shallows with bottom temperatures <0° and <1°C during September 1996.

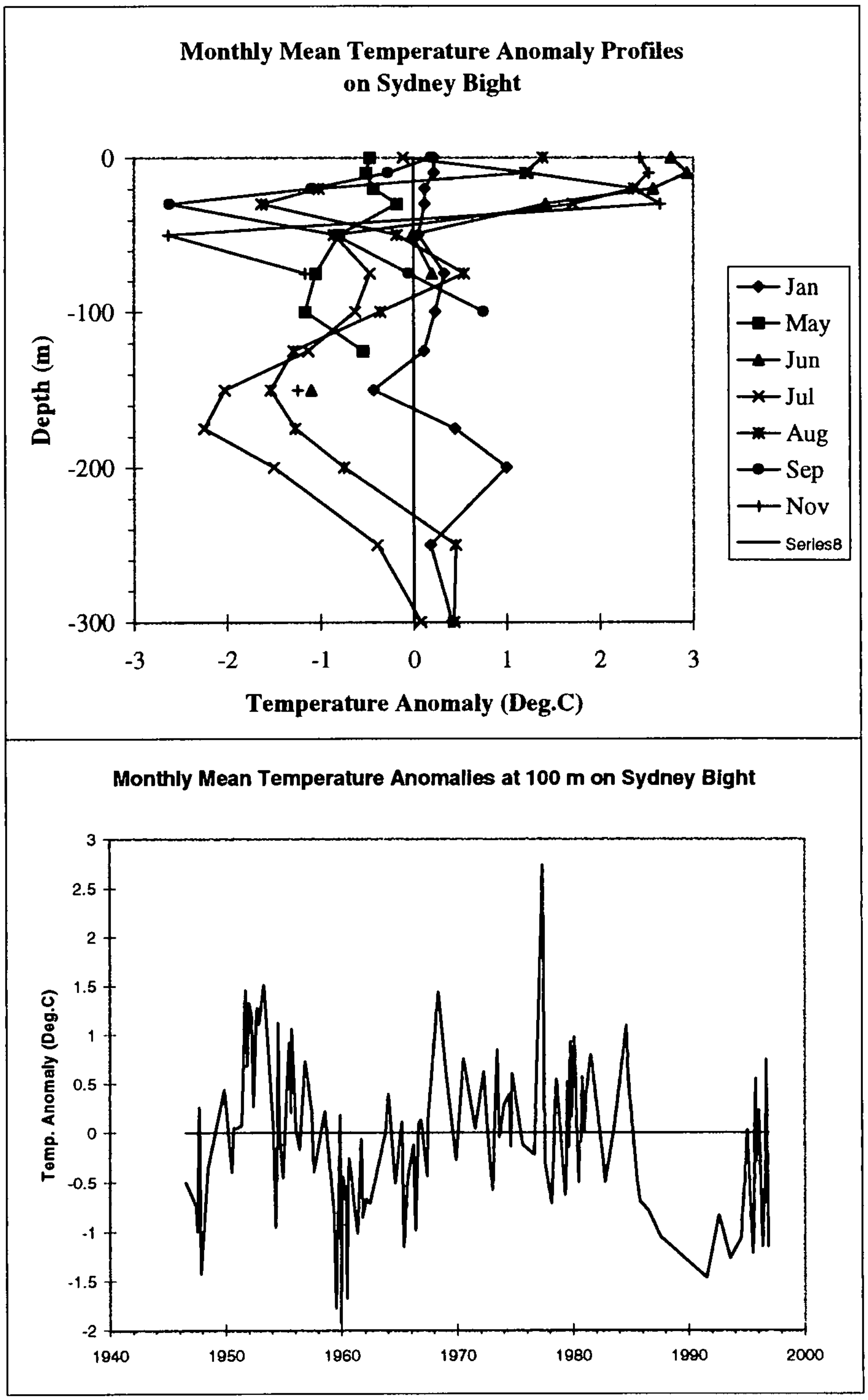


Fig. 9 Monthly mean temperature anomaly profiles during 1996 (top pannel) and the time series of monthly temperature anomalies at 100 m (bottom panel) for Sydney Bight (area 1 in Fig. 2).

