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Herring Larvae and Currents West of the Orkneys

by

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Introduction

Wood (1971) and Zijlstra (1972) have commented on the possibility of the abundance of small larvae produced by the NW North Sea stock near Orkney being overestimated because of transport of larvae into this area from the west. This implies that a proportion (or perhaps a major part) of the herring larval concentrations off northern Scotland are derived from spawning grounds in the Hebrides area to the west of Scotland (VIa).

The transport of larvae from the west coast of Scotland to Orkney would demand the presence of persistent currents which can transport considerable quantities of water. It has previously been shown (Dooley 1970, 1973) that a strong current, the Fair Isle current, flows southwards about 20 nm's east of the Orkneys but has a width of only 8 nm's. Although the strength of this current is such that it could transport larvae at a rate of about 5 nm's/day (quite large by North Sea standards) it is not necessarily a major transporter of larvae because of its limited spatial extent. On the other hand, as discussed in Dooley (1970), such an offshore current may act to confine the larvae to the Orkney area where there is clear evidence of an increase in herring larval abundance in 1972 after several years of lower abundance there (Saville and McKay (1974)).

In order to understand in more detail the origins of the herring larvae found near Orkney, and in the adjacent part of the north-western North Sea, it is evident that current measurements west of Orkney are desirable; Ramster et al (1973) have reported a drift marker experiment in this area from which they concluded that larvae hatched in VIa may be transported into the northern North Sea via the Pentland Firth. Subsequent to Ramster's experiment more detailed current measurements were made from 8-25 August 1974 by the Marine Laboratory, Aberdeen (Fig. 1) as part of a study of the Fair Isle current. In this paper these measurements are interpreted in relation to the typical herring larval distributions in the same area during September and October. Although the current measurements were not made at the exact time when herring larvae are present in the area it is expected that hydrographic conditions are sufficiently stable there (see eg Craig (1959), Ramster et al (1973)) to justify a small extrapolation. Because the 1974 larval data were not available at the time this paper was written, the 1973 data were used. These are fairly typical of what is observed in this area in all years (Wood (1975)).

Current measurements in August 1974

Five current meter moorings were deployed at positions 125-129 (Fig. 1) from 8-25 August. On most of these moorings recording current meters were set at depths of about 25 m and 80 m, the average depth of water in this locality being about 100 m. The south-easternmost mooring was located very close to the west Orkney coast, in coastal water of salinity 34.75‰. This location is one of typically large abundances of larvae in September (see eg Saville and McKay (1973)). Progressive vector diagrams of the residual (tidally-averaged) flow, which give an impression of the cumulative water movement flowing past a current meter at position 125 (35 m depth), 126 (21 m depth) and 127 (30 m depth) (Fig. 2), produce contrasting diagrams indicating considerable variability over comparatively short distances. The strong east-going current at 127 indicates the presence there of the Fair Isle current which exists as a narrow south flowing current east of Orkney. The presence of a strong northerly current at 125 was, however, quite unexpected and is interpreted as an artifact of the complex tidal streams there with flood and ebb streams flowing at an obtuse angle to one another. Consequently the residual current at position 125 must be considered to be extremely localised (this was confirmed by parachute drogues) and cannot be regarded as a residual current in the same manner as that at position 127. Thus, since residual currents at position 126 were also very weak it is clear that there is no significant movement towards the Pentland Firth, at least from this particular area.

From the current measurements at positions 125-129 a vertical section of the Fair Isle current west of Orkney was produced (Fig. 3a); the residual flow at position 125 was ignored, for the reasons given above. The location of the northerly limit of the current can only be estimated since the current meter positions did not extend beyond this limit. Its location was, in fact, based on the known density distribution and its relation to currents east of Orkney. Even though quite a lot of conjecture has gone into Fig. 3a the current distribution is probably quite realistic since it represents a volume transport of 0.2×10^6 m^3/s whilst the Fair Isle current east of Orkney has typically a transport of 0.3×10^6 m^3/s (Dooley 1974). The difference in transport may be a natural fluctuation or, more likely is a consequence of entrainment due to the violent mixing in the strong tidal streams near Fair Isle. This would also explain an increase in salinity within the current from about 35.05‰ to the west of Orkney to 35.15‰ to the east of the islands. Apart from this changing salinity within it, the location of the current itself is usually easily identifiable since it is marked by a slight levelling in the salinity gradient between the inshore coastal waters and the 'Atlantic' water lying just beyond 129. This 'Atlantic' water spreads along the bottom to as far as position 127 on occasions.

