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Some physical oceanographic features relevant to larval herring distribution on Georges Bank

by

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INTRODUCTION

A cruise designed to gain preliminary information on larval herring patchiness, oceanographic structure and dispersion characteristics on the northern edge of Georges Bank was undertaken in September 1977 in preparation for a multiship larval herring patch study planned for autumn 1978. Owing to ship scheduling difficulties, the cruise had to be run earlier than planned, and hence it was not expected that herring larvae would be found. Accordingly the cruise focussed on physical oceanographic facets in the area where spawning beds have been found historically.

NATURE AND LOCATION OF DATA GATHERED

The cruise track and station number at turn points are shown in Figure 1. Only the results for the grid on Georges Bank (stations 51-175) are reported here. Temperature and salinity were measured with a Guildline STD and logged directly from the head onto magnetic tape with an HP2100M computer. In addition salinity and temperature with depth were logged on X-Y recorders, and a Decwriter was coupled to the deck unit to give a time, depth, temperature, salinity listing at 5-second intervals.

On Georges Bank a rectangular grid of 28 stations (7 x 4) was occupied once, with STD's taken at all stations and a 30-minute oblique plankton tow to 30M depth, using a ½M ring net and a 405μ mesh, at 14 stations. One of the lines in the grid was reoccupied several times to examine in more detail the N-S spatial temperature and salinity structure. A total of 110 STD's were taken within the Georges Bank study area. The ship was anchored for 25 hours at one site in about 45M of water (see Fig. 1). A profiling Aanderaa current meter was lowered and raised at hourly intervals, reading current speed and direction, temperature, conductivity, and pressure at 5M intervals of depth. The STD was lowered at hourly intervals alternately with the current meter.

A 10-litre quantity of rhodamine (WT) dye was released at the anchor station site and tracked visually, and with a Turner fluorometer fed by a towed submersible pump for approximately 9 hours. Drogued high-flyers were released with "window-shade" type drogues set at surface, 10M and 30M, and tracked for approximately 10 hours. Additionally 56 drift bottles were released at the same time as the dye.

A detailed, 30-mile south-north plankton transect was made at stations 155-174. A ½M ring net, set at 30M depth was towed continuously for approximately 30 minutes, at which time it was quickly raised, removed, and a new net relowered to 30 metres. The tows taken at a speed of about 3 knots, totalled 20 for the 30-mile transect.

RESULTS

Surface temperature and salinity were relatively uniform within the grid survey area, and generally were in the 13-15°C and 32.4-32.7 $^{o}/_{oo}$ range respectively. Bottom temperature and salinity are shown in figures 2 and 3 respectively and revealed marked spatial variations. Interestingly the zone of maximum gradient was not coincident for temperature and salinity. The two zones which were stretched out in an E-W direction were separated by 5-10 miles. The strongest salinity gradients were located in depths greater than 100M (Fig. 4), whereas the thermal cold front, which is arbitrarily taken to be centred on the 10°C isotherm, was found at a depth of 40-60 metres (Fig. 4). Although no egg beds were found with the bottom grab, earlier studies by the USSR and by Canada (Isles, personal communication) indicate that egg beds have been found in other years, almost exactly where the cold front was located in 1977 (Fig. 5).

The position and character of the cold front can also be readily seen from the N-S cross-sections (Figures 6,7,8,9). Repeated N-S transects showed the cold front always to be present, although its detailed shape and position differed between sections.

Additionally, several points should be noted: the water off the bank was thermally structured into 3 layers with a relatively warm surface layer >13°C and 20-40M in thickness, an intermediate cold water layer with minimum temperatures <6°C and centred at 75-125M, and a deeper warm water layer with temperatures >6°C; on the bank, away from the edge, the water was nearly homogeneous from top to bottom with temperatures >14°C; the thermocline intersects the bottom near the edge of the bank, with the result that bottom temperatures decrease from south to north by as much as 7°C in less than 10 miles. From the bank it can be viewed as a subsurface cold front. Temperature-salinity diagrams shown for three of the transects (Fig. 10) strikingly reveal the different water masses on and off the bank. Off the bank, the vertical structure, as mentioned previously is readily apparent. At the southern end of the transects (stations 57, 71 and 72) the water column was virtually homogeneous from top to bottom, so that the T-S curves shrank to a point which was clearly separated from the surface waters of the Gulf of Maine as measured on the transect.

The site of the anchor station was chosen to coincide with one of the historic egg beds. A progressive vector plot of the currents measured at hourly intervals is shown in Fig. 11 for 10, 20 and 40M depths. A strong semi-diurnal tidal current was present at all depths, with values at 40 meters, commonly in excess of 50 cm/sec. The elliptical character of the tidal currents was partially masked at 10 and 20M depths, owing to the very strong residual current which was computed to be 60 cm/sec at 068°T for the 10M depth, 30 cm/sec at 078°T at 20M, and 6 cm/sec at 081°T at 40M. It is interesting to note that while the tidal currents at 40M were typically about 50-75% of the 10M values, the residual currents were an order of magnitude less.

From the temperature, salinity and density depth-time plots (Figs. 12, 13) the semi-diurnal cycle in the vertical structure is readily apparent, as water moving past the site changed from a 2-layer to a homogeneous system and back again. Temperature at the bottom (Fig. 12) changed from $<9^{\circ}$C to $>13^{\circ}$C in a 6-hour period. The progressive vector plot of currents at 10 meters shows that there was a N-S tidal component in the current which was advecting the cold front back and forth across the anchor station site. By comparison with temperatures, the salinity change on the bottom was less marked varying by about 0.3 $^{o}/_{oo}$. Density changes, however, varied by nearly 1 σ_t unit.

Just before weighing anchor on September 24, 10 liters of rhodamine WT dye (40%) were released into the surface waters. Three high-flyers drogued with plastic "window shades", one each at the surface (200 ft^2 area), 10M and 30M (100 ft^2 area) were released as well. The tide was setting towards the southeast at the time, and was gradually diminishing in speed. The dye patch began to stretch out (Fig. 14) but appeared to be neither aligned with the wind nor with the surface current, but rather at an angle between the two. The patch was tracked visually for the first few hours. About 2½ hours after release the first fluorometer transects were made, and were continued for about 5-6 hours, at which time, dye concentrations appeared to be rapidly dropping to near background levels, and the detectable size of the patch was diminishing. The maximum size of the patch, as measured by the fluorometer was just over 1 mile in the largest dimension, and had a length to width ratio of about 3.

DISCUSSION

Although there is a lack of sufficient data from other years concerning the physical oceanographic structure along the northern edge of Georges Bank during and immediately following the herring spawning period, it appears that the egg beds may often be located very near the cold front, and possibly in some years the front could be located south of the beds for a period of time, giving rise to alternately cold and warm water sweeping over them.

The surface layer residual current measured at the anchor station may have been considerably higher than normal, although its direction and magnitude compares favourably with those reported by Butman (1978) from a 113 day current meter mooring located on the northern slope of the bank. Over this period an ENE residual current of about 40 cm/sec was measured.

If the vertical variation in residual currents measured at the 25-hour anchor station is representative of conditions over larger time and space scales, it could well have important ramifications for larval herring advection and dispersion. If for example, a patch of larvae a kilometer in diameter had been uniformly distributed vertically throughout the water column at the start of the anchor station, then the patch would have been stretched to more than 45 km through advective effects alone. Although diffusion, due to tidally induced mixing is obviously high in the region as evidenced from the dye experiment, the dispersion arising from the strong vertical shear may be the dominant factor to be considered.

If vertical shear in the currents such as that measured in 1977 commonly exists, then clearly measurable 3-dimensional larval "patches" will not exist for more than a few hours. Even a "point source" of larvae at a fixed depth would be dispersed over several square kilometers in a day, if they behaved as passive drifters.

SUMMARY

1) In September 1977 a bottom cold front extended in a roughly E-W direction near the northern edge of Georges Bank. The front was positioned well up on the bank in water depths of 40-60 meters.

2) A bottom salinity front was also present, which ran parallel to the bank but was positioned about 5-10 miles north of the thermal front, and hence in much deeper water.

