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Hydrographic Conditions on the Flemish Cap in July 1996

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ABSTRACT

On July 1996 a fishing research survey was carried out over the Flemish Cap area (Northwest Atlantic) aboard the R/V "Cornide de Saavedra". It was the ninth of a series of surveys conducted by the European Union since 1988. During this survey, salinity and temperature data were collected using a CTD sound. This report analyzes hydrographic conditions on the bank, as well as it describes three different water masses. First there is the water around the bank, showing the typical features of Labrador Current's waters; secondly, the central water, originated by solar heat input on Labrador waters; and, finally, an unusual type of water which appears between 200 and 300 m and seems to be mixed with North Atlantic Current waters.

INTRODUCTION

The Flemish Cap is a fishery situated in international waters regulated by NAFO (3M division). Its upper part reaches 125 m near the 47° N - 45° W position, while the bank spreads out to 720 m, with a diameter of about 200 km. It is a relatively isolated bank, separated from the Grand Bank by a pass (about 1100 m deep) known as the Flemish Pass.

Labrador Current dominates the general system of currents on the Flemish Cap (Fig. 7, upper map). The offshore branch of Labrador Current flows southward along the Grand Bank slope. Water temperature ranges between 3-4° C, and salinity values are between 34.88-34.92 psu (Lazier, 1982). Northwest of the Flemish Cap the offshore branch forks: the main branch continues across the Flemish Pass while a lateral branch goes around the Flemish Cap by the north. The north-eastward moving component is particularly significant to the oceanography of the Flemish Cap region (Hayes *et al.*, MS, 1977). South from the Grand Bank, the Gulf Stream flows north-eastward along the 4000 m isobata lying around the Grand Bank, as it continues flowing northward as North Atlantic Current, then surrounding the Flemish Cap by the East.

On the Flemish Cap, the typical movement of waters is the anticyclonic gyre, which has been described by analysis of geostrophic circulation (Kudlo and Burmakin, 1972; Kudlo and Borovkov, MS 1975; Kudlo *et al.*, 1984). Ross (MS, 1980) has also reinforced this idea using moored current metre data and drift buoys (Ross, 1981). More recently, Colbourne (MS, 1993; MS, 1995; MS, 1996) has described the circulation on the Flemish Cap using an acoustic Doppler current profiler, thus confirming the existence of a general anticyclonic motion. The stability of the gyre is one of the main factors regulating the retention of ichthyoplankton within the Flemish Cap ecosystem; the destruction of the gyre by the action of winds results in transport of eggs and larvae away from the bank (Kudlo *et al.*, 1984).

Several authors have discussed the influence of such a general system of currents on thermohaline properties of the Flemish Cap. According to Hayes *et al.*, (MS, 1977), the water mass lying between Labrador Current and North Atlantic Current is originated by the mixing of both these currents. Keeley (MS, 1982), by means of clusters analysis, distinguishes several areas showing different thermohaline characteristics, depending on the water input provided by each current. One of

these areas, east from the Cap, might stand as the melting pot where all different waters get mixed. In Akenhead's opinion (1986), the Flemish Cap waters proceed exclusively from Labrador Current, whereas North Atlantic Current has not any influence on the area. According to Colbourne (MS, 1993; MS, 1995; MS, 1996), the water heating offshore the Cap is due to the influence of North Atlantic Current. Colbourne has analyzed the 47° N transect.

Many oceanographic surveys have been carried out in this area in recent years. Stein (1996) has resumed the results of these works.

The aim of this report is to give a view over the hydrographic conditions on the Flemish Cap during the summer of 1996, as well as to analyze the influence of the main currents and their possible relationships with the Flemish Cap fishery. A complete network of CTD stations established all over the Cap has allowed us to determine the different thermohaline properties of the area. In addition, there has been also available a biologic sampling that coincides in time and space with the physical sampling, thus facilitating the task of establishing relationships between them both.

MATERIALS AND METHODS

The survey consisted of a series of randomized 121 bottom trawls over the Flemish Cap inside the boundaries of the 732 m isobata (400 f.). The first fishing occurred on June 28, and the last one was made on July 14. A CTD station was established whether at the beginning or at the end of each fishing, so a total of 116 stations had been established at the end of the survey.

The CTD sound used was of the type Sea-bird SBE 19. It was dropped at a speed of 1 m/sg to take 2 samples per second down to a depth limit of 410 m.

The collected data were processed using the CTD's proper software (Seasoft 4.2). Depth, temperature, salinity and density data were taken at each station. Later on, all data considered to be wrong have been deleted. Salinity and density were measured using a low pass filter, and all variables were finally promediate, metre by metre, to get a proper data base which would later allow a correct processing of the results.

Two transects were outlined on a chart of the Flemish Cap showing the distribution of stations. One transect, consisting of 11 stations established from July 2 to July 13, lies from north to south, next to the 45 parallel. The other one spreads from east to west, next to the 47 parallel, and it also consists of 11 stations, established from July 9 to July 14 (Fig. 1). The aim was obtaining some results that could be later be compared to those previously provided by other authors. Figures 2 and 3 show graphics of salinity and temperature values in relation with depth.

Salinity and temperature distribution charts were established for all stations. The results are shown in figures 4 and 5. The measures were taken at different depths (10, 50, 100 and 200 m).

Two T-S diagrams are displayed in Figure 6: one shows the totality of stations (6b); the other one (6c) only includes three standard stations with their respective depths. An stations are compared with the T-S diagram values (6a) which serve as a criterion to define the water masses found near the Grand Banks (Hayes *et al.*, MS, 1977).

The maps in Figure 7 respectively show the main currents in the area (above), and the domains of water masses found in the Flemish Cap (below). The profiles shown in the map below are drawn out according to the data from the T-S diagrams.

The map in figure 8 shows the distribution of temperature at the bottom in comparison with the distribution of some biological species also studied during the survey.

All contour maps were made from a grid that had been traced with a linear variogram, according to Krigin's method.

RESULTS

The vertical distribution of temperature down the W-E transect shows values ranging from 5 °C at 50 m, and 10 °C near the surface. Minima values appear about 100 m deep, ranging from 2.5 °C at the western edge to 3.5 °C on the Cap and 3 °C at the eastern edge. In the area between 100

m and the bottom, the temperature becomes stable, about 3.5 °C. Values above 4 °C were registered at the western area, between 150 and 200 m. This fact seems to have been the only significant difference in comparison with the data taken by Colbourne (MS, 1996) on the standard 47 N transect during the same season of the year (Fig. 2). Along this transect, salinity ranges from 33.5 psu near the surface to slightly higher than 34.75 psu at the bottom. No significant variations on longitude have been observed (Fig. 2).