Herring larvae and the Fair Isle current

The Fair Isle current (Fig. 3a) is assumed to be a persistent feature west of Orkney. Its precise position may alter with time but, according to the distribution of density (Ramster et al 1973) which remains unchanged over considerable periods, fluctuations in its position are likely to be small. It is important to note that this current, which has a core speed in excess of 10 cmS^{-1} (5nm's/day displacement) may be modified by the wind and other meteorological forces but is certainly not a consequence of them. Consequently larval distributions would be expected to be affected by it in a similar way each year if, as seems to be true, the centres of larval hatching are fairly constant. In relation to the core of the current near position 127, which is 18 nm's west of Orkney and 30 nm's north of the mainland of Scotland, most of the young herring larvae (< 10mm) are seen to be confined to the area between the current and the coast (Fig. 3b). Consequently these may have a relatively undisturbed distribution in this area, and, by analogy with the east coast may also be relatively unaffected by wind driven processes. Fig 3b also shows the corresponding (1973) distribution of > 10mm larvae which is quite different from that of the younger larvae. In particular there is a significant peak within the core of current itself, and it is possible that at least a proportion of these larvae may have been transported by the current from the west.

Discussion

To reach any meaningful conclusions on the distribution of larvae and its relationship to currents west of Orkney it is necessary to spatially extrapolate the current measurements described above. It has already been noted that the location of the current can be identified by features of the salinity/density distribution at least between the area of these measurements and previous measurements east of Orkney. Extrapolating westwards the current can be identified according to mean salinity distributions published by Craig (1959), as a narrow band to the north of the Hebrides, passing Cape Wrath near North Rona then continuing eastwards towards position 127 after which it turns northwards, rounding Turbot Bank at roughly 60°N 2°30'W, before entering the North Sea through the Fair Isle Gap. Combining the information in Fig 3a with the above deduced current distribution it is possible to estimate how larvae spawned off the Hebrides may be transported towards Orkney (Fig 4). The 5 day displacement contours represent the estimated distance larvae could travel within that time, longer distances occurring at the current axis. A and B (Fig 4) represent respectively the limits of transport of < 10mm and < 15mm larvae which have growth rates of X mm/day. There is a wide range of estimates of herring larval growth rates in the literature see, eg Schnack (1972). Some are based on laboratory experiments and there is some doubt that these estimates can be extrapolated to the open sea. It seems however that typical growth rates may lie in the range .17-.35 mm/day. With a hatching length of 6.5mm these figures have been used in calculating A and B. No account has been taken of the effect of vertical migration but this has in part been allowed for since no attempt was made to extrapolate the current speeds at 30 m depth to the surface, where it is reasonable to suppose currents are stronger. In spite of all these uncertainties it seems clear that < 10mm larvae hatched north of the Hebrides could account for some of the observed distribution west of Orkney and east of 4°W only at growth rates of less than .20mm/day. Even if this rather low growth rate is the correct one it is important to note that the width of the axis of the current is less than 10 nm's and thus the contribution made by larvae transported in this way to the total is likely to be small.