3) Currents measured over a 25-hour period reached maximum values of 155 cm/sec at 5M depth. The residual current varied from 60 cm/sec at 10M depth to 6 cm/sec at 40M. The tidal current by comparison, diminished by less than a factor of two over the same depth range.

4) At the time the current measurements were taken (Sept 23-24), the cold front was oscillating semi-diurnally over at least one of the sites where egg beds have been present in other years. Temperatures fluctuated from <9°C to >13°C.

5) If, after herring larvae are hatched, they move or are dispersed vertically in the water column quickly, then the vertical variation in residual currents may be much more important in dispersing the larvae laterally, than is the tidally induced mixing.

6) It will be extremely important to know how herring larvae are distributed vertically if significant progress is to be made in identifying the role played by physical processes in determining the distribution and fate of larvae.

ACKNOWLEDGEMENTS

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REFERENCES

Butman, Bradford, John Vermersch, Robert Beardsley and Marlene Noble. (1978) Long term current observations on Georges Bank. Paper given at 1978 spring meeting, American Geophysical Union, Miami Beach. April 17-21, 1978.

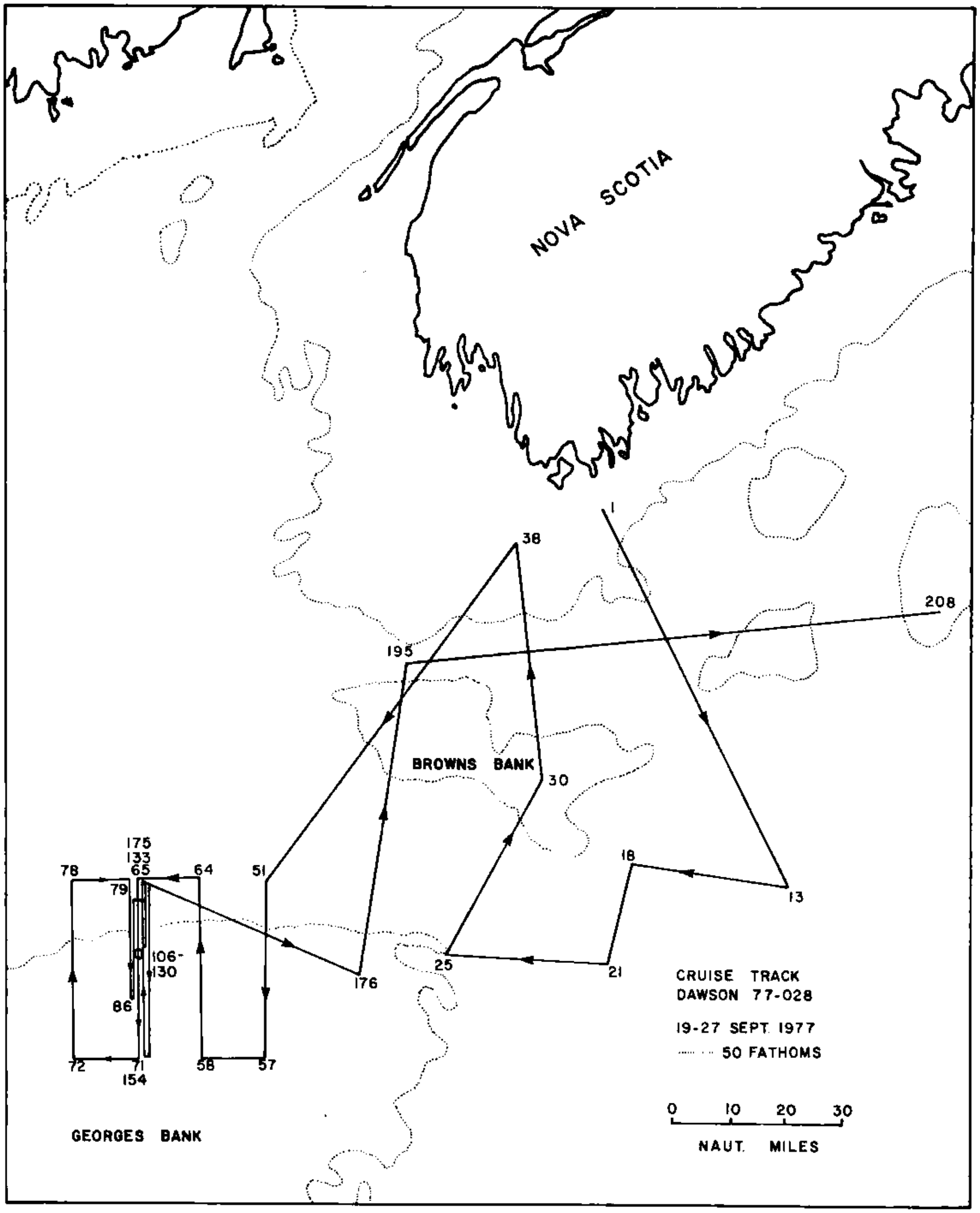

Fig. 1 Cruise track for cruise 77-029, Sept 19-27, 1977. Station numbers are shown at turn points. Position of anchor station and dye release is shown as ⊕.

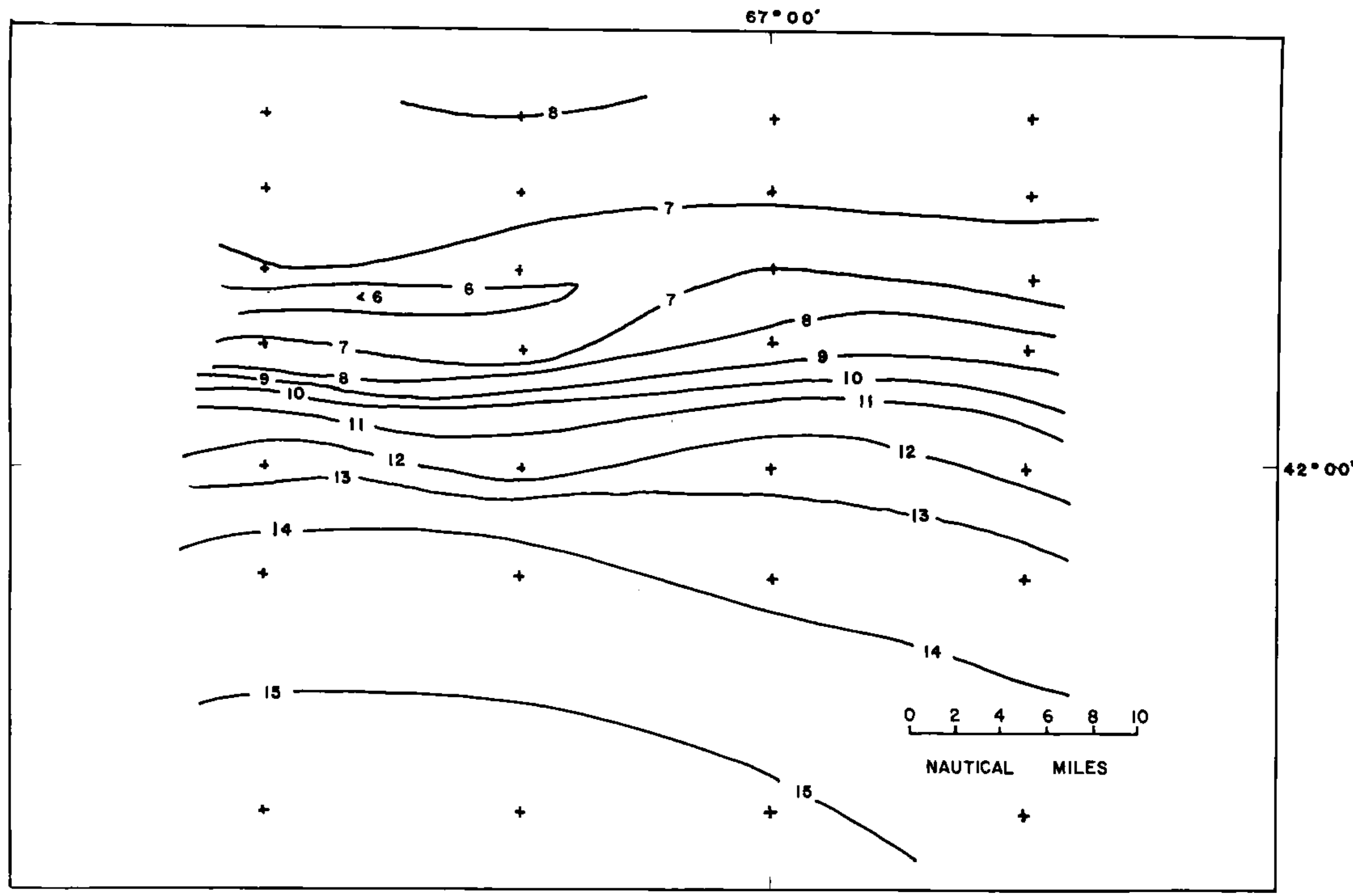

Fig. 2 Bottom temperature distribution near northern edge of Georges Bank (Sept 21-24, 1977).

