International Council
for the
Exploration of the Sea

C.M. 1996/S:48
Theme Session on the Shelf-Edge
Current and its Effect on Fish Stocks

The vertical distribution of eggs and larvae of horse mackerel (*Trachurus trachurus*)

S. H. Coombs, D. V. P. Conway and N. C. Halliday

Plymouth Marine Laboratory, Prospect Place, The Hoe, Plymouth PL1 3DH, Devon, UK.

Abstract

Vertical distribution sampling was carried out for eggs and larvae of horse mackerel (*Trachurus trachurus*) to the west of the British Isles and in the Bay of Biscay. Both eggs and larvae occurred predominantly above the thermocline in the upper 80m of the water column. Eggs were taken in increasing numbers towards the surface whereas larvae (2-6mm in length) were most abundant at 15-30m depth. As the seasonal thermocline developed there was a progressive reduction in the mean depth of both eggs and larvae; by June (0-50m Δt of 4.1C°) 97% of eggs and 95% of larvae were in the upper 40m of the water column.

Introduction

Information on the vertical distribution of fish eggs and larvae is an essential pre-requisite for efficient sampling e.g. for stock estimation based on plankton egg surveys (Eaton, 1989); equally, this information is required for studies of transport and survival of eggs and larvae in relation to current systems and biological processes in the water column. In the latter context, an EU funded programme (SEFOS - Shelf-Edge Fisheries and Oceanography Studies) has been designed to study the effects of the shelf-edge current on fish stocks from Portugal through Biscay and west of the British Isles to Norway. One aspect of the SEFOS programme is an investigation of advection of the planktonic stages of horse mackerel (*Trachurus trachurus*) and their subsequent recruitment; the present work on the vertical distribution of the eggs and larvae of horse mackerel is part of this study .

Spawning of horse mackerel is widespread over much of the European shelf, extending from the North Sea and west of Ireland as far south as Portugal and West Africa (John *et al.*, 1991; Eaton, 1983). The highest incidence of spawning is from May to July at the shelf-edge and over adjacent shelf regions of the Celtic Plateau and Biscay (Franco *et al.*, 1993; Eaton, 1989). The limited information which is available on the vertical distribution of eggs and larvae is derived mostly from widely distributed sites, away from the main spawning grounds along the northern European shelf-edge, but is consistent in showing the increased abundance of both eggs and larvae towards the surface (e.g. off Portugal - John and Ré, 1993; off West Africa - John *et al.*, 1991, John, 1985; in the English Channel - Southward and Barrett, 1983, Russell, 1930; at the shelf-edge in Biscay - Coombs *et al.*, 1979). Concentrations of eggs and larvae in the neuston have also been noted (e.g. in the North Sea - Nellen and Hempel, 1970; in the Black Sea - Zaitsev, 1970). A similar near-surface habit has been described for the early development stages of other *Trachurus* species (e.g. *Trachurus symmetricus* off California - Ahlstrom, 1959; *Trachurus trachurus capensis* in the northern Benguela system - Olivar, 1990).

The purpose of the present work is to provide a more complete description of the vertical distribution of eggs and larvae of horse mackerel from sampling in their main areas of spawning at the edge of the Celtic Shelf. Included in the results are vertical distributions by stage of egg development and size of larvae.

Methods

Occasional sampling was carried out along the shelf-edge of the Celtic Sea and Biscay between March and June on various cruises between 1977 and 1987 (Fig. 1; Table 1). A more detailed set of samples was obtained over a 33 hour period in June 1995 at a site in the Porcupine Seabight to the southwest of Ireland (Fig.1; Table 1).

All sampling was carried out using an LHPR sampler (Longhurst-Hardy Plankton Recorder; Williams *et al.*, 1983; see also Pipe *et al.*, 1981) which takes a sequential series of plankton samples along an oblique tow at a ship's speed of 3-4 knots. Filtering nets of 280μm mesh aperture were used in the earlier hauls and 200μm for those in 1995. Data on the depth range over which each sample was taken and volume of water filtered, monitored by a flowmeter in the inlet nose-cone, were recorded either by self-contained electronics units on the sampler frame or transmitted via cored-cable for display and storage to a PC on the survey vessel. Additional sensors incorporated into the system included temperature (all years), salinity (1995 only) and chlorophyll *a* fluorescence (1995 only).