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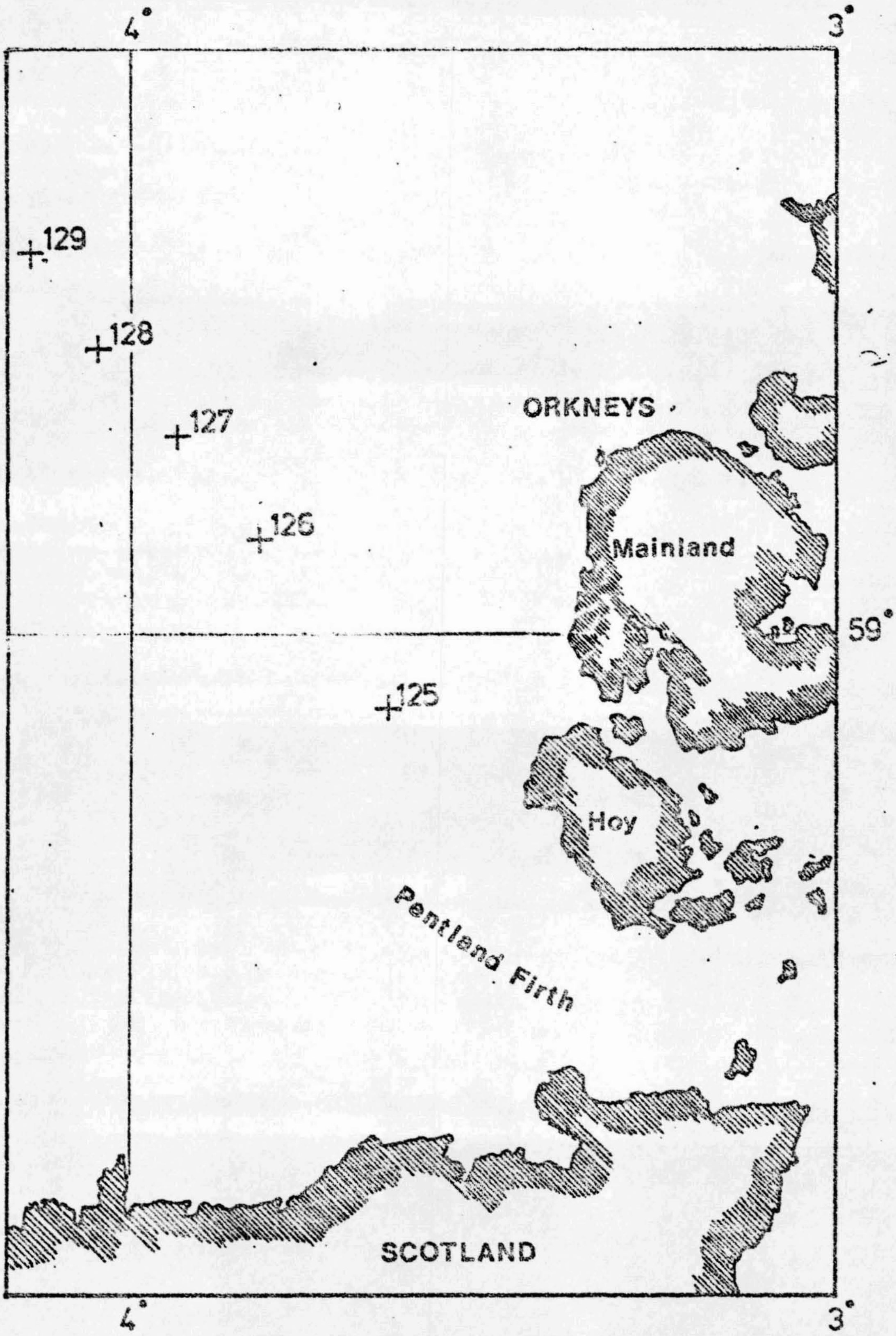