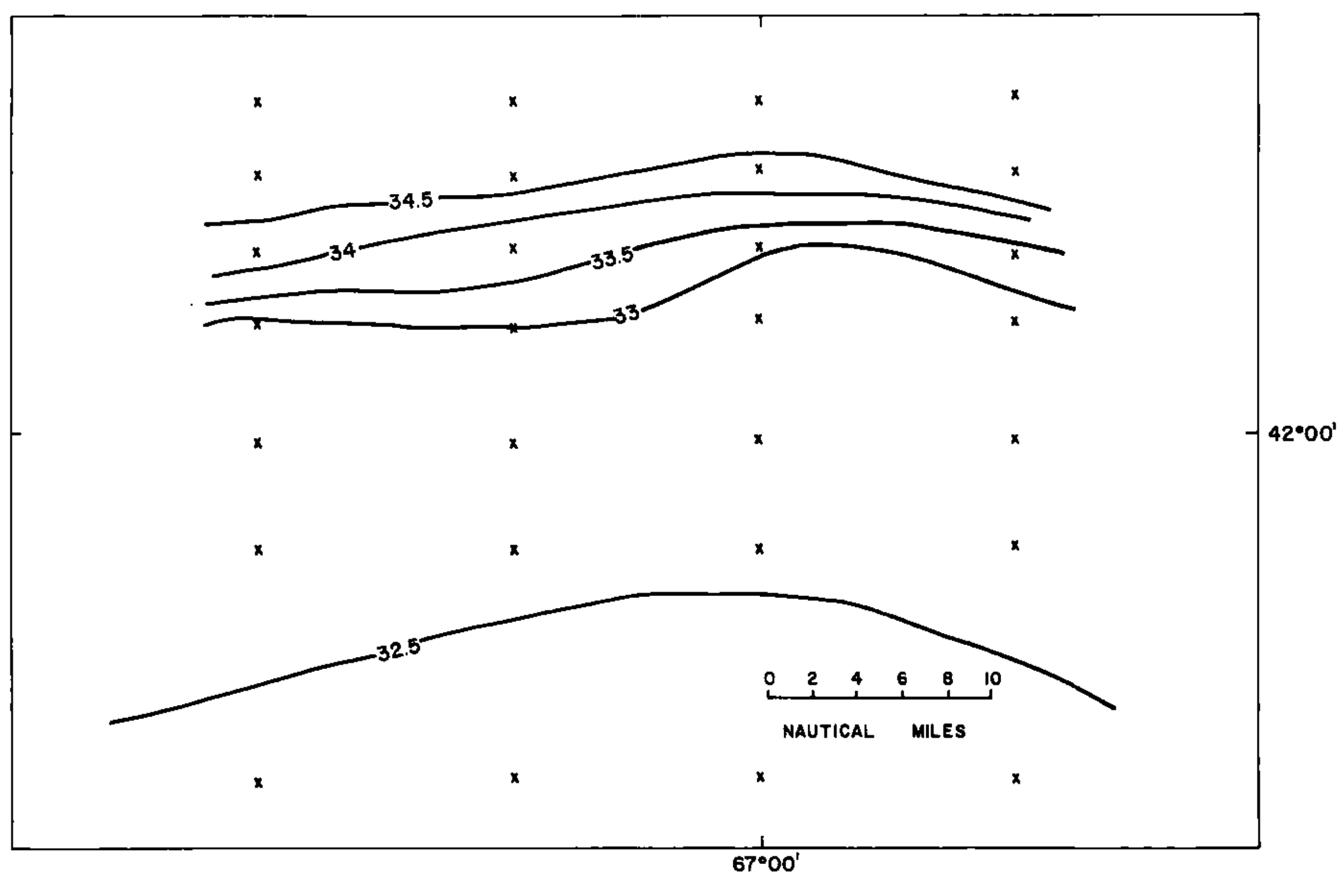

Fig. 3 Bottom salinity distribution near northern edge of Georges Bank (Sept 21-24, 1977).

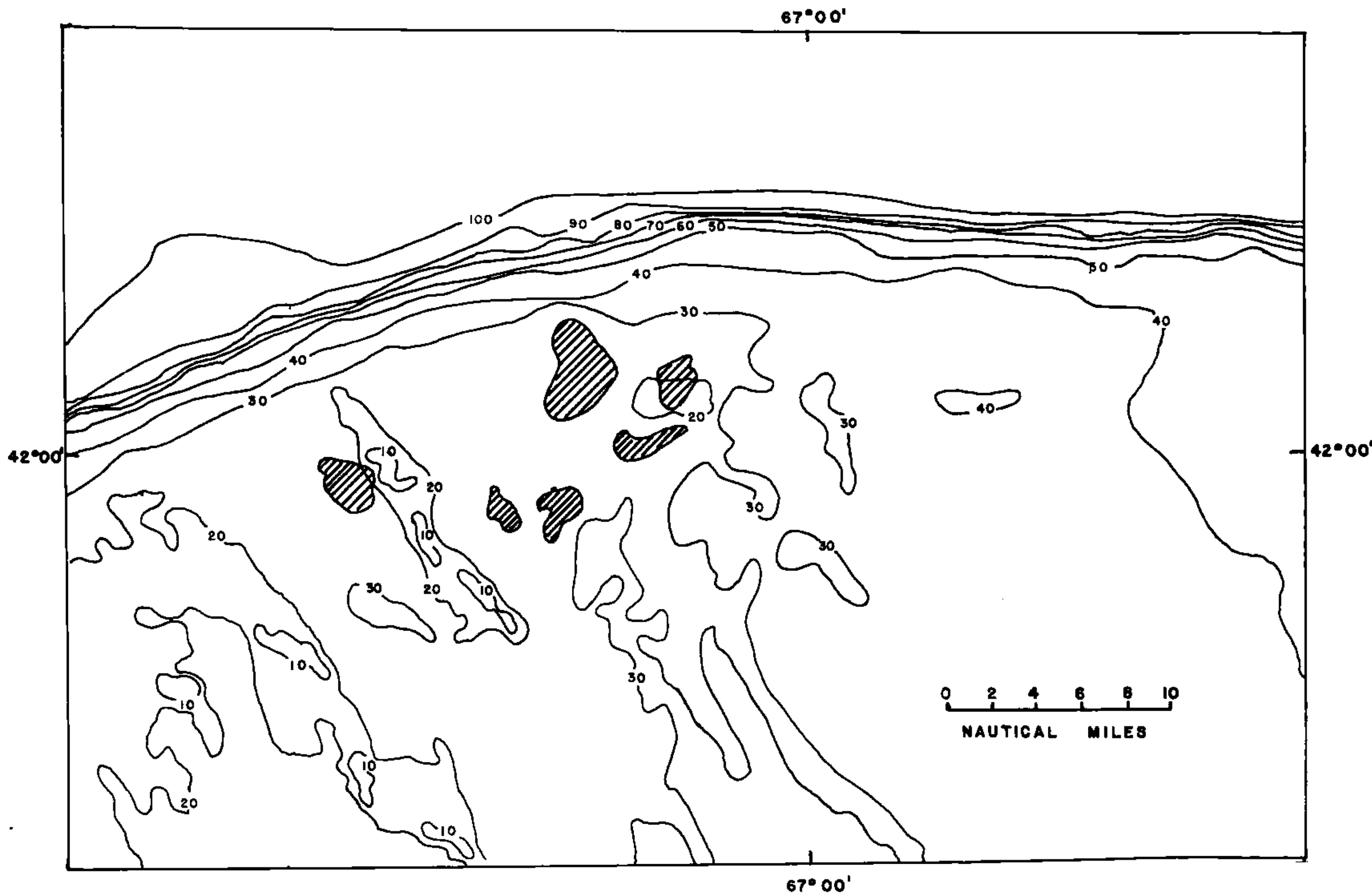

Fig. 4 Map of a portion of the northern edge of Georges Bank showing depth contours in fathoms. (Shaded areas are sites where herring eggs have been found in other years).