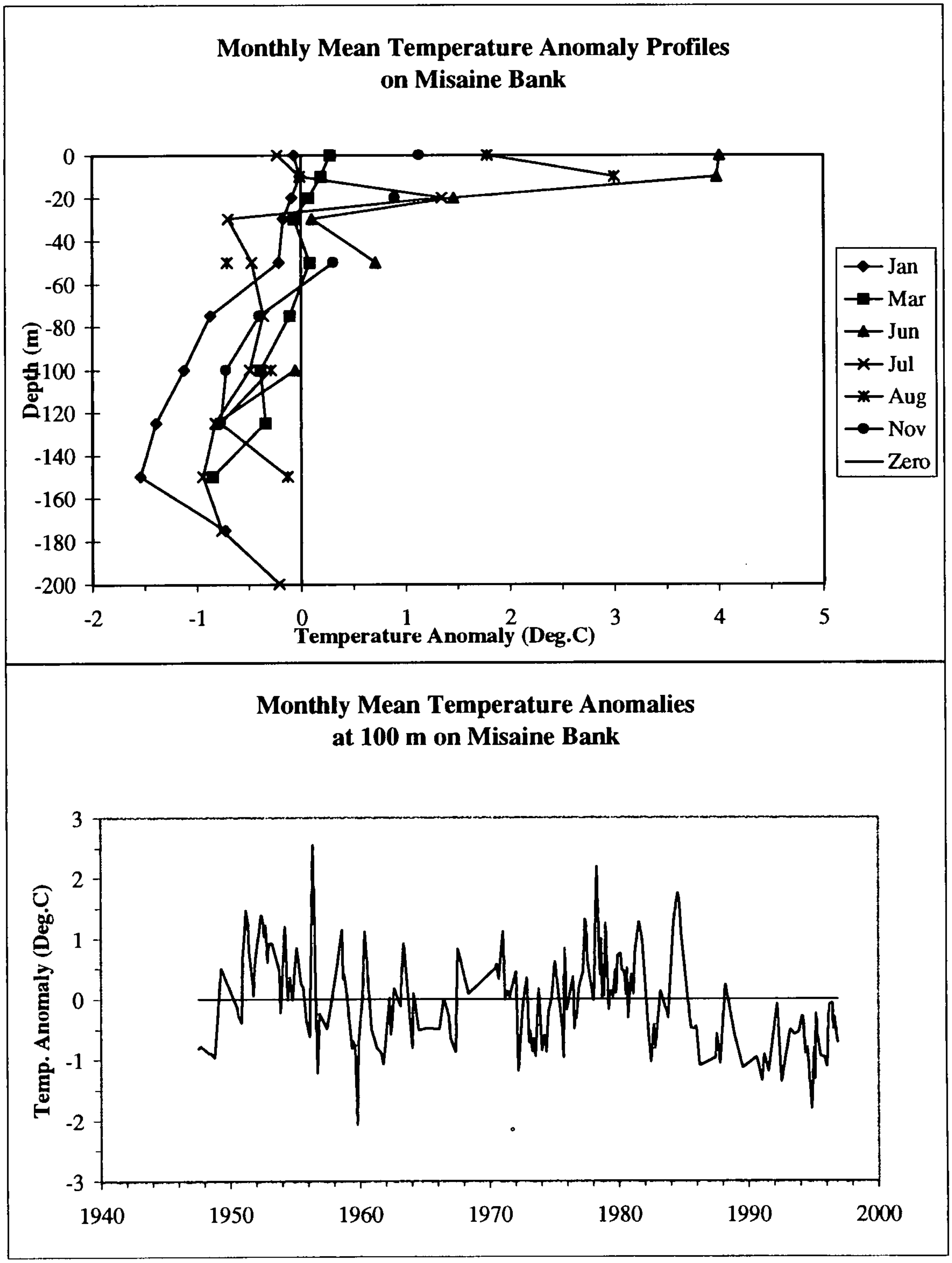


Fig. 10 Monthly mean temperature anomaly profiles during 1996 (top panel) and the time series of monthly temperature anomalies at 100 m (bottom panel) for Misaine Bank (area 5 in Fig. 2).