FIG. 1 : LOCATION OF AUGUST 1974 CURRENT MEASUREMENTS

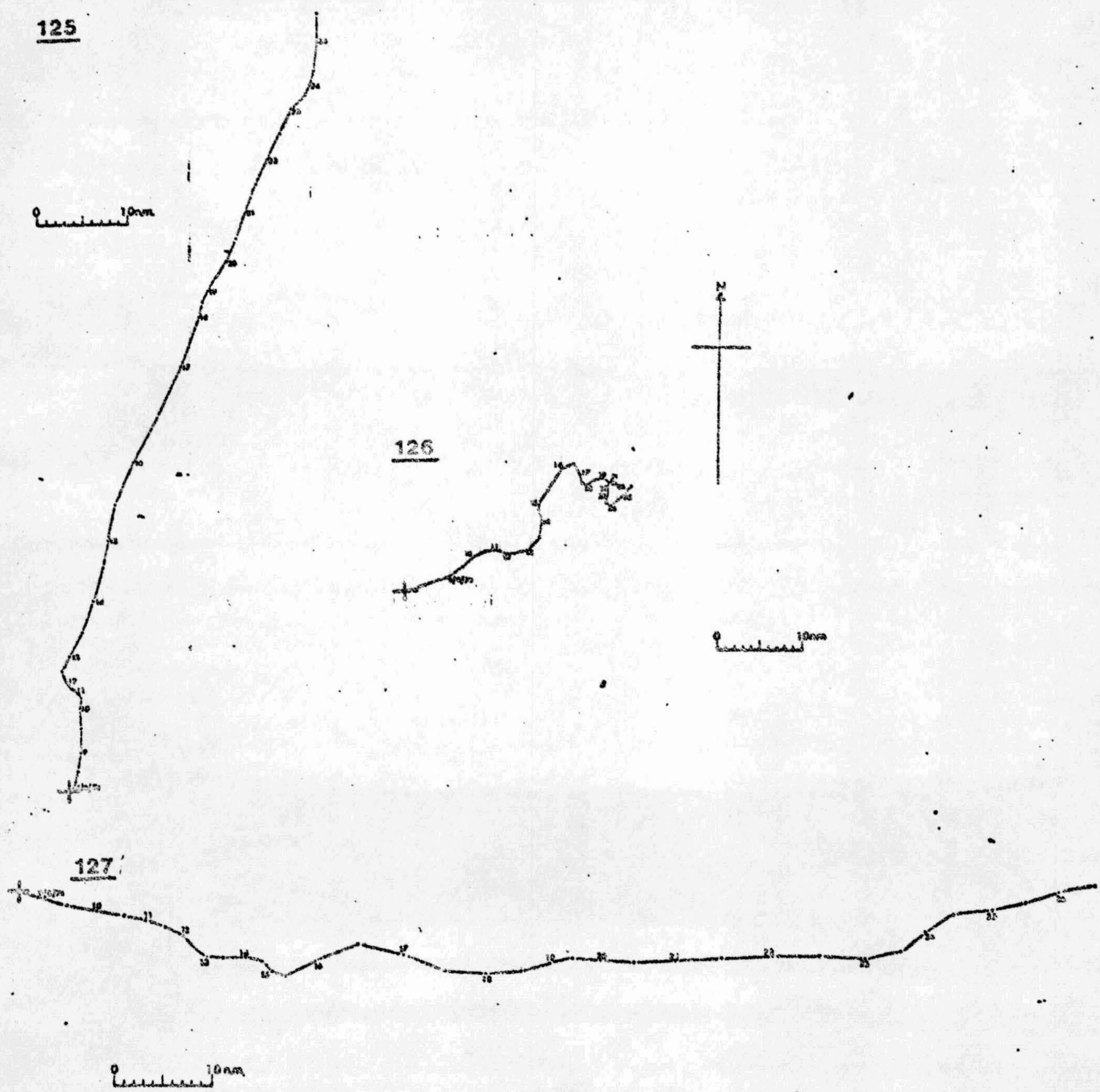
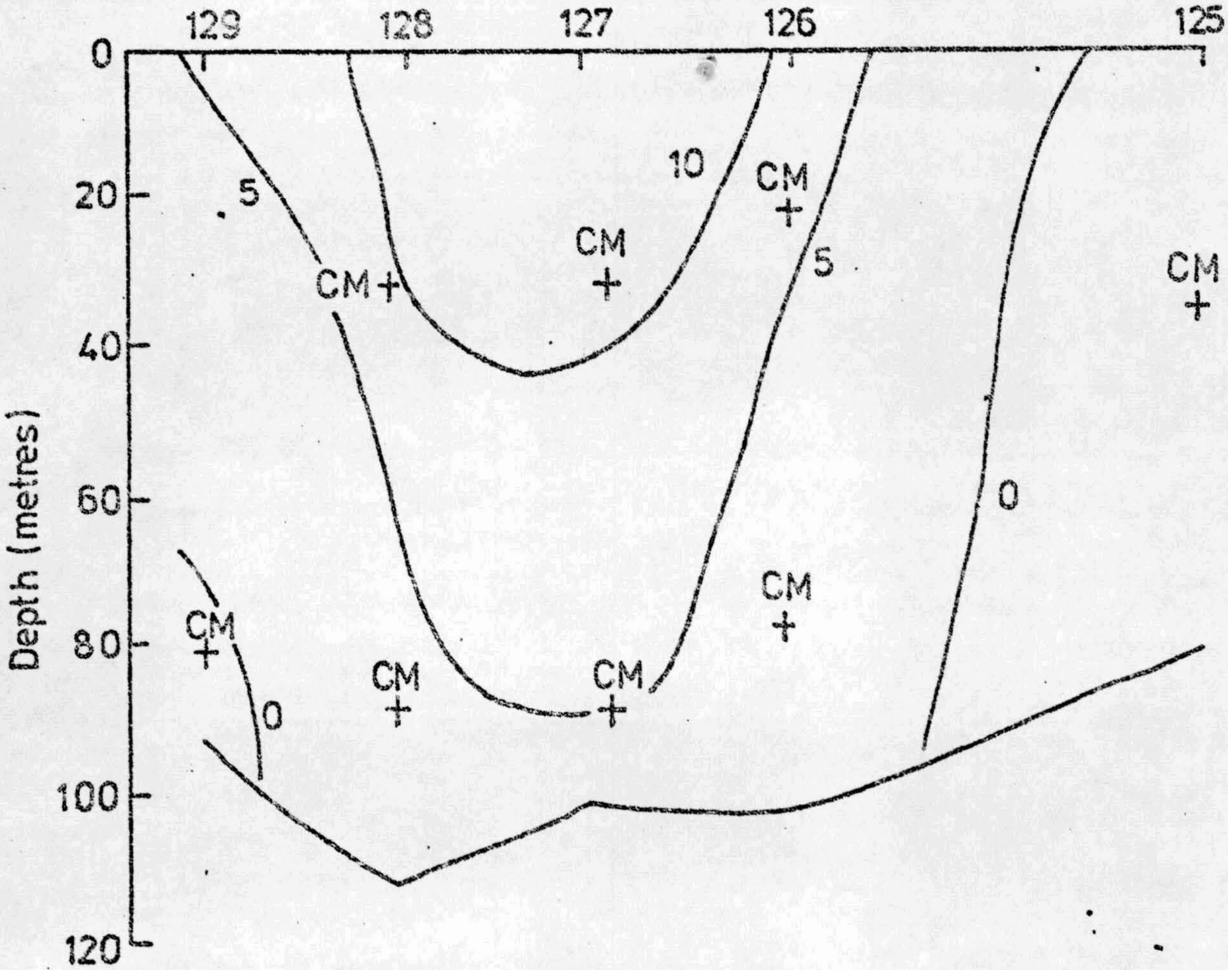


