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THE VERTICAL DISTRIBUTION OF EGGS AND LARVAE OF BLUE WHITING (*MICROMESISTIUS POUTASSOU*) AND MACKEREL (*SCOMBER SCOMBRUS*) IN THE EASTERN NORTH ATLANTIC AND NORTH SEA

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INTRODUCTION

Since the earliest investigations of Damas (1909) and Schmidt (1909), a considerable literature has accumulated on the geographical distribution of the young stages of marine fish, but relatively few observations have been made on their vertical distribution. In recent years, increased interest in the survival of fish larvae has raised the need for detailed information on the distribution of both eggs and larvae, particularly in the vertical plane (see, for example, Lasker, 1975). In the present paper the vertical distributions of the eggs and early larvae of blue whiting (*Micromesistius poutassou*) and mackerel (*Scomber scombrus*) are described and discussed in relation to temperature conditions and food availability for the larvae.

METHODS

In conjunction with the Ministry of Agriculture, Fisheries and Food, Lowestoft and the Department of Agriculture and Fisheries for Scotland, Aberdeen, seven cruises were undertaken in the spring months of 1974, 1975, 1977, and 1978 to investigate the distribution of young stages of blue whiting and mackerel to the west of the British Isles. A further cruise was carried out in cooperation with the Institute of Marine Research, Bergen, in the central North Sea in June and July of 1978. Plankton samples were taken on the ascent or descent, or on both stages, of oblique hauls at selected stations (Fig. 1), using a Longhurst-Hardy Plankton Recorder (LHPR) which takes discrete samples of plankton, each from a known depth range and volume of water filtered, while recording temperature continuously throughout the

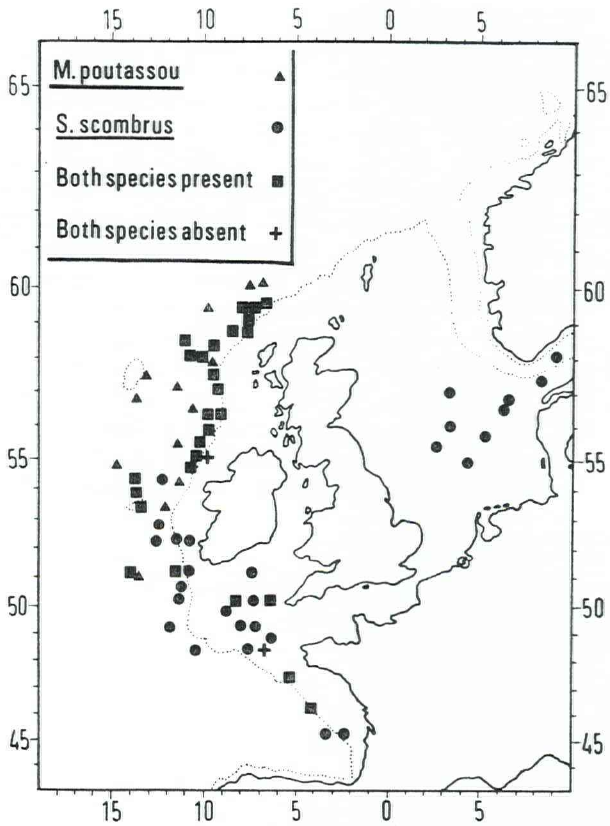

Figure 1. Positions of LHPR hauls on which eggs or larvae of *M. poutassou* and *S. scombrus* were taken.

haul (Longhurst et al., 1966). The LHPR used in these cruises was fitted with a conical nylon net (mesh aperture 280 μm) and a cod-end unit containing two rolls of nylon filtering gauze (mesh aperture 280 μm) which were advanced in steps to take discrete samples of plankton at pre-determined intervals of 15, 30, 60, or 120 seconds, selected according to the expected abundance of plankton and the spatial resolution required. On completion of a haul the filtering rolls were placed in 3 or 4% formaldehyde solution and were subsequently cut into samples from which the fish eggs and larvae were identified and counted, the counts being converted to numbers per 10 m^3 of water over depth intervals selected according to the sampling resolution of the haul.