In the southern area of the S-N transect the temperature of the upper layer ranges from 6 °C at 50 m to 10.5 °C near the surface. In the northern area, it ranges from 3 °C to 7.5 °C. Minima temperature values, almost reaching 3 °C, appear about 100 m depth. Temperature becomes stable near the bottom, being about 3.5 °C (Fig. 3). Along the same transect, salinity values range from 33.5 psu at the surface and 34.75 psu at the bottom (Fig. 3).

Figure 4 shows the distribution of temperature at several depths (10, 50, 100 and 200 m). At 10 m it was observed the temperature had increased from the north southwards: from 7 °C down to 11 °C. The temperature gradient was very abrupt at the eastern and western edges, while it was much softer on the Cap. At 50 m, the gradient was established from the centre towards the periphery: it showed temperature values ranging from 7 °C to 4 °C. At 100 m, the temperature was very homogeneous all over the area (about 3 °C); except for the south-eastern section, where it reached 4.5 °C and even surpassed this mark. At 200 m the general temperature reached 3.5 °C, while it was observed an area of warmer water on the south-east. In general, it was observed that temperature decreases with depth: it reaches its minima values at about 100 m depth, and then it increases up to 3.5 °C at the bottom.

Figure 5 shows the distribution of salinity at the above-mentioned depths. Near the surface, the salinity decreases in direction north-southwards and east-westwards: from 34.0 psu down to 33.3 psu. At 50 m, the lowest salinities were found on the central area of the Flemish Cap, showing values of about 33.7 psu. On the surrounding area, maxima salinity values reached 34.2 psu. At 100 m, minima values (34.1 psu) still appear on the central area, while maxima values (34.6 psu) occur on the waters around. At 200 m, the central area showed minima values of 34.65 psu, while there was 34.8 psu on the edges. In general, it was observed that salinity values increased with depth and from the centre to the periphery.

Fig. 6b shows all the stations with T-S values taken each 10 m. It is observed a special type of water showing all the characteristics of Labrador Current's. However, it also presents some significant differences with Labrador Current waters, and these differences were precisely the basis on which a map showing the boundaries of both water masses was made. A discussion on this fact is presented below.

DISCUSSION

The water found on the Flemish Cap (showing temperature values about 3.5 °C and salinity values about 34.85 psu) shares, in general, the features of the offshore branch of Labrador Current. On the south-western areas appear, however, some areas showing temperature values higher than 4.5 °C and salinity values higher than 34.9. Such water masses might not have been exclusively originated from Labrador Current.

On the T-S diagram showing the totality of stations, three different types of water masses may be observed (Fig. 6 b): the different waters have been remarked by the representation of three standard stations (Fig 6 c). The first type of water corresponds to the stations showing minima temperature values lower than 2.8 °C (example: Station 46). The second one corresponds to the stations showing minima temperature values higher than 2.8 °C (example: Station 90). Both types of water tend to become stable at the bottom (400 m), with temperature values about 3.5 °C and salinity values about 34.85 psu. Finally, there exists a third water mass that, from 200 m downwards, reaches temperature values higher than 4.5 °C and salinity values higher than 34.90 psu (example: Station 111).

Once the correct stations have been selected and then shown on a chart (Fig. 7) it was observed their boundaries were well defined. The first area (showing minima temperature values lower than 2.8 °C) spreads around the periphery of the Cap: in this work, we will name it *peripheral water*. The second one appears on the central area; here, it will be named *central water*. The third one is found on the south-west of the Cap, where it occupies two separated areas; as it has not been well described in previous bibliography, henceforth we will call it *atypical water*.

Space distributions, along with thermohaline characteristics, are the basis on which the explanation about how these three main water masses were originated stands.

According to Akenhead (1986) the central water is originated by solar heating input retained over the Flemish Cap. The slow anticyclonic motion typical of the area favours this retention, as well as it concentrates the water over the central area and causes its sinking down. The renovation rate of the Cap surface waters is about 50 % each month (Akenhead, 1986). During this period of stay, the water surface warms up and then sinks, thus transmitting the heat to the bottom. This fact results highly evident at about 100 m deep (Fig 6 b and 6 c).

Peripheral water (Fig. 6 a) shows the typical features of Labrador Current waters, as defined by Hayes *et al.* (MS, 1977). This type of water flows over the Flemish Cap without being retained by any anticyclonic gyre, so it preserves Labrador Current characteristics unaltered.

Deeper water (200-300 m) on the south-western area of the Flemish Cap reveals itself as an atypical watermass, different from any of the previous ones. As it was the case of central water, it cannot be explained by heating processes. First, it must be taken on account that each watermass occupies a different position along the water column: central warm water appears more clearly over the 100 m level, whereas south-eastern warm water appears at a deeper level, between 200-300 m. Secondly, there are the thermohaline properties: central water is fresher than the water around (Fig. 5), whereas atypical water proves to be saltier than the one surrounding it. Figure 6 c shows how Station 111 reaches temperature and salinity values next to those of North Atlantic Current's at about 300 m deep, while T-S values coincide with those of Labrador Current's at upper and deeper levels. This fact seems to indicate there is a mixing process between both currents.

Keeley (MS, 1982), using the method of clusters analysis, identifies some regional differences among the thermohaline characteristics of the water lying over and around the Flemish Cap. The area where the presence of atypical water has been observed coincides with the area where, according to Keeley, the mixing of the Flemish Cap different types of water might occur.

This water originates from North Atlantic Current, which flows northwards along the eastern boundaries of the Grand Bank, while it keeps in contact with Labrador Current along the 4000 m bathymetric contours. This interface NAC-LC is a complex system of meanders, extrusions and eddies that change rapidly in time and space (Krauss *et al.*, 1987). Karen *et al.* (1994) also describe the presence of a vigorous eddy field, especially in deep water, which follows the 4000 m contours. According to Drinkwater (1996), exchange between shelf and offshore waters is a continuous process with enhanced mixing in the southern NAFO area, due to the presence of Gulf Stream rings which interact strongly with the shelf waters.

These intrusions of warmer, saltier water may shift northwards and reach the Flemish Cap, thus having an influence on the distribution of some biological species over the area (Fig. 8). The intrusion of this water, which may reach a temperature of 3.6 - 3.8 °C at the bottom, coincides with the breaking of continuity in the distribution of some demersal species, like *Sebastes marinus* and *S. fasciatus* (Fig. 8). The effect derived from the intrusion of this water into the Flemish Cap fishery may offer an accurate idea of what catastrophic results a massive intrusion of water from the Gulf might cause.

Generally, the hydrographic characteristics registered during this survey correspond with those expected for the area. There is a water sharing the features of Labrador Current's which warms up over the Cap. This typical situation on the Flemish Cap is complemented with the presence of another type of water, warmer and saltier, which proceeds from North Atlantic Current and which also might collaborate to the heating of the Flemish Cap waters.