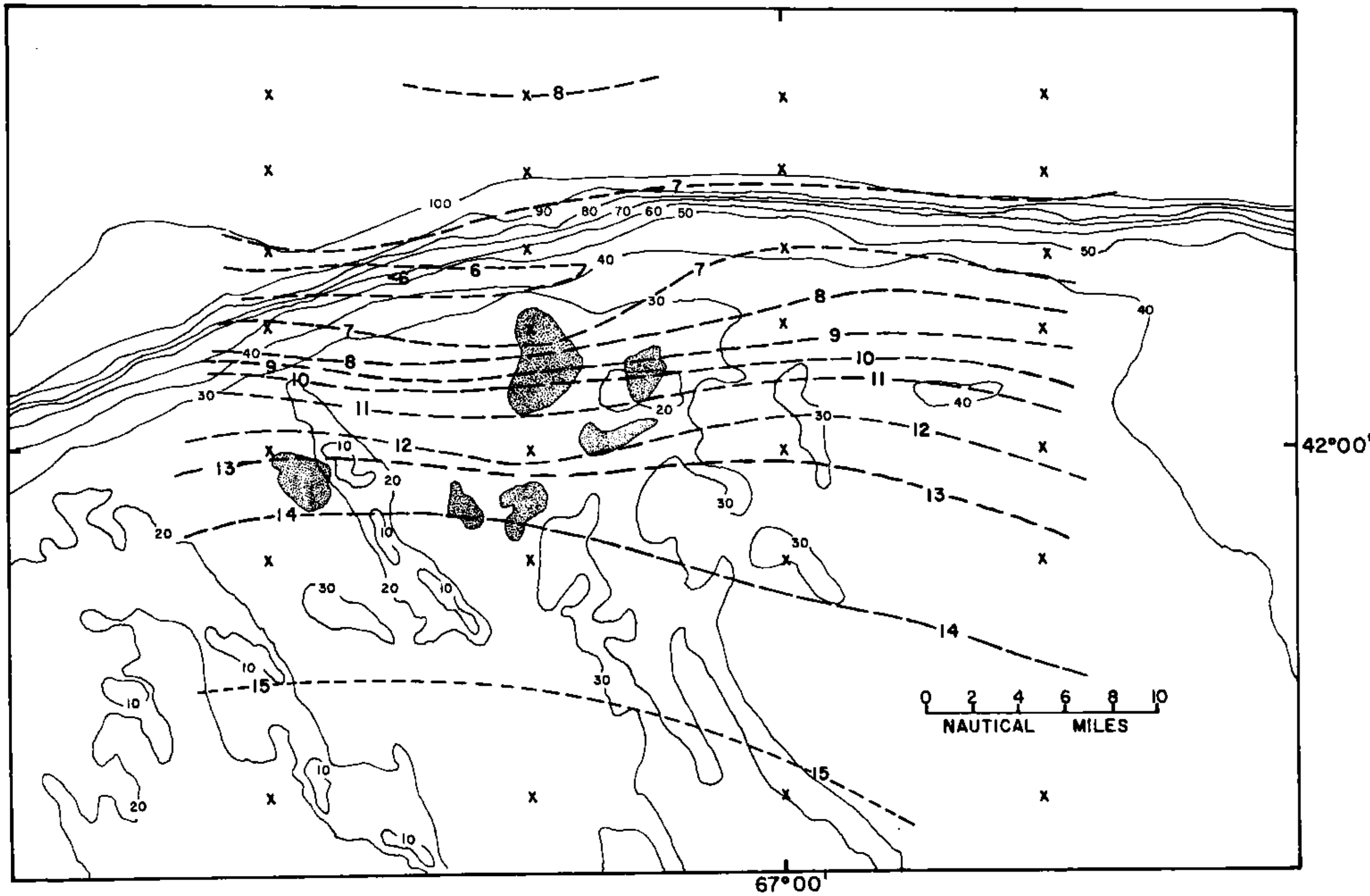

Fig. 5 Bottom temperature map (Fig. 3) overlaid on the bottom contour map (Fig. 2).

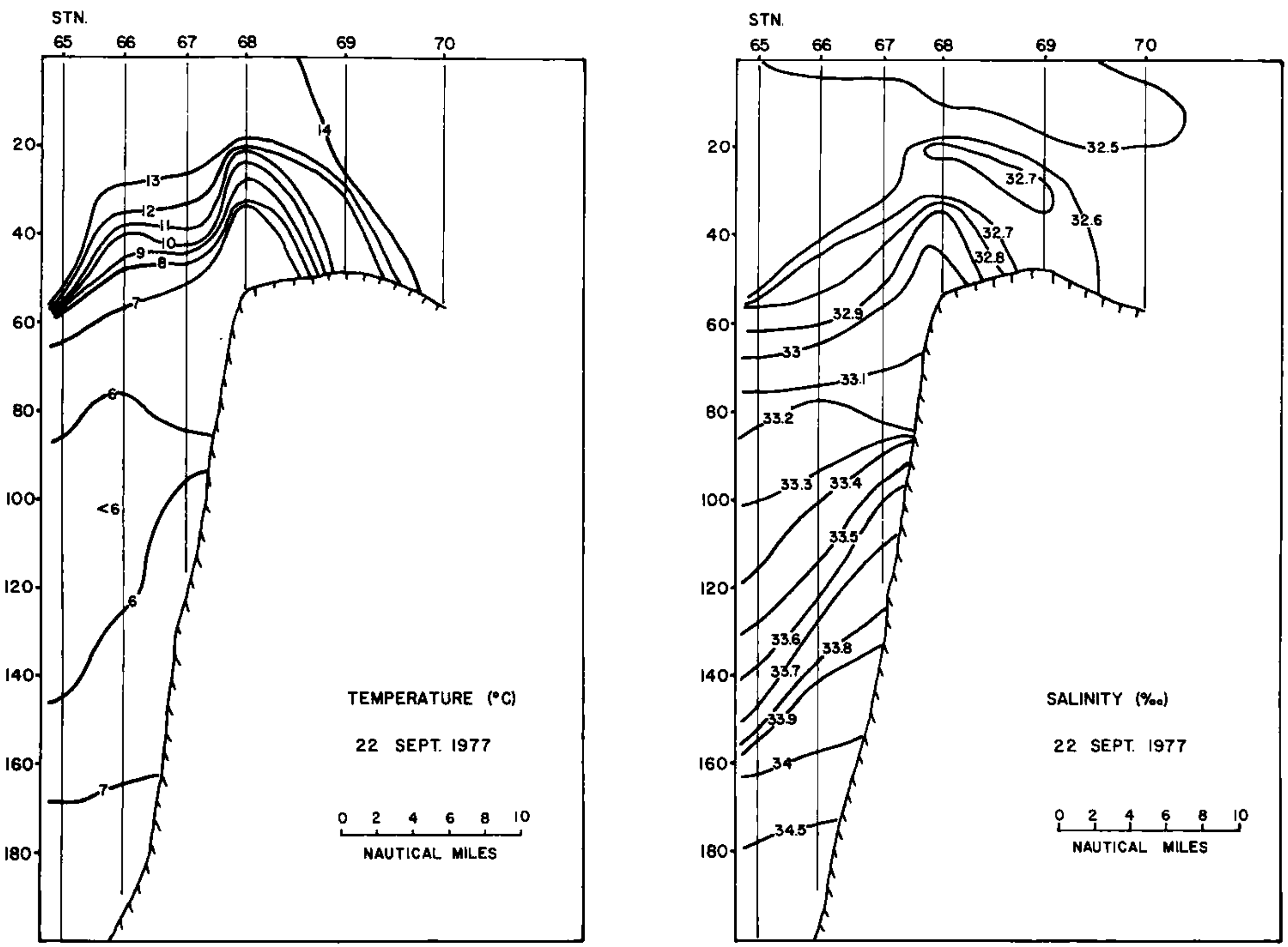

Fig. 6 Temperature and salinity cross-section across northern edge of Georges Bank, September 22, 1977.