Throughout the present paper the term "larva" is used to include all stages of development from hatching to juveniles; stages of development are also described as "yolk-sac larva" or "post-larva" (yolk-sac absorption to metamorphosis).

The sampling mechanism and storage caused some damage to the fish larvae with the consequence that shrinkage was greater than is usual in formalin-preserved specimens; it is estimated that the measurements of larvae made in the present study are some 15% less than would be obtained from preserved material taken by more conventional samplers.

RESULTS

BLUE WHITING (*MICROMESISTIUS POUTASSOU*)

In order to summarise the vertical distributions of blue whiting eggs, results from all positive hauls within each year have been combined to give a mean distribution for each year (Fig. 2). Grouping of the data in this way is justified since there is no obvious geographical variation between hauls and they were all taken from a single spawning ground (Coombs and Pipe, 1978) at a time of year when an unstratified and fairly uniform hydrographic regime is found throughout the area.

Since results were obtained in all years, eggs being taken from the surface to a depth of 600 m (Fig. 2); a few were found in the upper 200 m, but, as indicated by Bailey (1974), the greatest concentrations were in deep water, generally between 250 and 450 m. Adult blue whiting at the spawning grounds have been observed by echo-sounder at comparable depths (350–500 m: Pawson et al., 1975; 250–450 m: Pawson et al., 1978; 200–500 m: Walsh et al., 1978) and running ripe fish