BIBLIOGRAPHY

- AKENHEAD, S.A. 1986. Water retention over Flemish Cap. The Role of Freshwater Outflow in Coastal Marine Ecosystems. *NATO ASI Series*, vol G7, pp 283-293. S. Skreslet ed.
- COLBOURNE, E. MS 1993. Oceanographic Conditions on the Flemish Cap During the summer 1993, with comparisons to the Long-Term Average. *NAFO SCR Doc.*, n° 107, Serial n° N2300.
- COLBOURNE, E. MS 1995. Oceanographic Conditions on the Flemish Cap During the summer 1995, with comparisons to the 1961-1990 Average. *NAFO SCR Doc.*, n° 102, Serial n° N2625.
- COLBOURNE, E. MS 1996. Oceanographic Conditions on the Flemish Cap During the summer 1996, with comparisons to the previous year and the 1961-1990 Average. *NAFO SCR Doc.*, n° 87, Serial n° N2770.
- DRINKWATER, K. F. 1996. Climate and Oceanographic Variability in the Northwest Atlantic During the 1980s and Early- 1990s. *NAFO Sci. Coun. Studies*, 24: 7-27.
- HAYES, R. M., D.G. MOUNTAIN and T.C. WOLFORD. MS 1977. Physical oceanography and the abiotic influence on cod recruitment in the Flemish Cap region. *ICNAF Res. Doc. N° 54*, Serial n° 5107, 33 p.
- HEYWOOD, K. J., E. L. McDONAGH and M. A. WHITE. 1994. Eddy kinetic energy of the North Atlantic subpolar gyre from satellite altimetry. *J. Geophys. Res.* 99. 22525-22539.
- KEELEY, J. R. 1982. Regional differences in Water Types on the Flemish Cap. *NAFO SCR Doc.*, N° 82, Serial n° N531, 8 p.
- KUDLO, B. P. and V. V. BURMAKIN. 1972. Water circulation in the South Labrador and Newfoundland areas in 1970-71. *ICNAF Redbook 1972(III)*: 27-33.
- KUDLO B. P. and V. A. BOROVKOV. MS 1975. Circulation of waters in the ICNAF area in 1973-1974. *ICNAF Res. Doc. N° 79*, Serial n° 3506, 12 p.
- KUDLO B. P. , V. A. BOROVKOV and N. G. SAPRONETSKAYA. 1984. Waters Circulation Patterns on Flemish Cap from Observations in 1977-82. *NAFO Sci. Coun. Studies*, 7: 27-38.
- KRAUSS, W., E. FAHRBACH, A. AITSAM, J. ELKEN and P. KOSKE. 1987. The North Atlantic Current and its associated eddy field southeast of Flemish Cap. *Deep-Sea Research*. 34. 1163-1185.
- LAZIER, J. R. N. 1982. Seasonal variability of temperature and salinity in the Labrador Current. *J. Mar. Res.* , 18 (Suppl.), 341-356.
- ROSS, C. K. MS 1980. Moored Current Meter Data from Flemish Cap January-July, 1979. *NAFO SCR Doc.*, N° 128, Serial n° N200, 13 p.
- ROSS, C. K. 1981. The drift of satellite-tracked buoys on Flemish Cap, 1979-1980. *NAFO Sci. Coun. Studies*, 1: 47-50.
- STEIN, M. 1996. Flemish Cap - A review on Research Activities With Focus on Oceanographic Conditions. *NAFO Sci. Coun. Studies*, 25: 1-24.

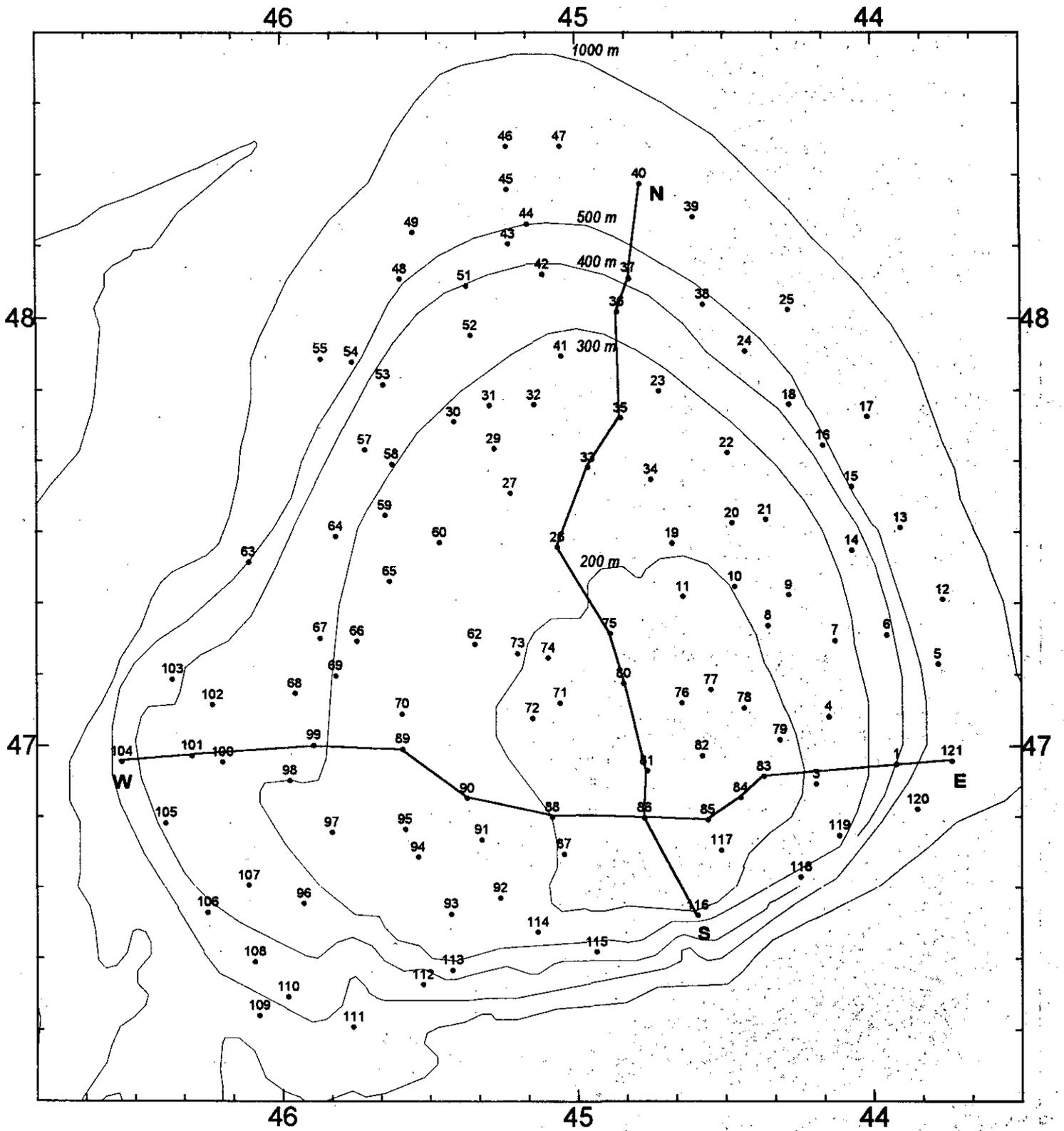


Fig 1 .- Location of CTD stations and S-N and W-E transects established on Flemish Cap (July 1996).