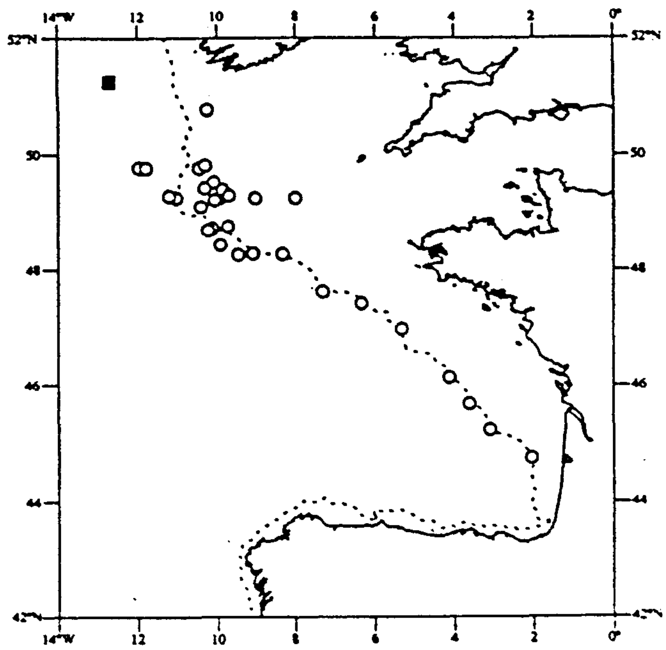

Fig. 1 Positions of LHPR hauls in the years 1977-1987 (circles) and the site of intensive sampling in 1995 (square).

Table 1. LHPR haul information.

Haul No	Date sampled	Time (GMT)	Depth sampled (m)	Position		Trachurus trachurus	
				Lat (N)	Long (W)	No of eggs	No of larvae
77/01	21/03/77	09:24	290	46 08	04 08	42	0
80/01	09/04/80	20:22	190	48 26	09 55	300	0
80/02	07/05/80	22:28	200	47 37	07 19	394	0
80/03	09/05/80	10:38	270	45 14	03 06	271	0
80/04	10/05/80	18:39	170	44 45	02 03	59	0
80/05	03/06/80	16:52	200	48 16	08 19	161	19
80/06	04/06/80	13:37	270	46 59	05 18	439	0
80/07	08/06/80	19:57	210	45 41	03 37	72	674
80/08	09/06/80	18:07	250	47 25	06 21	0	12
80/09	11/06/80	15:56	160	49 16	11 08	280	0
83/01	09/06/83	08:14	110	49 15	11 02	617	43
83/02	09/06/83	14:54	120	49 15	09 57	978	0
83/03	09/06/83	20:29	120	49 13	09 02	334	0
83/04	10/06/83	02:30	120	49 15	08 02	2147	0
83/05	14/06/83	15:06	200	49 46	12 03	59	0
83/06	14/06/83	15:30	200	49 45	11 56	36	0
83/07	15/06/83	03:56	105	49 45	10 28	802	25
83/08	16/06/83	18:39	120	49 25	10 18	596	59
83/09	17/06/83	15:36	110	49 06	10 29	8353	68
83/10	18/06/83	18:08	30	48 15	09 28	1417	16
85/01	12/06/85	13:50	115	49 47	10 24	51	0
85/02	12/06/85	19:00	100	49 32	10 06	114	0
85/04	13/06/85	08:55	105	49 24	09 53	71	0
85/05	13/06/85	11:12	105	49 20	09 46	20	0
86/01	19/05/86	12:14	160	48 45	09 43	75	0
86/02	20/05/86	13:53	190	48 16	09 05	469	440
86/03	20/06/86	10:25	140	49 13	10 05	451	34
86/04	26/06/86	20:53	140	50 46	10 07	342	0
87/01	12/05/87	02:14	70	48 43	10 07	1009	108
87/02	13/05/87	14:32	75	48 43	10 07	427	106
95/01	26/06/95	23:45	200	51 14	12 42	491	334
95/02	27/06/95	01:46	70	51 14	12 42	520	1738
95/03	27/06/95	03:35	70	51 15	12 42	584	1366
95/04	27/06/95	06:20	70	51 15	12 42	813	1783
95/05	27/06/95	08:20	70	51 15	12 42	1036	1108
95/06	27/06/95	10:15	70	51 15	12 42	1037	1182
95/07	27/06/95	12:30	70	51 15	12 42	954	2287
95/08	27/06/95	14:15	100	51 15	12 42	638	1024
95/09	27/06/95	16:20	100	51 15	12 42	718	1373
95/10	27/06/95	18:25	100	51 15	12 42	418	215
95/11	27/06/95	20:25	100	51 14	12 42	1165	54
95/12	27/06/95	22:20	100	51 15	12 42	430	191
95/13	28/06/95	03:20	100	51 15	12 42	885	32
95/14	28/06/95	06:20	100	51 15	12 42	353	18
95/15	28/06/95	08:15	100	51 15	12 42	172	38