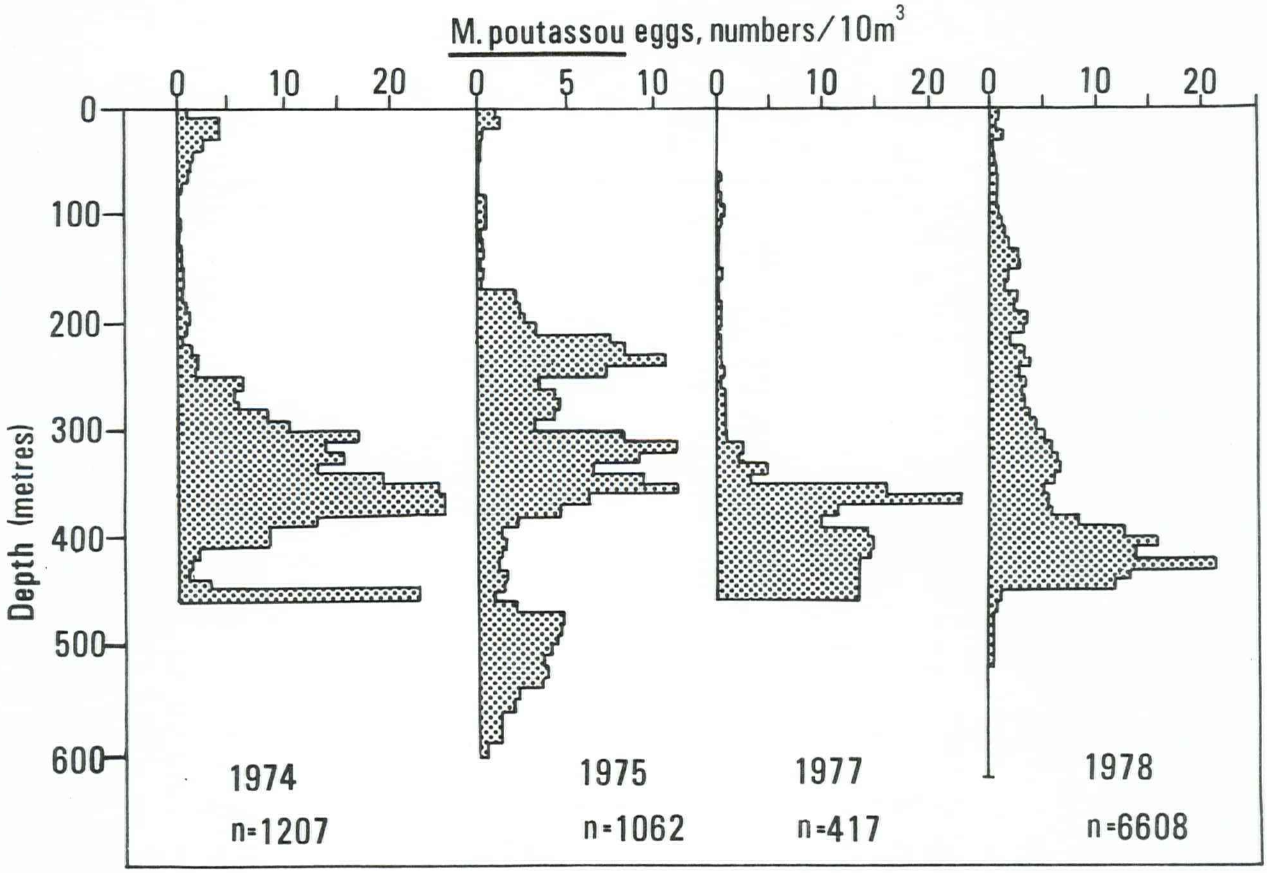

Figure 2. The vertical distribution of *M. poutassou* eggs plotted as the mean abundance for all positive hauls in each year.

have been taken by trawling at 250–450 m (Forbes et al., 1974).

The vertical distribution of blue whiting larvae showed greater variability between hauls than did the eggs. However, it became evident that there was a clear relationship between depth distribution and the size of the larvae, as shown in Figure 3 where all hauls on which larvae were found have been combined and the results plotted for three size categories of larvae. The smallest larvae (⩽2.5 mm in length), many of which were at the yolk-sac stage of development, were taken at all depths down to the limit of sampling at 620 m, the majority being below 400 m; the distribution had a maximum at 480–490 m and there was some indication of a small group of larvae in the upper 100 m. Larvae of between 2.6 and 5.0 mm in length were taken from the surface to 600 m; there was some suggestion of aggregation between 300 and 500 m but the majority of specimens were taken in increasing numbers from 100 m to the surface. The largest larvae, between 5.1 and 7.5 mm in length, were not found below 190 m and the majority occurred in the upper 40 m. Using the limited growth data available for blue whiting larvae (Seaton and Bailey, 1971; Bailey, 1974; Coombs and Hiby, 1979) this ontogenetic migration through a depth range of about 500 m would be expected to take place within approximatley 8 days of hatching.

MACKEREL (*SCOMBER SCOMBRUS*)

Comprehensive sampling for mackerel eggs and larvae to the west of the British Isles was undertaken during four cruises in 1977 (see Fig. 1 and Lockwood et al., 1977). Although their distribution was variable it became clear that in 1977 there was a relationship between depth distribution and the development of the thermocline. This is summarized in Figure 4 where all hauls taken in each month have been combined and representative temperature profiles for each month have been drawn alongside the egg distributions; during March, April, and May the vertical temperature structure at the positions of the hauls was very similar within each month and only a single temperature profile is drawn for each of those months (Fig. 4). During June two distinct types of temperature structure were observed and a representative profile for each of those is shown (Fig. 4); the relatively pronounced thermocline, of the order of 3° C, at about 25–40 m depth occurred at the position of four of the