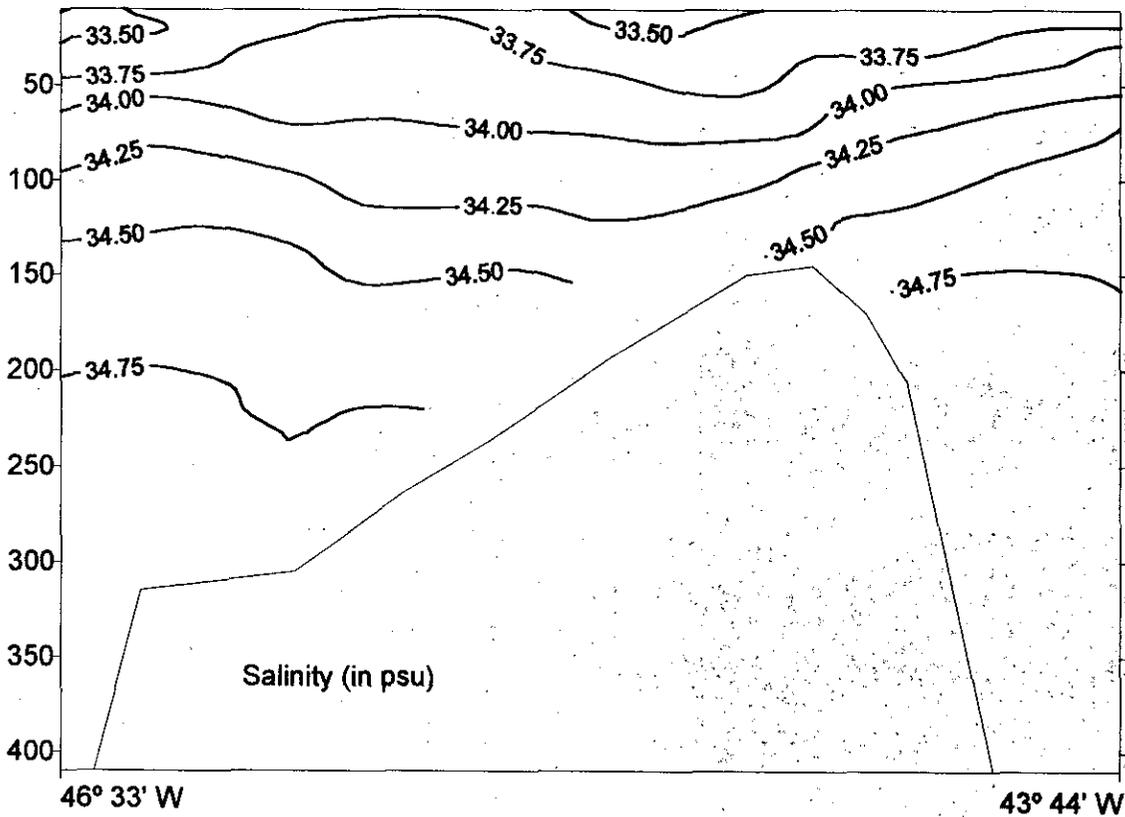
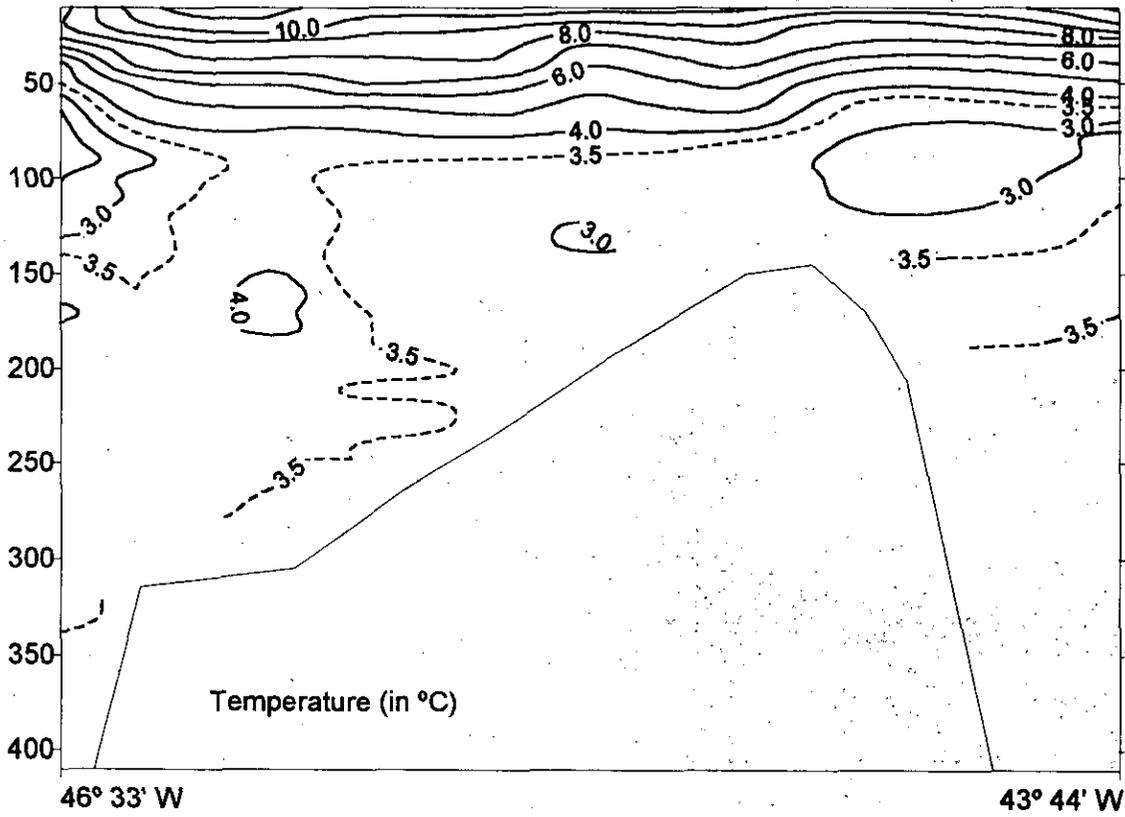


Fig 2 .- Map showing isotherms and isohalines versus depth in the W-E transect.