FIG.2: CUMULATED DRIFT AT POSITIONS 125,126,127

FIG. 3A: VERTICAL DISTRIBUTION OF RESIDUAL CURRENT SPEED (IN CM/S). DIRECTION OF FLOW IS EASTWARD.



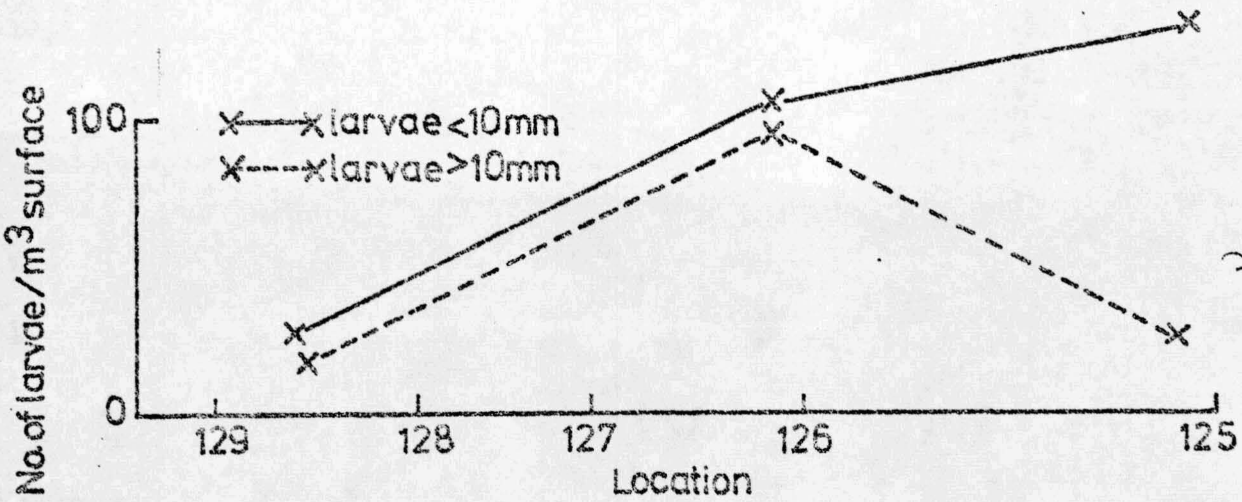


FIG. 3B: 1973 DISTRIBUTION OF LARVAE ACROSS AREA OF 1974 CURRENT MEASUREMENTS.