On completion of a haul, the plankton was preserved in 4% formaldehyde solution for subsequent sorting and identification. Eggs of horse mackerel were staged according to the descriptions of Pipe and Walker (1987) and larvae measured to the nearest 0.1mm (total length). Standardised plots of vertical distribution were produced from the analysis results taking into account the depth range over which each sample was taken and volume of water filtered. Plots of mean distributions were then prepared using the standardised data for each haul converted to percentage occurrence down the water column (i.e. giving equal weighting to each haul). Only those hauls on which 20 or more eggs or 10 or more larvae occurred for a particular egg stage or size of larvae are included in the results.

Measurements of the specific gravity of 30 horse mackerel eggs taken from the plankton were made in May 1980 using a density-gradient column (Coombs, 1981).

Results

The combined results from sampling over the period 1977-1987 showed that eggs of horse mackerel were mostly in the upper 80m of the water column (91% of eggs at all stages of development), with a progressive increase in abundance towards the surface (Fig. 2). A similar pattern was observed for results from the more intensive sampling in 1995, but with a more restricted depth range, most eggs being in the upper 40m of the water column (97% of eggs at all stages of development; Fig. 2). The 1977-1987 data showed no significant difference (p=0.7) between the mean depth of different stages of egg development, whereas for the 1995 data there were significant differences (p=0.0001) and a progressive increase in mean depth with development stage (Table 2).