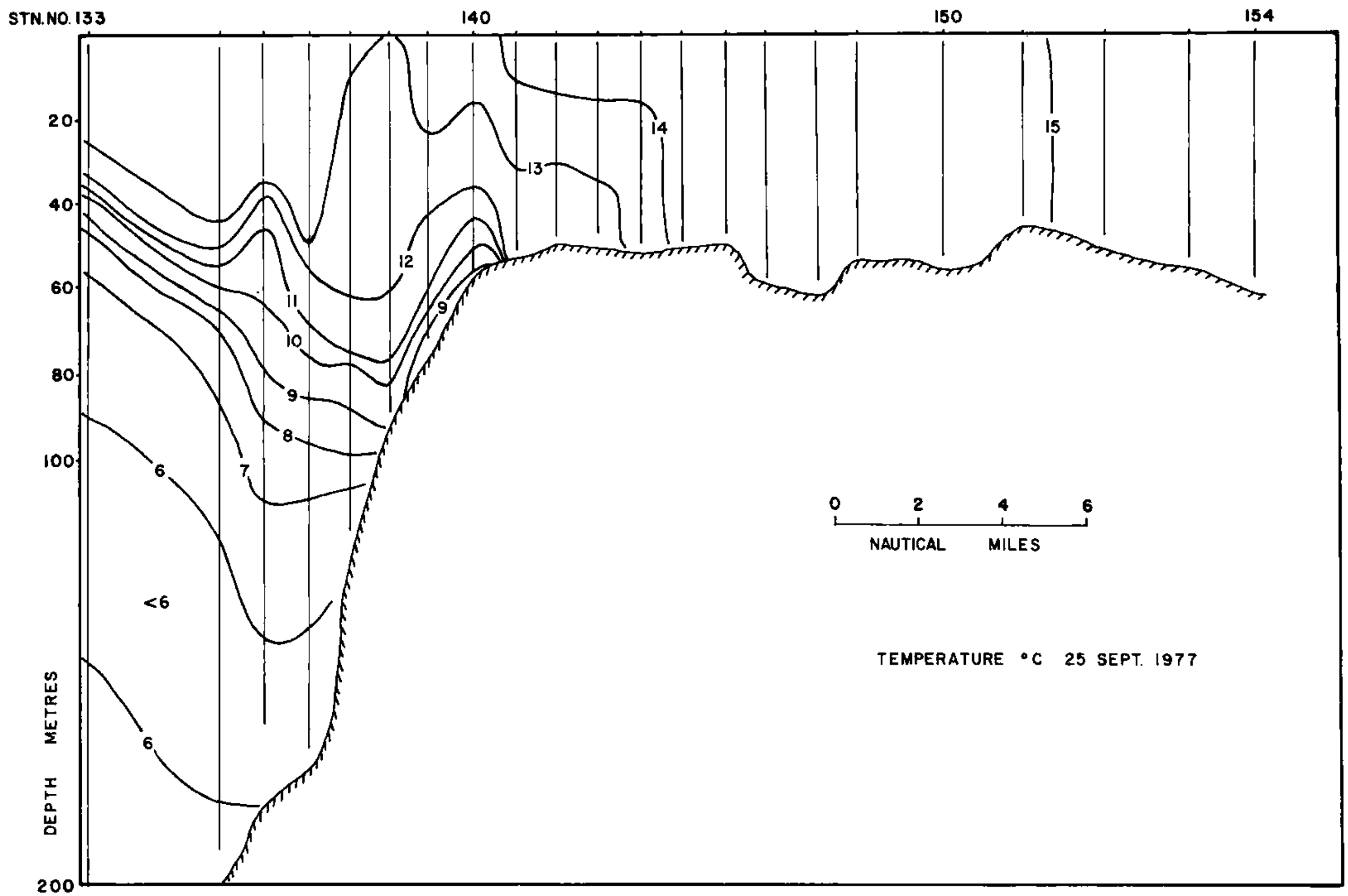

Fig. 7 Temperature cross-section, Georges Bank, September 25, 1977.

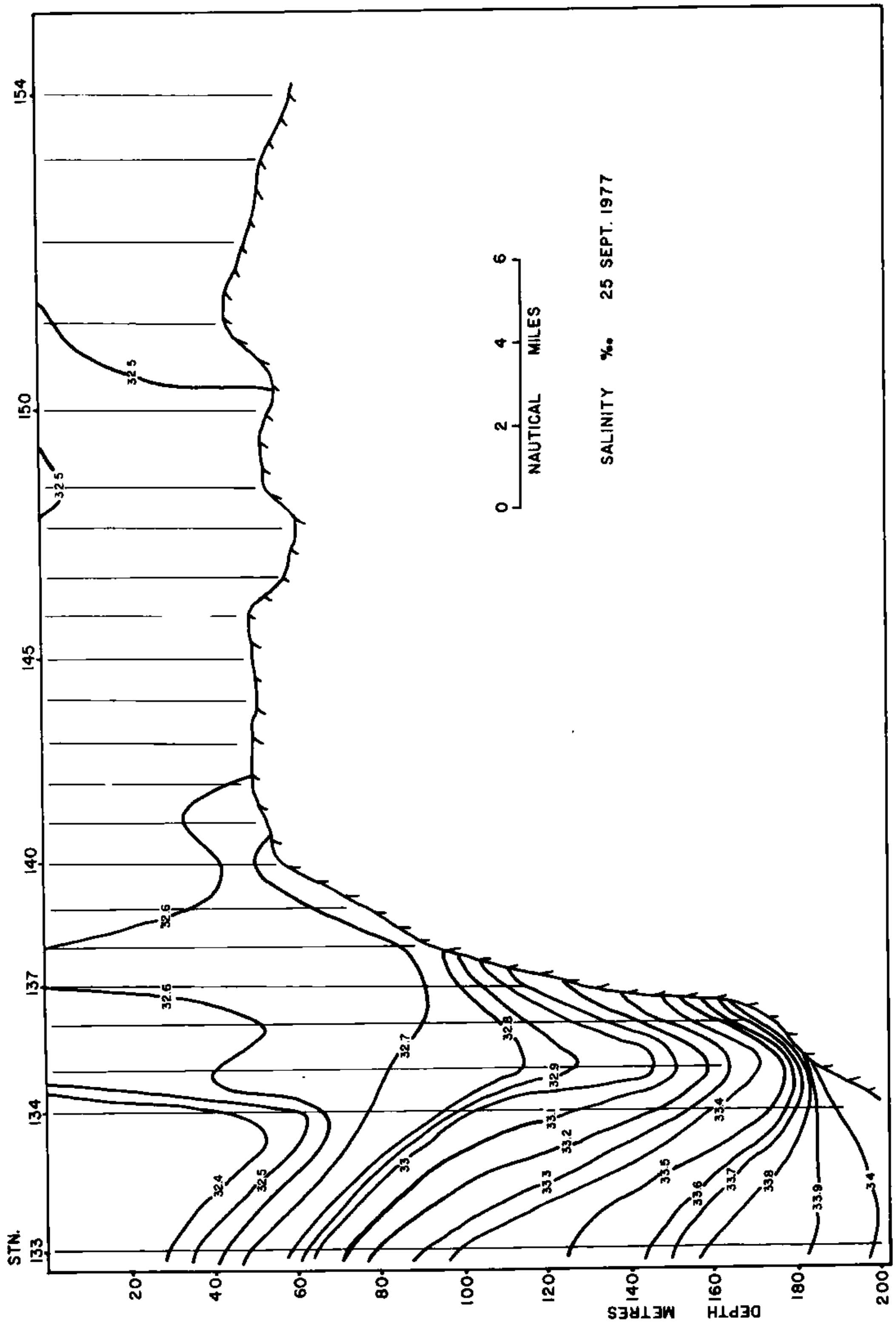

Fig. 8 Salinity cross-section, Georges Bank, September 25, 1977.