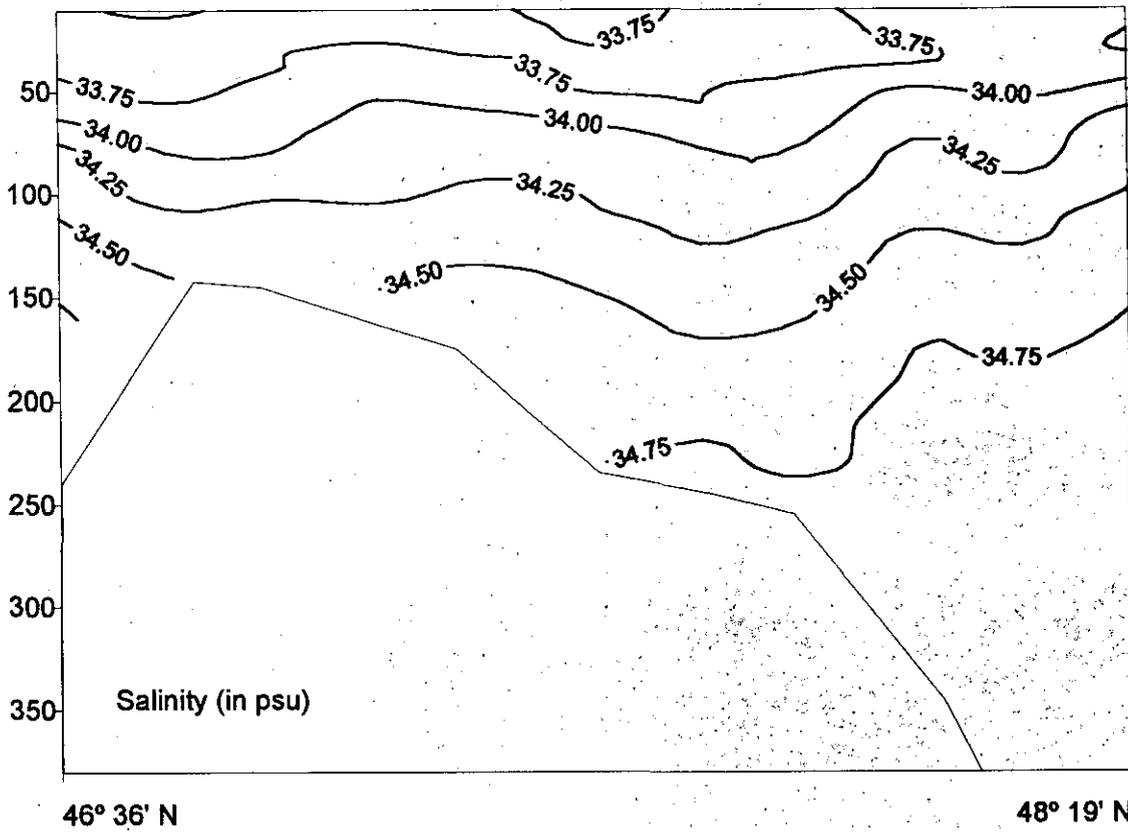
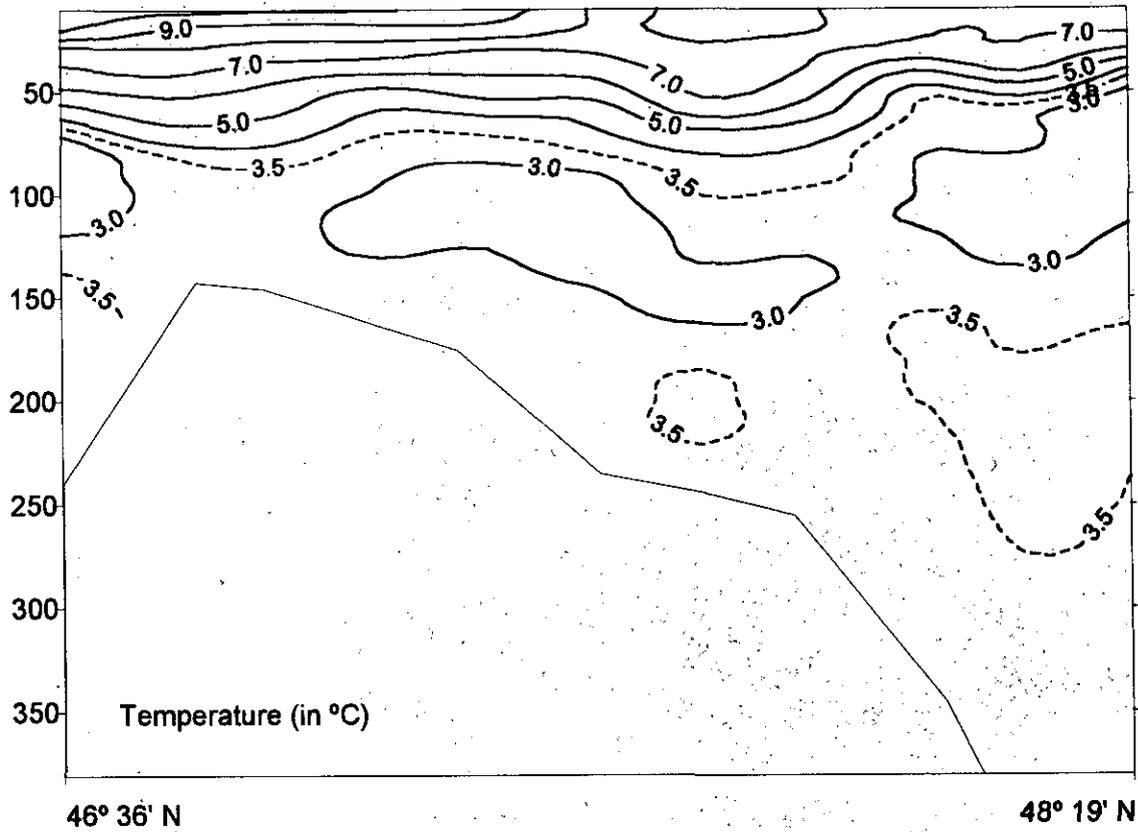


Fig 3 .- Map showing isohalines and isotherms versus depth in the N-S transect.