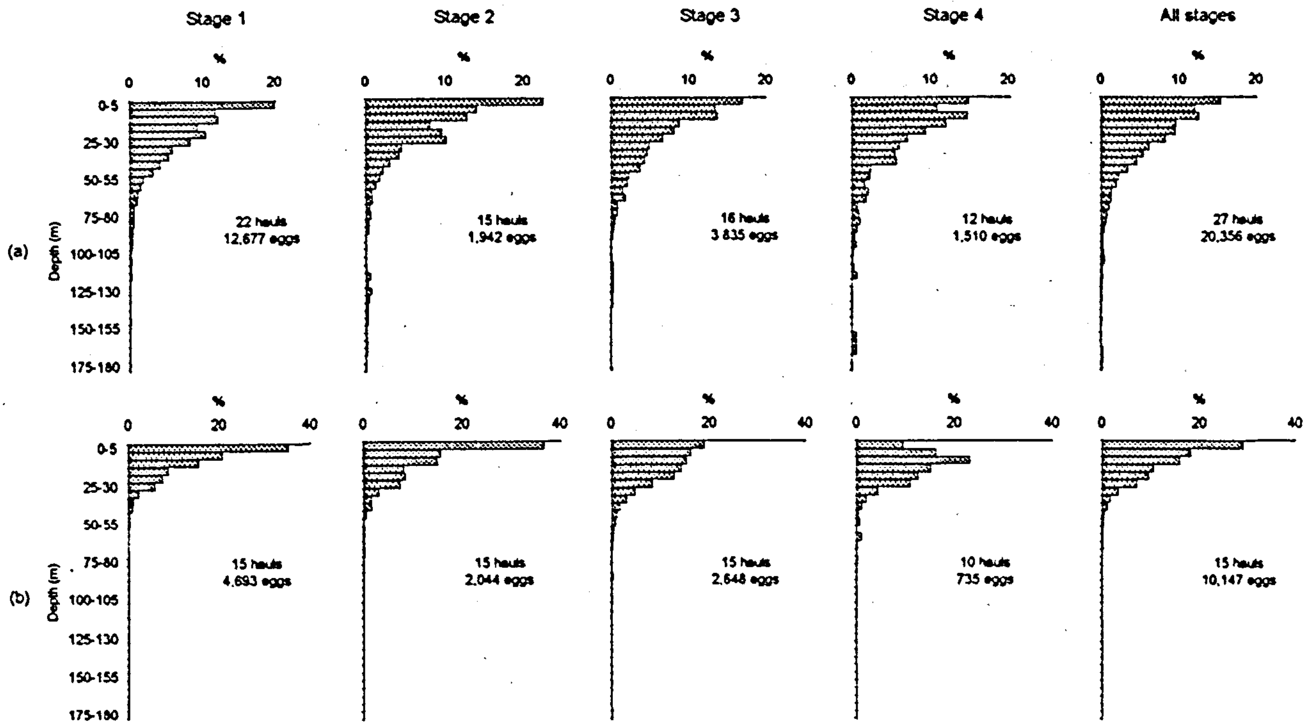

Fig. 2 Mean vertical distribution of eggs of horse mackerel plotted as percentage occurrence in 5m depth intervals by stage of development from sampling (a) in the years 1977-1987 and (b) in 1995. Sampling was to a maximum depth of 290m in the years 1977-1987 and to 200m in 1995. For comparability both sets of results are plotted to 180m depth only, no eggs being taken below that depth.

Table 2. Mean depth (m) of horse mackerel eggs and larvae.

Years sampled		1977-1987	1995
Eggs	Stage 1	24.2	11.9
	Stage 2	20.0	12.8
	Stage 3	24.2	17.1
	Stage 4	26.5	17.7
	All stages	25.8	13.9
Larvae	2-4mm	37.2	22.2
	4-6mm	34.1	21.5
	All <6mm	40.9 *	22.0

* Includes a number of hauls on which larvae were not separated into smaller sizes

The specific gravity of eggs of horse mackerel showed an increase over development corresponding to the increase in depth of the eggs. Measured values were from around 1.0245g.cm^{-3} at stages 1 and 2, 1.0253g.cm^{-3} at stages 2 and 3 to 1.0265g.cm^{-3} at stages 3 and 4. Sea-water salinity in the spawning area was around 34.45 psu and 13-16°C, equivalent to a specific gravity of between 1.02613g.cm^{-3} and 1.02677g.cm^{-3}; eggs would thus be positively buoyant for most of their development.

Sampling over the period 1977-1987 was on various dates between 21 March and 26 June, corresponding to the season over which there is progressive development of the thermocline (Fig. 3). Over these same months there was a parallel reduction in the mean depth of horse mackerel eggs (Fig. 4). The most extreme restriction of eggs towards the surface layers was in June 1995 when temperature stratification was most developed (0-50m Δt of 4.1C°, Fig. 5). For practical purposes the 1977-1987 data indicate that in order to sample 95% of stage 1 eggs (as used in surveys for stock estimation e.g. Eaton, 1989, Anon, 1994), sampling would need to be from a depth of 99.6m in April reducing to 51.9m by July (Fig. 4). Under the most marked conditions of temperature stratification, as observed at the end of June 1995, the sampling depth for inclusion of 95% of stage 1 eggs is further reduced to a depth of 29.2m.

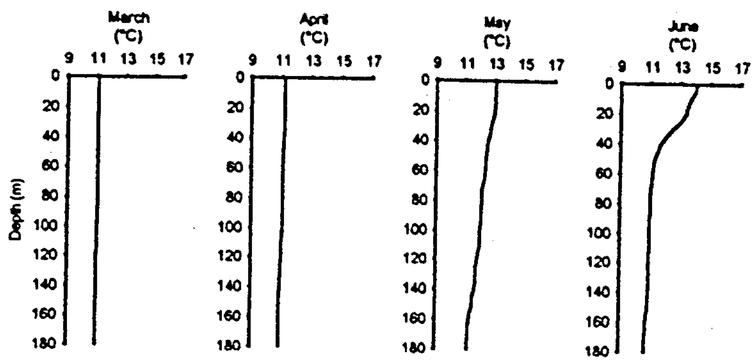

Fig. 3 Average temperature profiles by month for all LHPR hauls on which either eggs or larvae of horse mackerel were taken in the years 1977-1987.