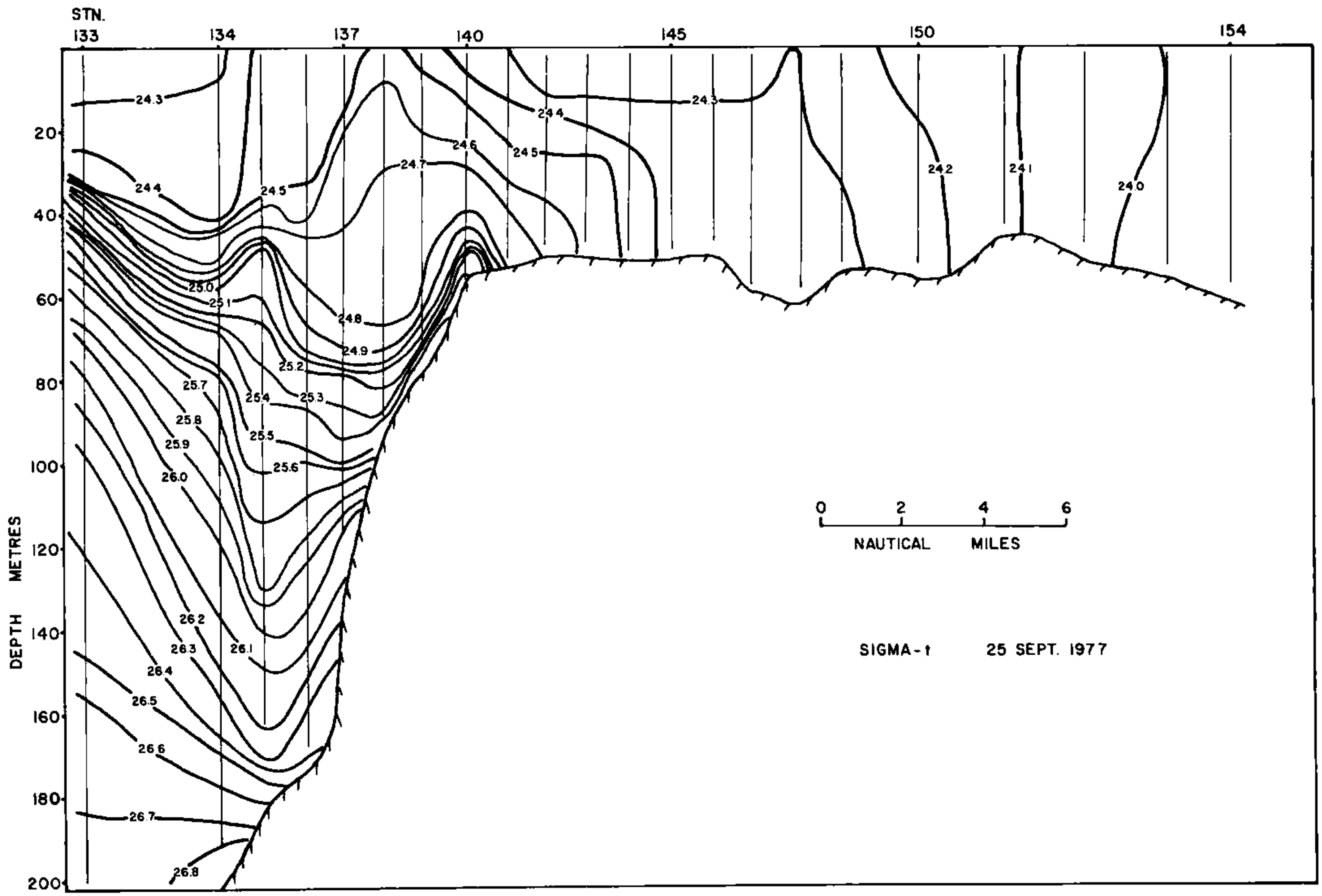

Fig. 9 Density (Sigma-t) cross-section, Georges Bank, September 25, 1977.

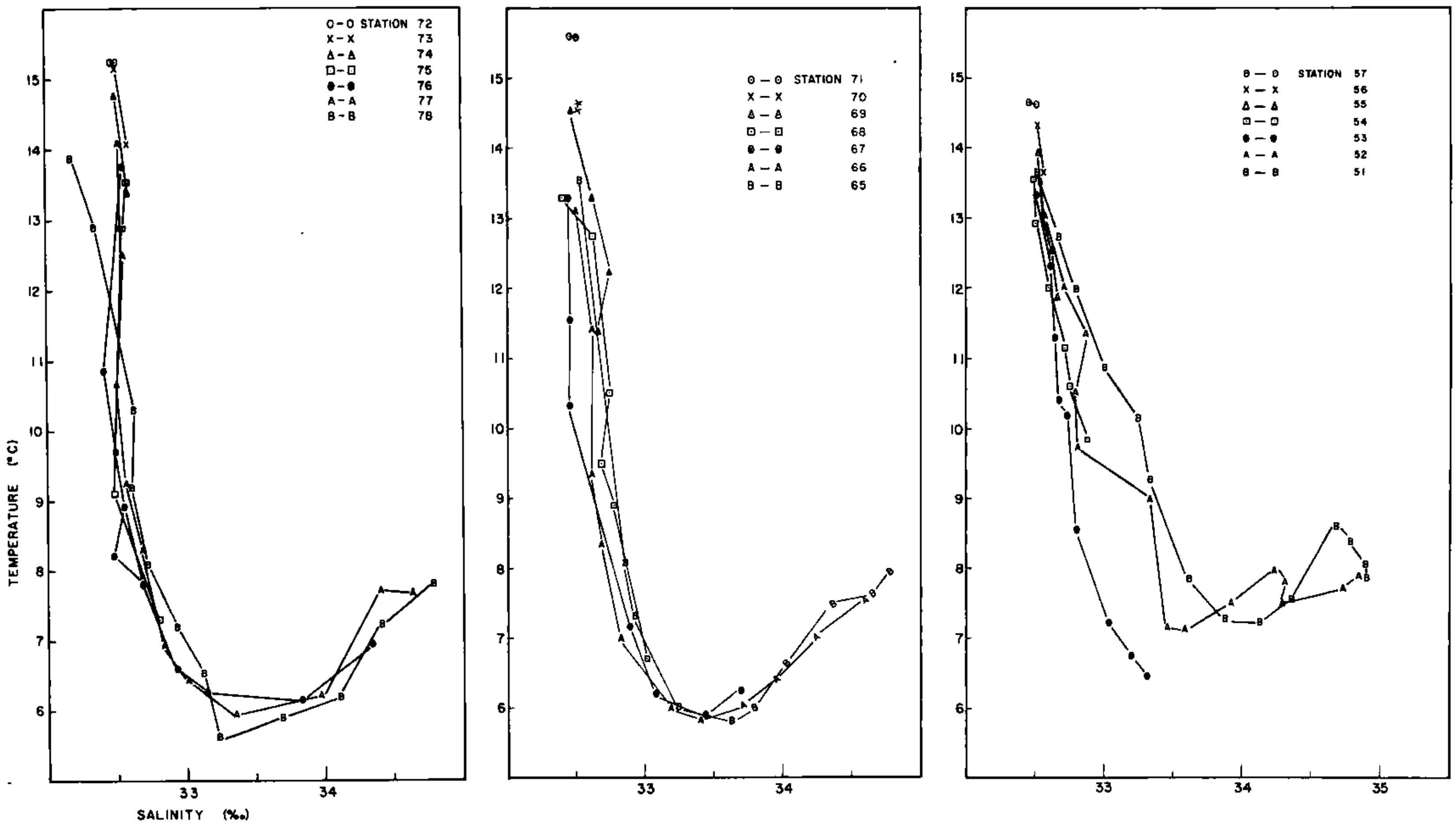

Fig. 10 Temperature-salinity diagram for three sections across northern edge of Georges Bank.