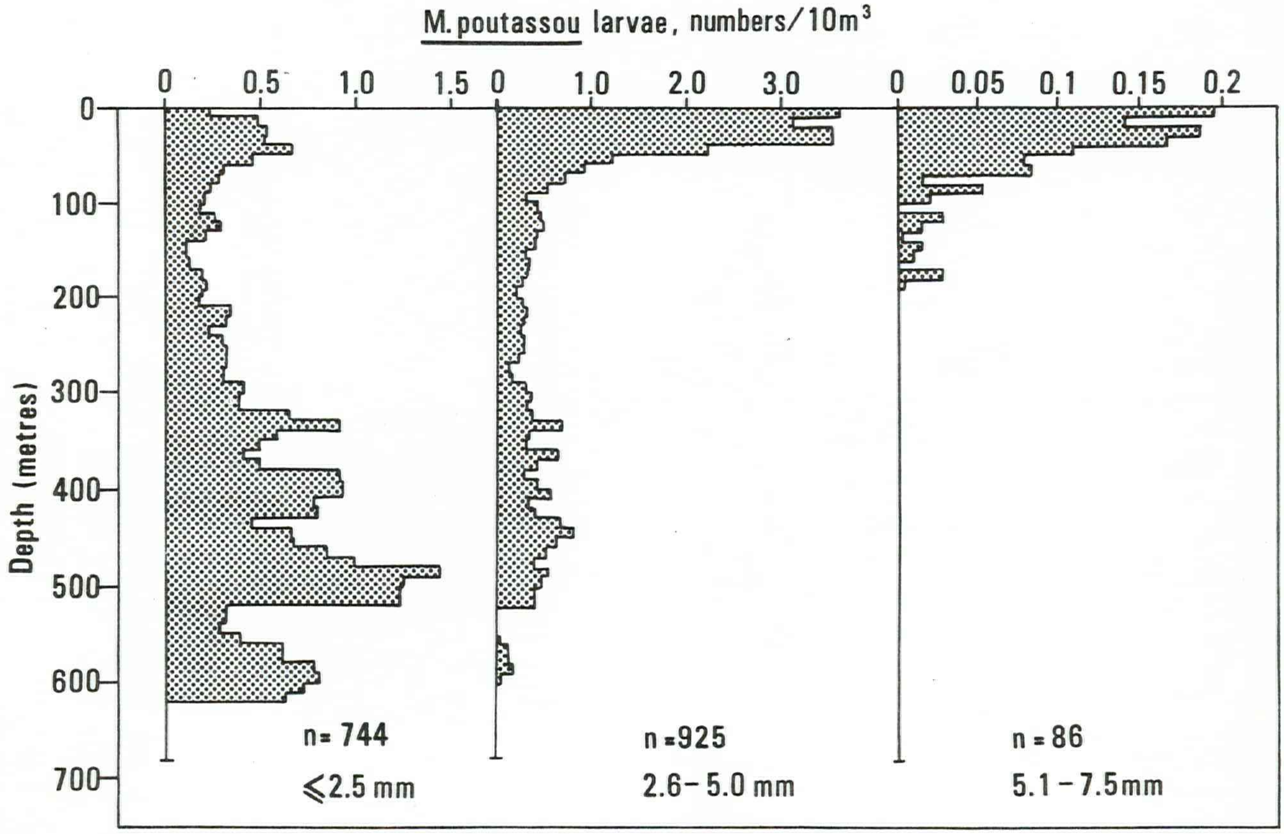

Figure 3. The vertical distribution of three size categories of *M. poutassou* larvae plotted as the mean abundance for all positive hauls in all years.