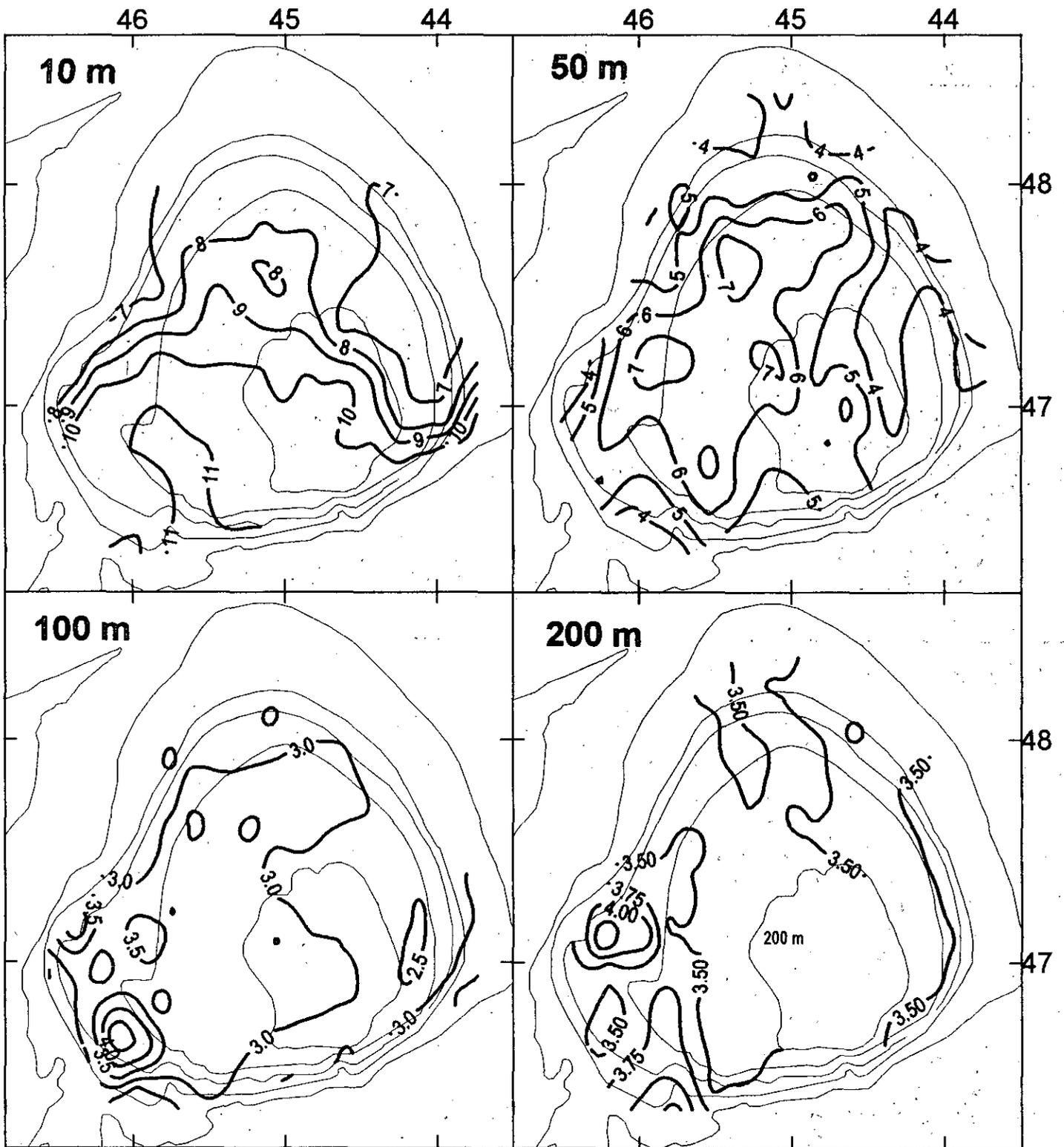


Fig 4 .- Distribution of temperature at several depths in the Flemish Cap (Summer 1996).