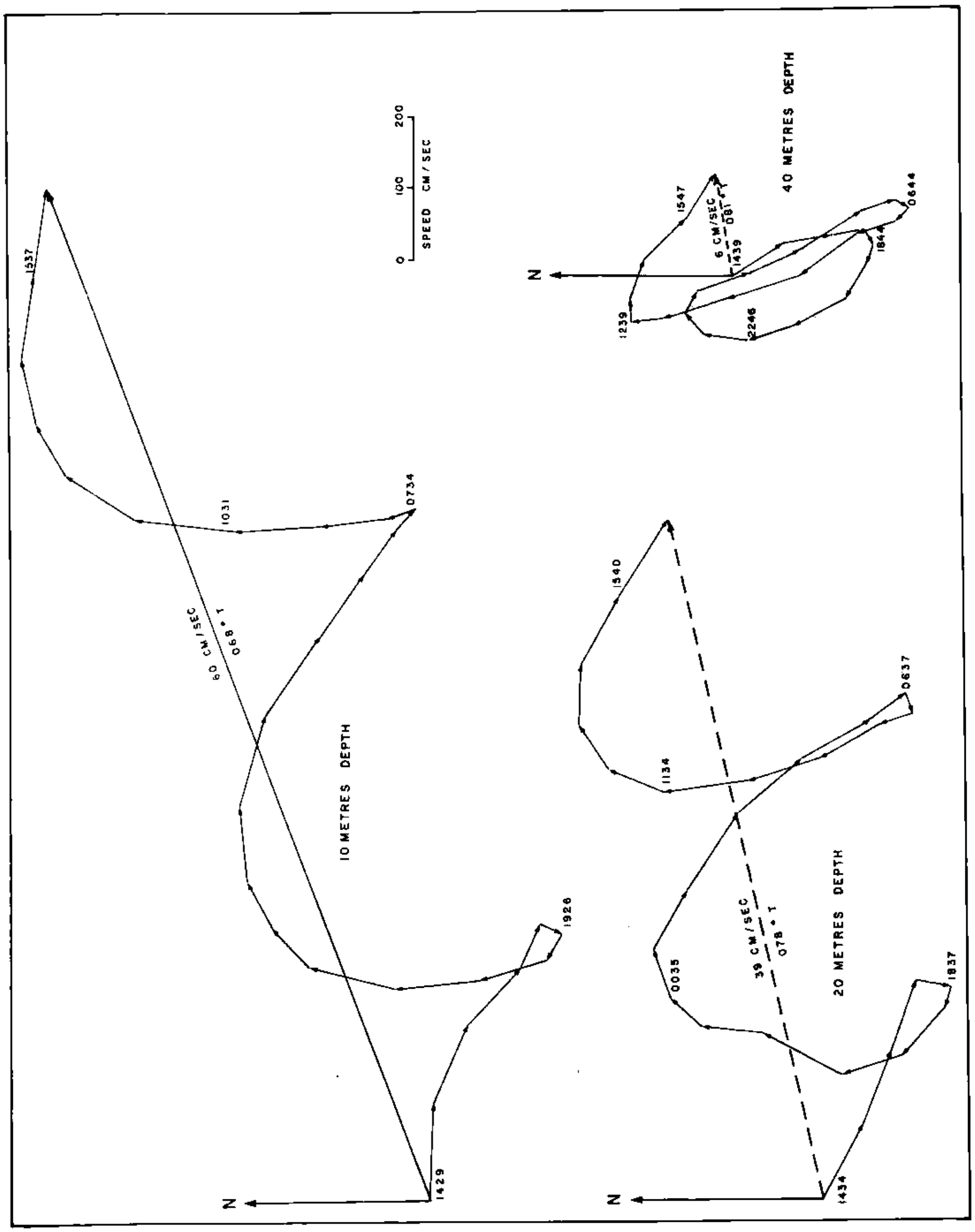

Fig. 11 Progressive vectorplot of currents at 10M, 20M, and 40M for 25-hour anchor station, September 23-24, 1977.

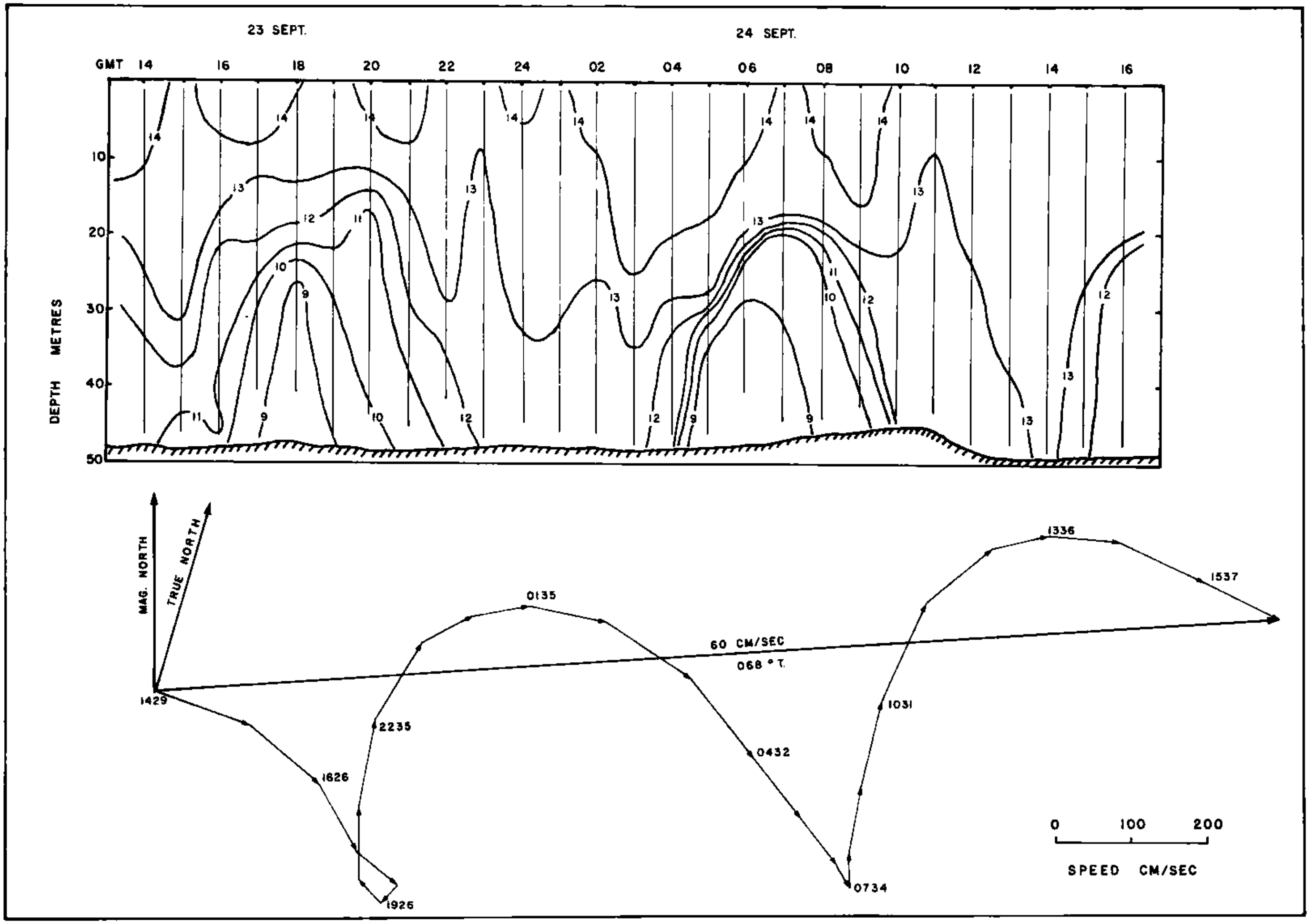

Fig. 12 Time-depth plot of temperature (upper half of figure) at anchor station, Sept 23-24, 1977. Progressive vector plot of currents at 10m depth are shown in lower portion of figure.