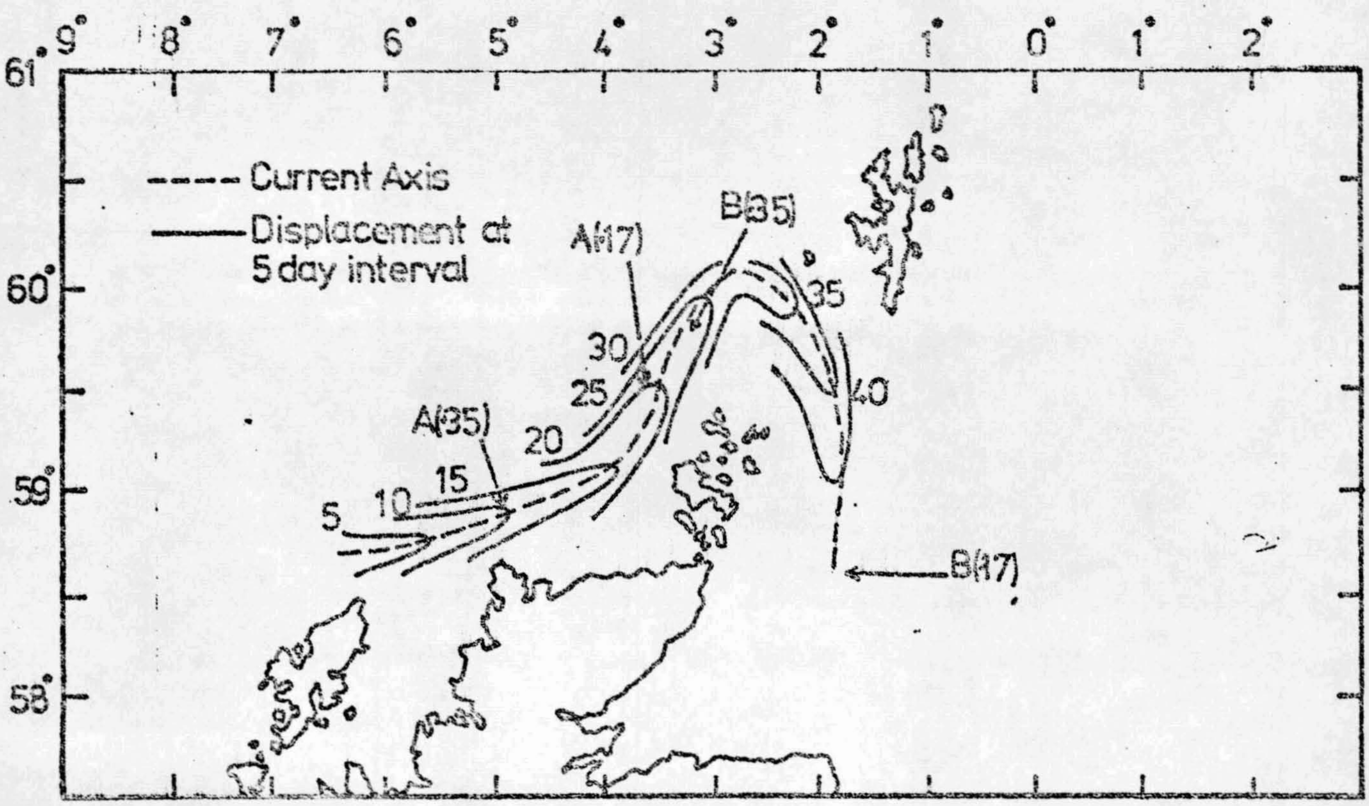


FIG.4: CHART SHOWING HOW LARVAE CAN DRIFT FROM NORTH OF THE HEBRIDES INTO THE NORTH SEA.