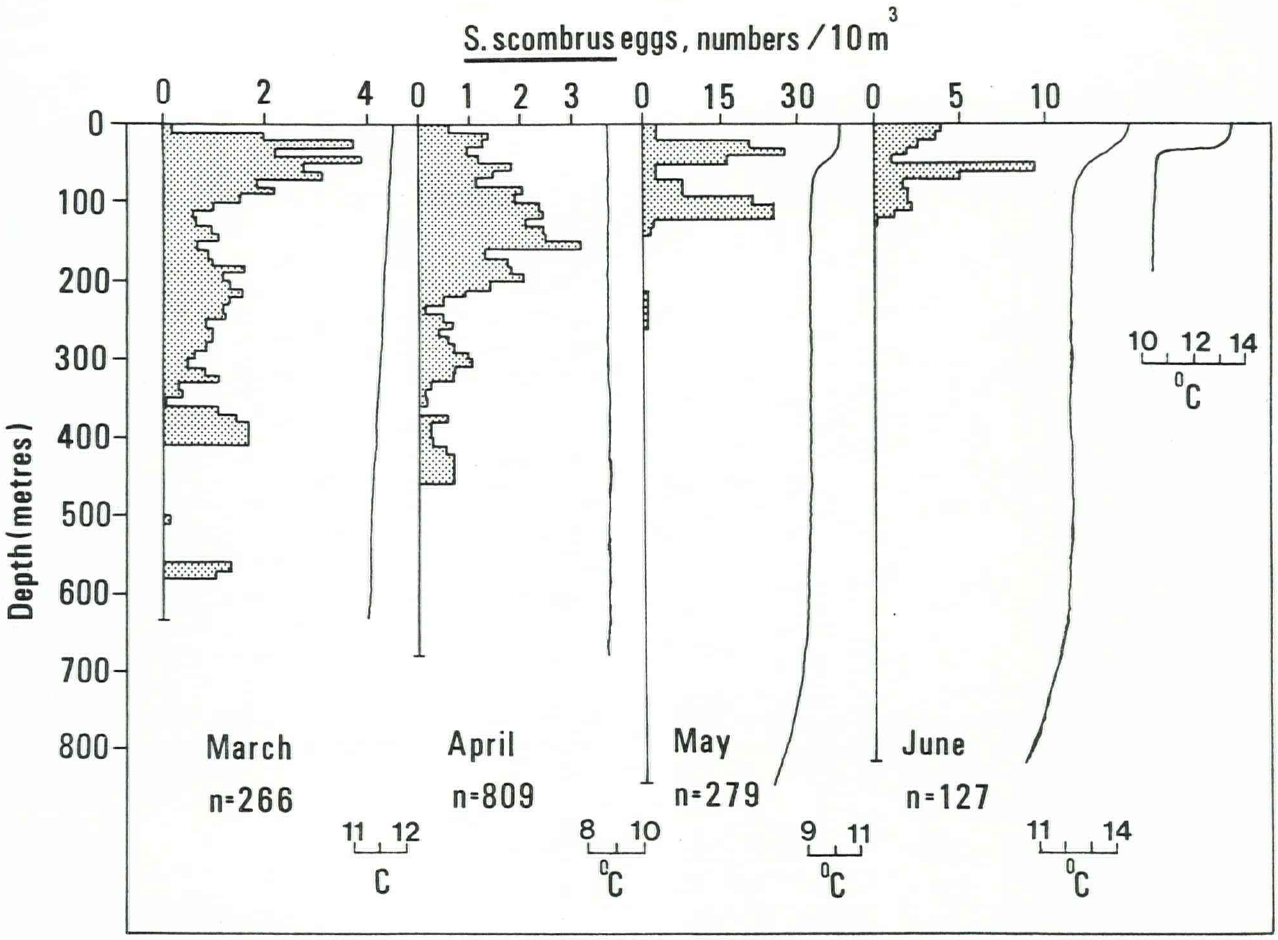

Figure 4. The vertical distribution of *S. scombrus* eggs taken to the west of the British Isles in 1977 and plotted as the mean abundance for all positive hauls in each month; alongside the distributions are shown representative temperature profiles.

hauls and accounted for 43% of the eggs taken in June, while the other less marked thermocline was found at the position of a further three hauls which included 57% of the eggs.

During March and April of 1977 there was no thermal stratification and eggs were taken down to a depth of 590 m (Fig. 4). In May and June, however, following the development of the seasonal thermocline, almost all the eggs were taken from the upper 120 m (Fig. 4). Furthermore, in those four hauls taken where the temperature profile changed by 3° C at the thermocline (Fig. 4), more than 96% of the eggs occurred above the temperature discontinuity at 50 m depth.

In the North Sea in June and July 1978 the vertical temperature structure varied between the positions at which the hauls were taken, but, most commonly, there was a thermocline of about 4° C at about 26 m depth. Considering the combined results from all of the hauls in the North Sea more than 91% of the eggs were taken above 26 m, that is generally in the upper mixed water layer, and more than 85% from 0 to 16 m (Fig. 5). This is comparable with Iversen's (1973) report that 90% of mackerel eggs in the North Sea were in the top 15 m. The eggs of Pacific mackerel (*Pneumatophorus diego*) off California, and Atlantic mackerel (*S. scombrus*) off the east coast of North America have also been found predominantly in the upper 15–25 m above a well-developed thermocline (Sette, 1943; Ahlstrom, 1959; Berrien, 1978).