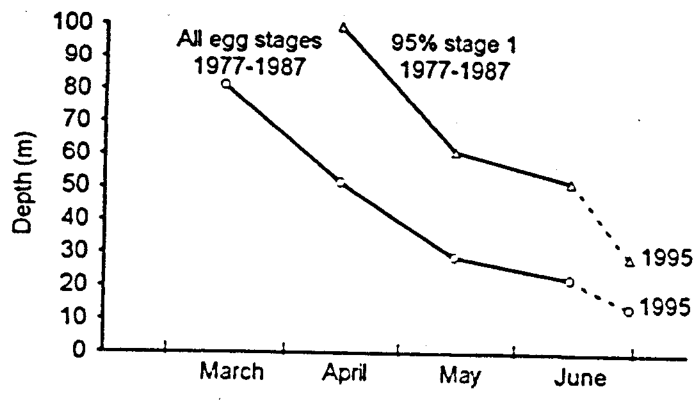

Fig. 4 Mean depth of occurrence of eggs of horse mackerel at all stages of development (circles) and depth above which 95% of stage 1 eggs occurred (triangles) plotted as monthly means at the mid-date of each month for sampling in the years 1977-1987 (solid lines). Corresponding values from sampling at the end of June 1995 are connected by dashed lines.

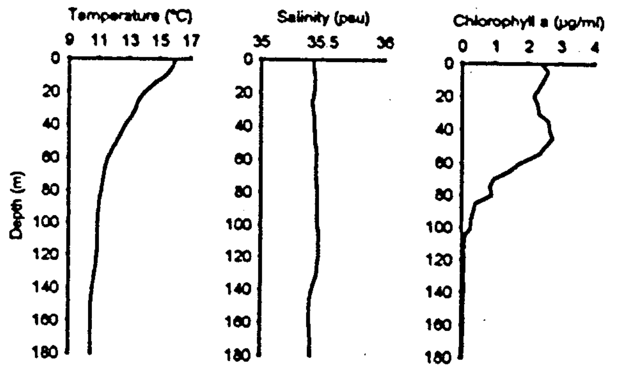

Fig. 5 Mean temperature, salinity and chlorophyll *a* profiles plotted for all LHPR hauls in 1995.

Larvae of horse mackerel occupied a similar depth range to the eggs (94% of larvae at all sizes in the upper 80m of the water column from sampling over the period 1977-1987 and 95% in the upper 40m in 1995; Fig. 6). However, the mean depth of horse mackerel larvae in the water column (Table 2) was significantly deeper than for eggs ($p<0.001$) reflecting sub-surface peaks in abundance of larvae (at depths of 25-30m in sampling over the period 1977-1987 and at 15-20m in 1995; Fig. 6). Within each set of data (1977-1987 and 1995) there was no significant difference between the mean depth of larvae at 2-3.9mm in length and those at 4-5.9mm in length ($p>0.6$).