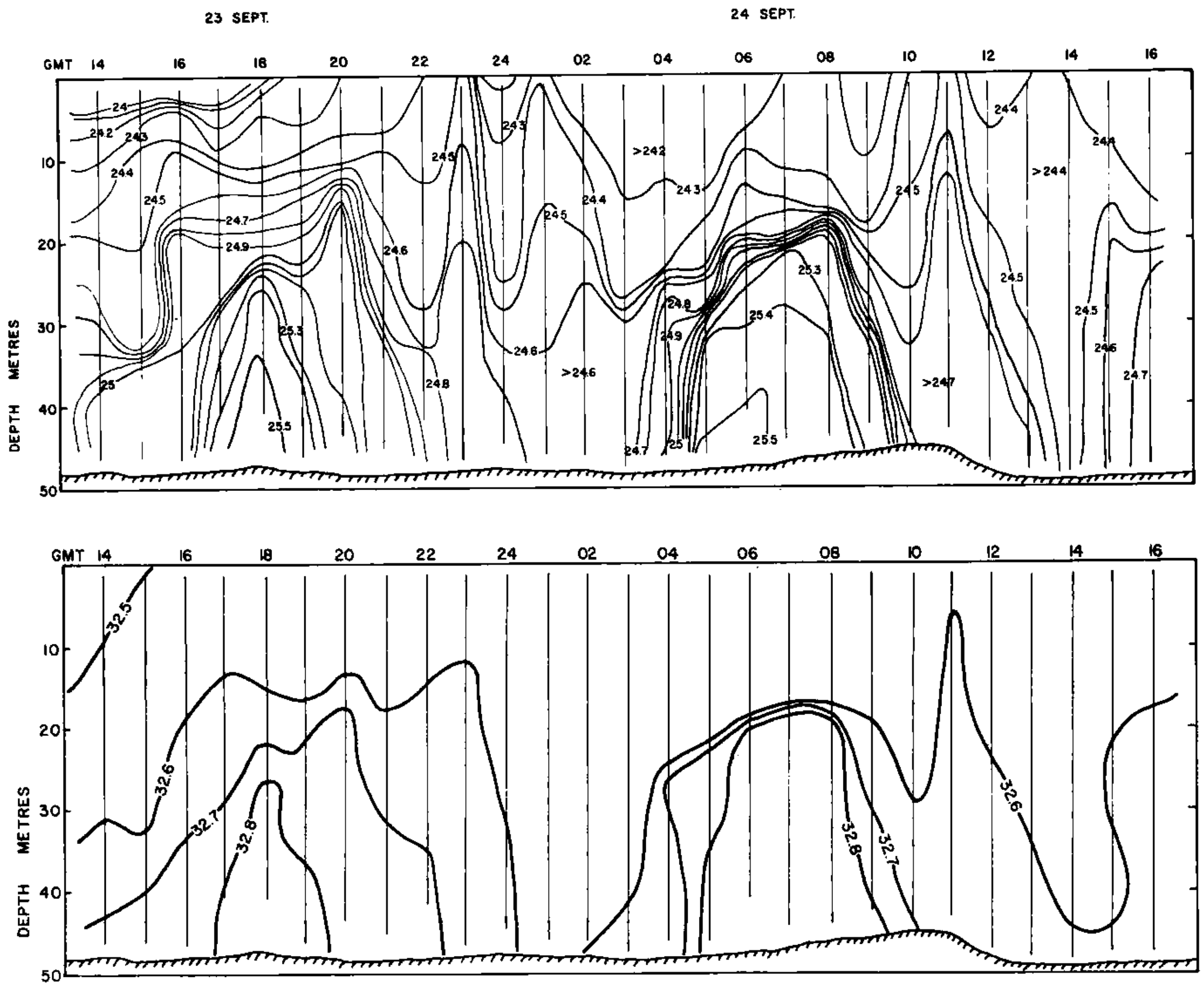

Fig. 13 Time-depth plot of density (upper diagram) and salinity (lower diagram) at anchor station Sept 23-24, 1977.

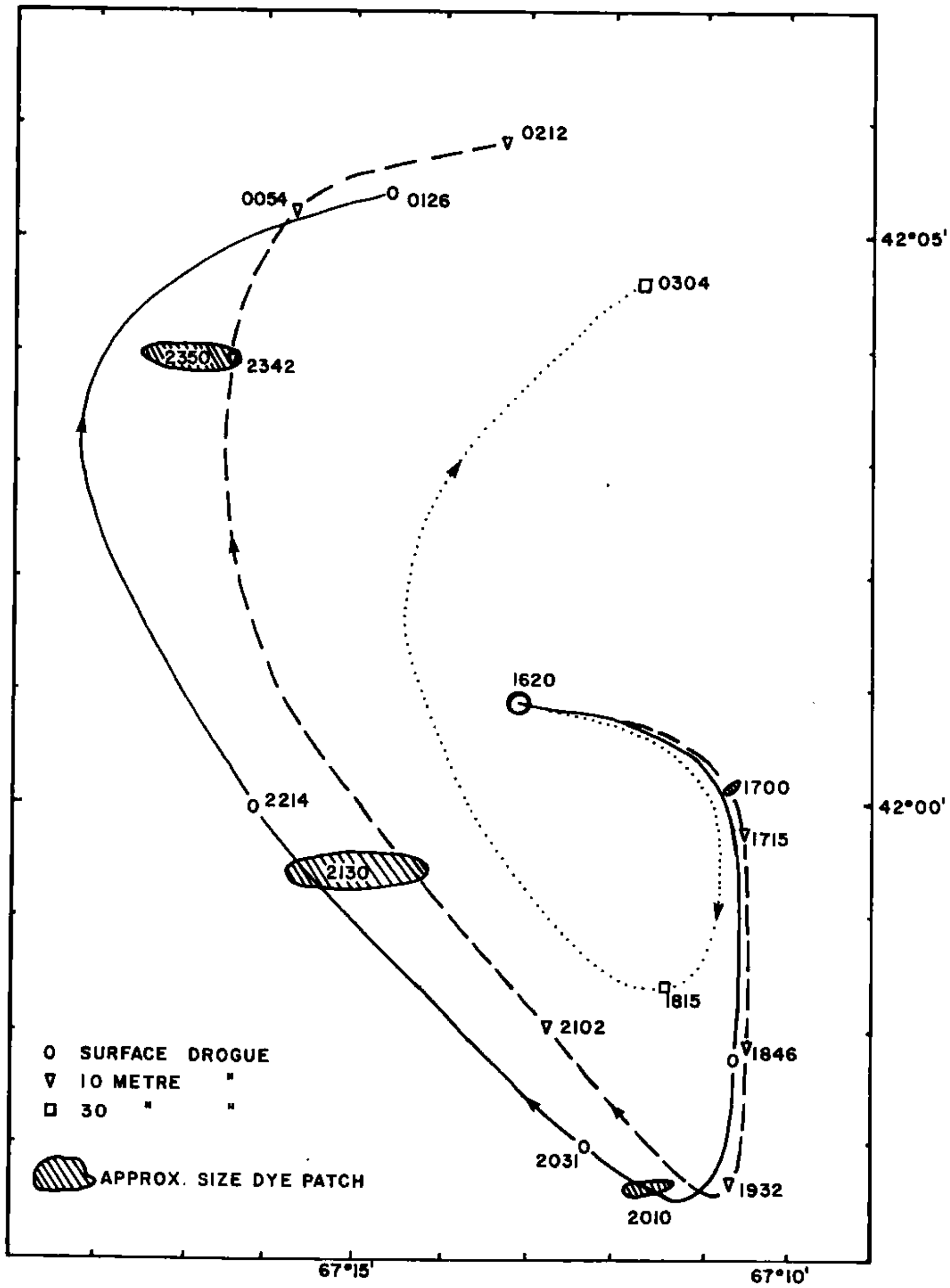

Fig. 14 Trajectories of dye patch and drogues following release Sept 24, 1977.