From a comparison of Figure 4 and Figure 6 it is apparent that, in 1977 at least, the main concentrations of mackerel larvae (mostly <5.0 mm in length) were nearer to the surface than the eggs. To the west of the British Isles most of the larvae were found in the upper 50 m (Fig. 6) compared with about 200 m for the eggs (Fig. 4); in May 1977, when the thermocline was weakly established, there was a deeper secondary peak of larvae at 70–140 m (Fig. 6). In June all hauls which included mackerel larvae were

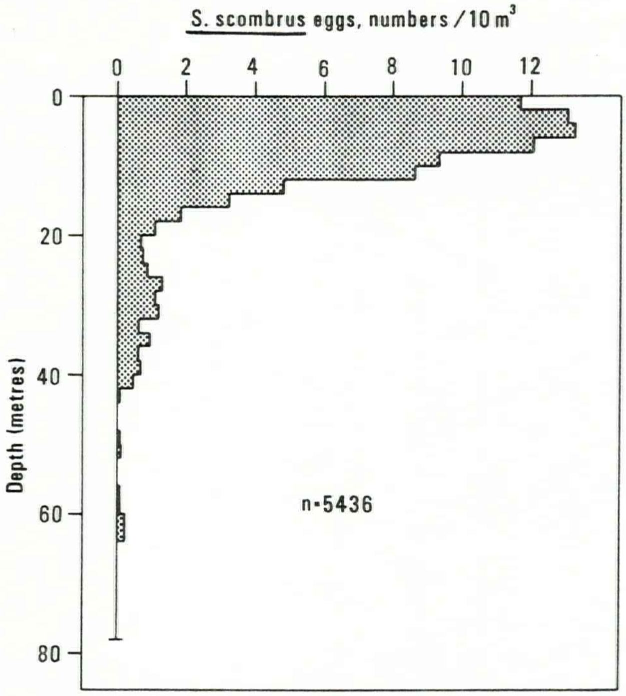

Figure 5. The vertical distribution of *S. scombrus* eggs taken in the North Sea in 1978 and plotted as the mean abundance for all positive hauls.

taken at positions having a similar vertical temperature structure, as shown in Figure 6, and more than 87% were taken in the top 20 m, above the thermocline. Larvae of the Pacific mackerel and Atlantic mackerel in the western North Atlantic have been caught similarly within that same depth range (0–20 m) under comparable hydrographic conditions (Ahlstrom, 1959; Kramer, 1960; Sette, 1943). Sampling at finer vertical resolution in the North Sea in 1978 showed that more than 91% of the larvae (mostly <5.0 mm in length) were in the upper mixed layer, from the surface to 26 m (Fig. 7), and highest numbers were at a depth of 6–8 m.

DISCUSSION

The work on which this paper is based was not designed to analyse the vertical distribution of blue whiting and mackerel eggs and larvae in relation to all environmental parameters and, therefore, additional sampling may reveal other connections. Nevertheless, there appears to be a relationship between the presence of a thermocline and the depth of mackerel eggs; in additon, larvae of both species tend to inhabit a relatively shallower depth range than their respective eggs.