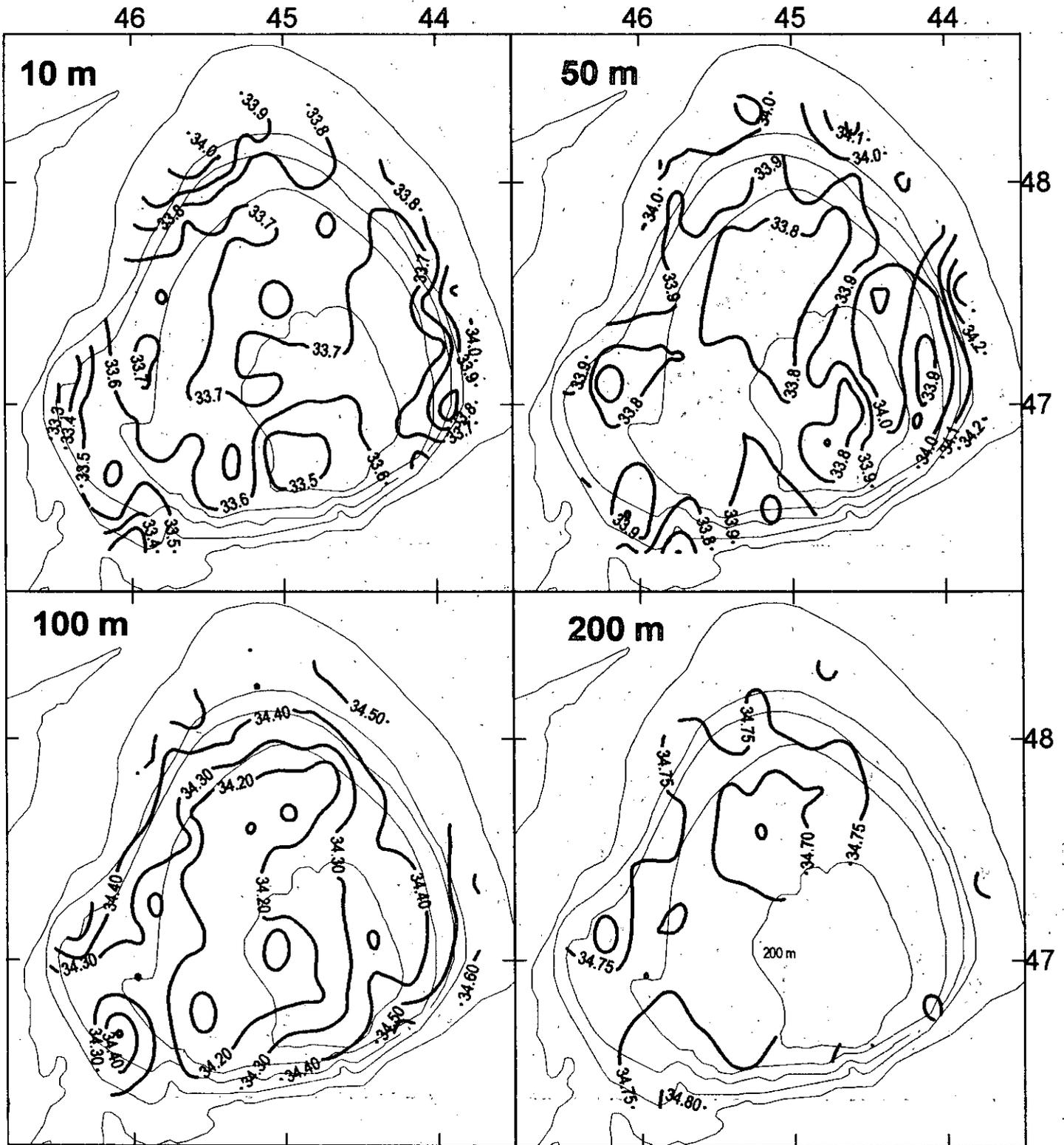


Fig 5 .- Distribution of salinity at several depths in the Flemish Cap (Summer 1996).

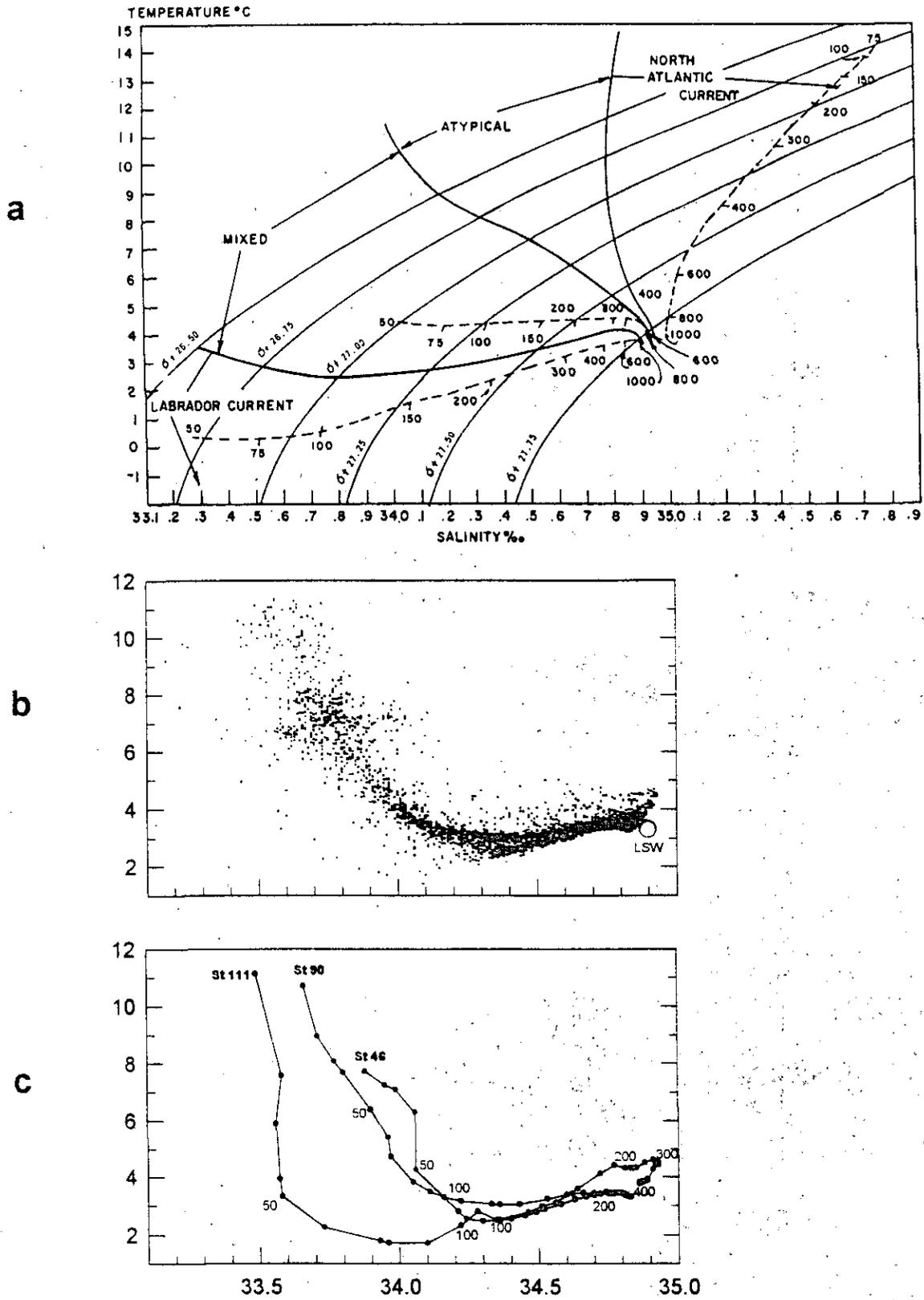


Fig. 6

- a. - Waters near Newfoundland (Hayes et al, MS 1977).
- b. - All FC-96 stations.
- c. - Standard stations.

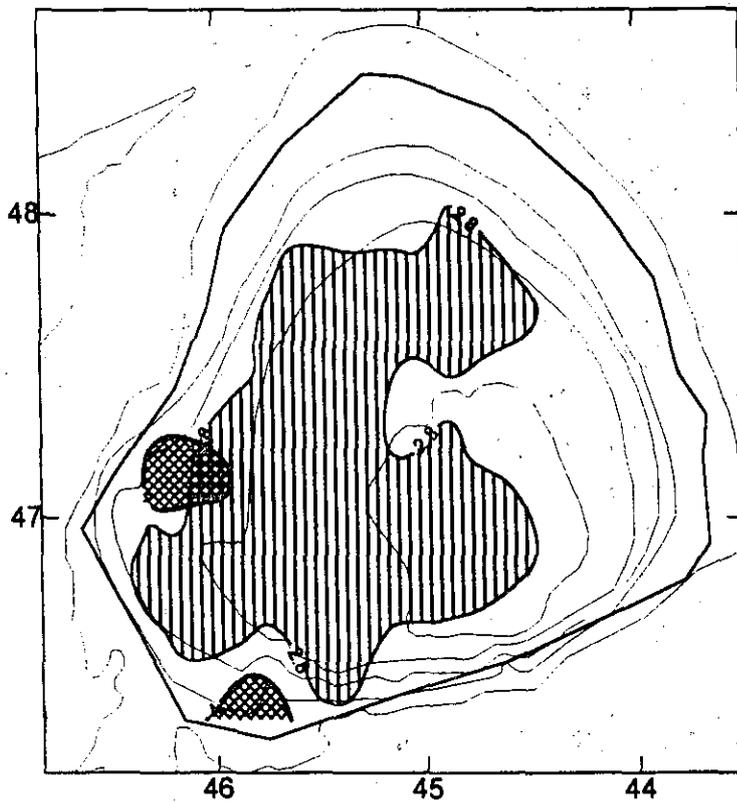
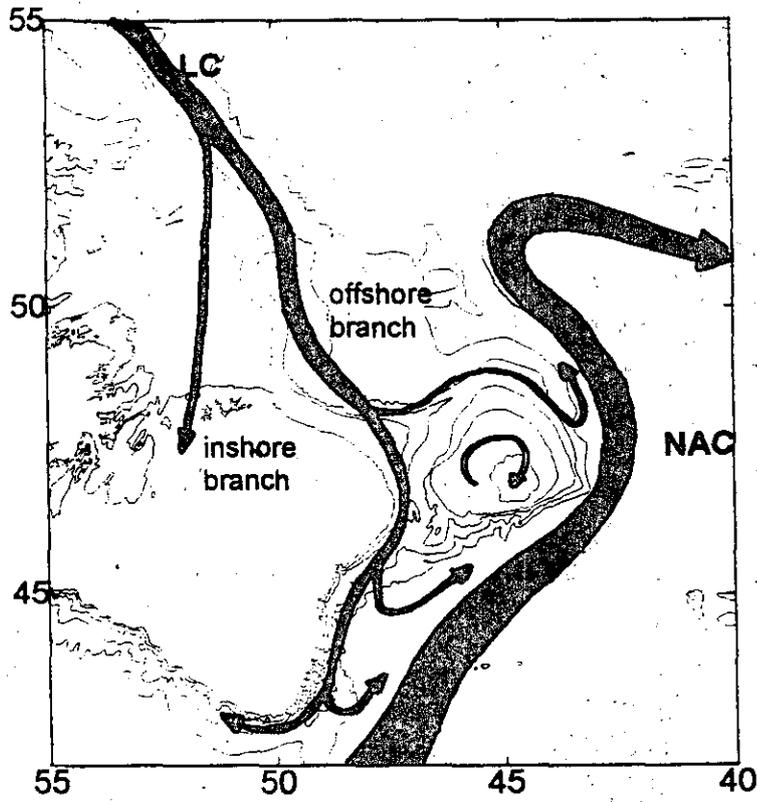


Fig 7 .- Main currents on the area (above)
Domain of water masses on the FLEMISH CAP (below).

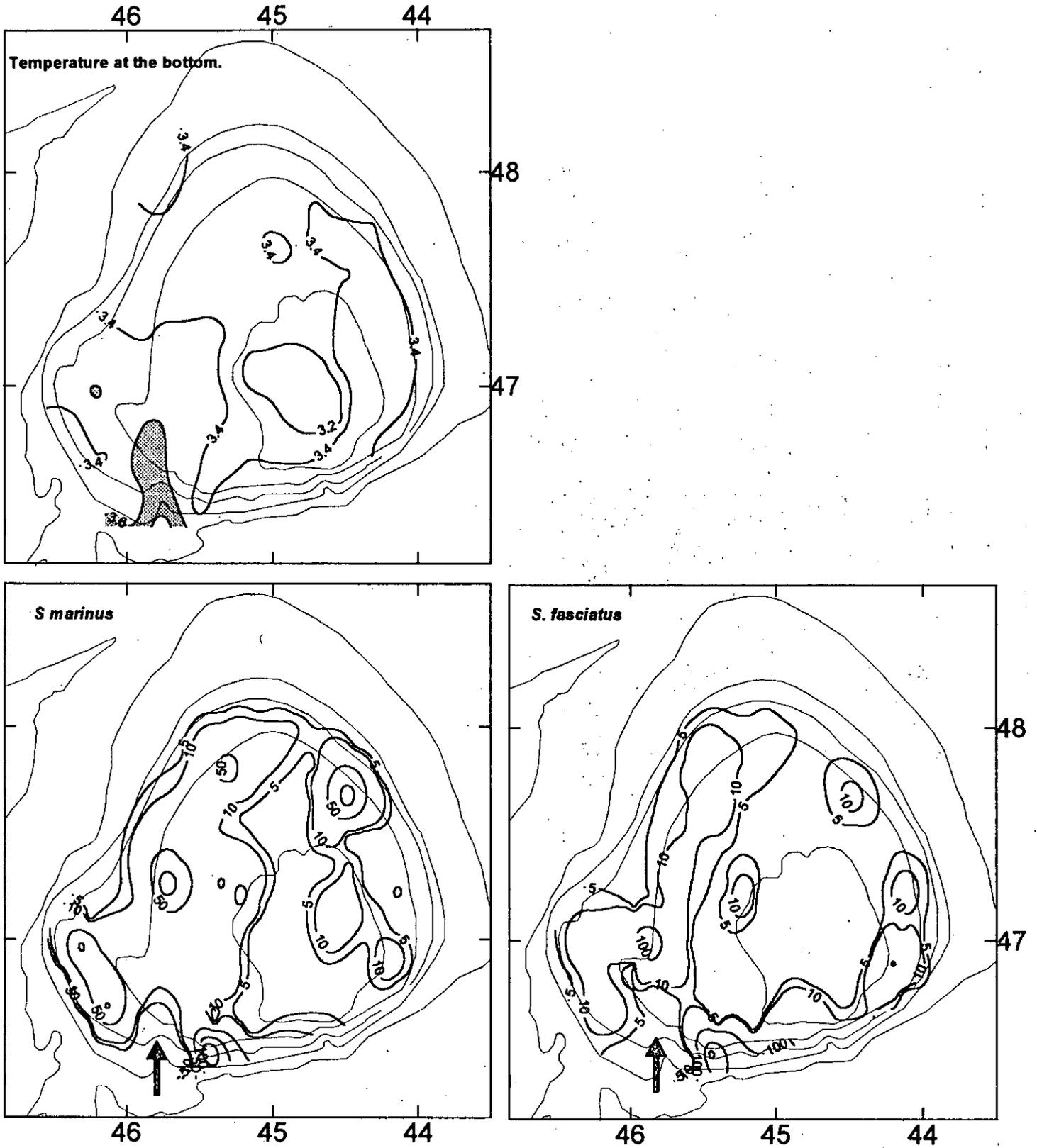


Fig 8 .- Distribution of temperature (°C) at the sea bottom and distribution of two species of the *Sebastes* genus (Kg).

The arrow indicates the area where the warm water coincides with the absence of these species.