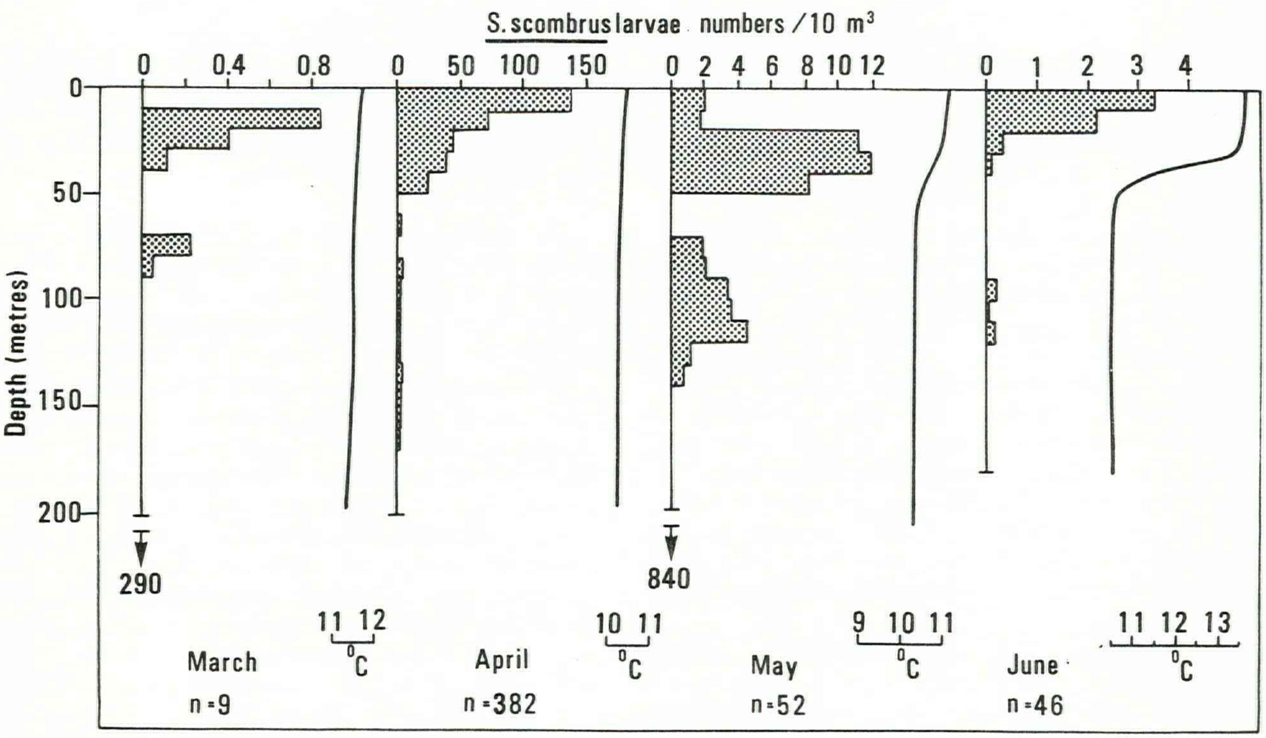

Figure 6. The vertical distribution of *S. scombrus* larvae taken to the west of the British Isles in 1977 and plotted as the mean abundance for all positive hauls in each month; alongside the distributions are shown representative temperature profiles.

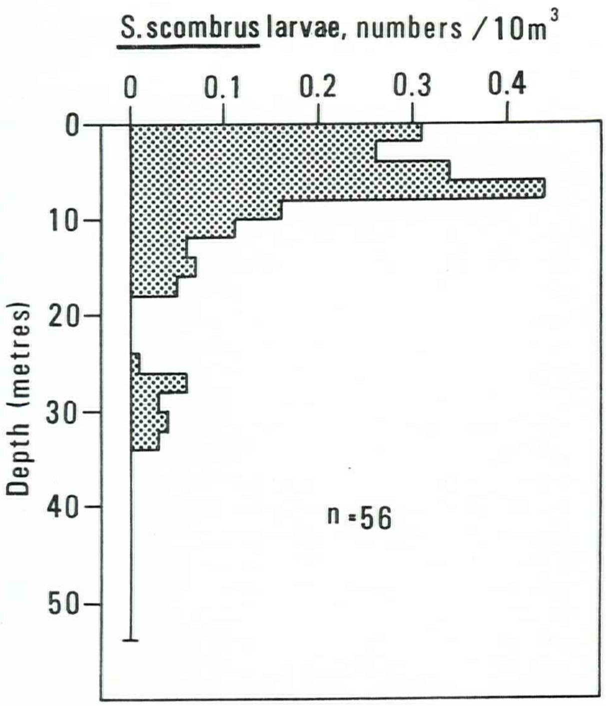

Figure 7. The vertical distribution of *S. scombrus* larvae taken in the North Sea in 1977 and plotted as the mean abundance for all positive hauls.

The relationship between temperature and vertical distribution of mackerel eggs reflects the diversity of spawning environments, from deep unstratified water in Biscay in the spring to relatively shallow stratified water in the North Sea in the summer. In contrast, blue whiting spawn during a shorter spring season when the hydrographic conditions are relatively uniform and the egg distributions were relatively consistent.

Clearly, mackerel spawning was taking place at depths close to those at which the eggs were found; that is, at 0–500 m (Fig. 4) in March and April to the west of the British Isles, but later in the season to the west of the British Isles and in the North Sea (Fig. 4 and 5) in the upper mixed layer. The vertical movement of eggs after release is governed to a large extent, by the combined effects of passive drift toward a position of neutral buoyancy (Myrberget, 1965; Zaitsev, 1971), and re-distribution due to mixing within the water column (Russell, 1976). Under these conditions the density gradient at the thermocline or halocline is an effective obstruction preventing further movement of the eggs and restricting them to the upper mixed layer (e.g. Fig. 4, Nilsson, 1914; Ahlstrom, 1959).

The preponderance of fish larvae in the upper 150 m of the water column, and above the thermocline, as shown in this study as well as by Ahlstrom (1959) and Ida (1972) is partly a reflection of the egg distributions, with the thermocline acting as a barrier, and also of active ontogenetic migration from deeper layers. This is seen most clearly in the example of blue whiting larvae (Fig. 3) and is supported by observations on mackerel larvae during March and April (Fig. 6).

The diet of early larvae, including blue whiting, consists chiefly of eggs and juvenile stages of copepods (Russell, 1976; Conway, 1978). These are most numerous in the upper 100 m of the water column and concentrated towards the surface (e.g. Conway and Minton, 1976; Williams and Wallace, 1977) where the larvae are most abundant (Fig. 3). The youngest stages may also feed on phytoplankton (e.g. Russell, 1976; Conway, 1978) which is concentrated in even more superficial layers (e.g. Williams and Wallace, 1977). During later post-larval development the diet is composed of more general zooplankton which is also found predominantly in the upper layers or above a thermocline (e.g. Conway and Minton, 1976; Longhurst and Williams, 1979). The aggregation of fish larvae in narrow depth layers (e.g. Fig. 7) and at the thermocline (e.g. Miller et al., 1963; Lasker, 1975) may be particularly advantageous, enabling them to utilise concentrations of phytoplankton and zooplankton occurring in discrete strata and associated with the thermocline (Eppeley et al., 1970; Lasker, 1975; Holligan and Harbour, 1977). Moreover ontogenetic and diel migrations of older larvae provide the young fish with an effective strategy for encountering localised concentrations of food with a minimum expenditure of energy. The importance to fish larvae of the availability of food and the marked spatial heterogeneity of plankton in the vertical plane suggest that in order to understand the process of survival we must look, in particular, at the detailed vertical distribution of fish larvae and their food.

SUMMARY

1) The vertical distributions of eggs and larvae of blue whiting (*Micromesistius poutassou*) and mackerel (*Scomber scombrus*) in the eastern North Atlantic and North Sea are described from the results of sampling with a Longhurst-Hardy Plankton Recorder.

2) Blue whiting eggs were taken to the west of the British Isles from the surface to 600 m, with highest numbers between 250 and 450 m. Larvae ≤2.5 mm in length were found from the surface to 620 m with the majority below 400 m; larvae of 2.6–5.0 mm length were taken most frequently in the upper 100 m and at 5.1–7.5 mm the majority

were above 40 m depth.

3) To the west of the British Isles, during March and April when there was no thermal stratification, eggs of mackerel were taken down to 590 m, with the majority from the surface to 200 m. During May and June, when the seasonal thermocline had developed, eggs were taken mostly in the upper 120 m, above the thermocline. In the North Sea more than 91% of mackerel eggs occurred above a thermocline at 26 m. The majority of mackerel larvae to the west of the British Isles were taken in the upper 50 m, and above the thermocline when present; in the North Sea more than 91% of the larvae were taken above the thermocline and highest numbers were recorded at a depth of 6–8 m.

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