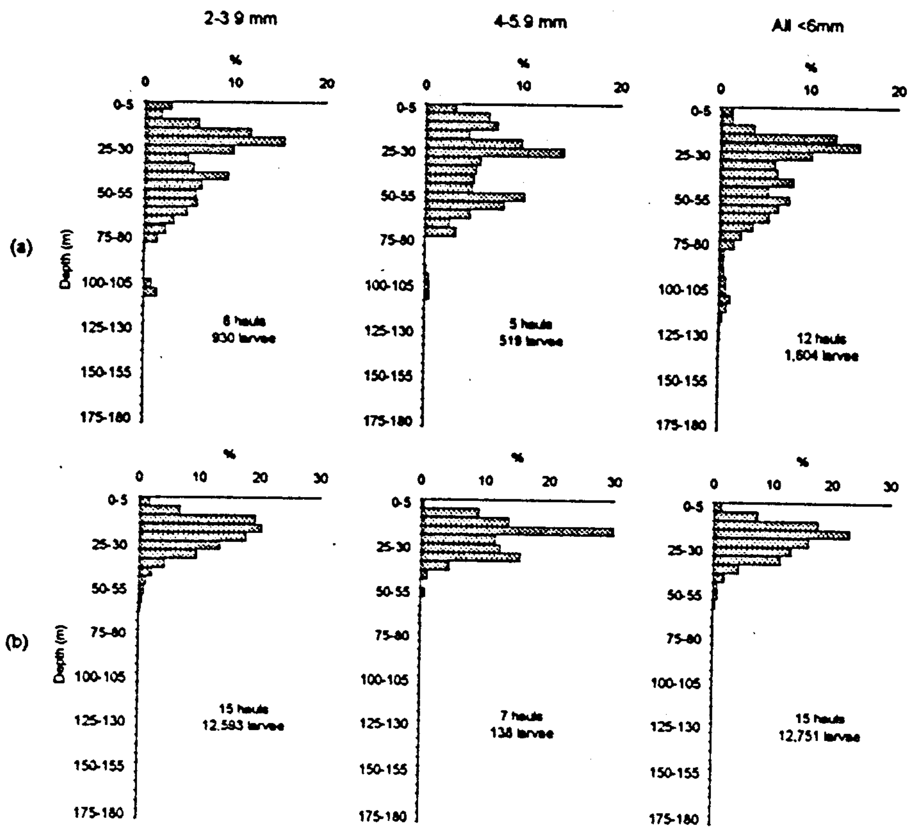

Fig.6 Mean vertical distribution of larvae of horse mackerel plotted as percentage occurrence in 5m depth intervals by size categories from sampling (a) in the years 1977-1987 and (b) in 1995. Other details as in legend to Fig. 2.

On all of the hauls on which larvae were taken (from mid-May but with most in June, Table 1) there was some development of the seasonal thermocline. Under these conditions larvae were predominately in the upper mixed layer (Fig. 6 c.f. Figs. 3 and 5). The most superficial distribution of larvae was observed in the 1995 hauls when the water column was most stratified (0-50m Δt of 3.8C°; mean depth of 22.0m for larvae at all lengths - Table 2) compared with the May and June hauls of 1977-1987 when the thermal structure was less developed (0-50m Δt of 1.0-2.6C°; mean depth of 40.9m for larvae at all lengths - Table 2).

Diel changes in vertical distribution could only be examined for the 2-3.9mm length category of larvae in the 1995 set of samples for which there were sufficient numbers sampled consistently over a day/night cycle. For these larvae there were only small variations in the pattern of depth distribution with no discernible diel cycle (Fig. 7).

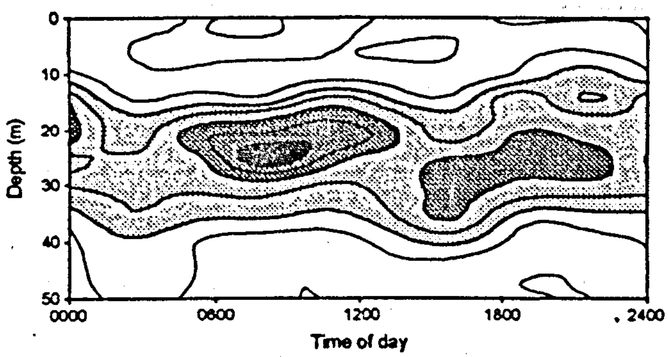

Fig. 7 Contoured distribution of horse mackerel larvae at 2-3.9mm in length in the upper 50m of the water column from sampling on LHPR hauls in 1995. The figure was constructed using the percentage occurrence of larvae in 5m depth strata on each haul plotted at the time of day each haul was taken. Contours are drawn at intervals of 5% occurrence and filled at progressively darker shades from the 10% contour.

Discussion

The observed relatively near-surface distribution of eggs and larvae of horse mackerel is typical of ichthyoplankton in general (e.g. Conway *et al.*, in press; Boehlert *et al.*, 1985); deep distributions (>100m depth) are less common and usually confined to habitually deep-water species, or those found at depth during the spawning season (e.g. halibut, *Hippoglossus hippoglossus*, Haug *et al.*, 1986; blue whiting, *Micromesistius poutassou*, Coombs *et al.*, 1981).

Pelagic fish eggs are passive particles, usually with a slight positive buoyancy. It is therefore expected, and as found for eggs of horse mackerel, that their abundance will increase towards the surface (Sundby, 1983). Since wind mixing is less and the water column is more stabilised in the later spring and early summer months of the year, it follows that under those conditions eggs will be distributed nearer to the surface. In the present work there was a progressive reduction in the depth of eggs which was most extreme in June 1995 when the thermocline was most developed. A similar restriction of eggs of horse mackerel (*Trachurus trachurus capensis*) to the upper 50m of the water column above a marked thermocline has been noted by Olivar (1990) from sampling in the northern Benguela system. The clear influence of physical processes in determining the vertical distribution of pelagic fish eggs is reinforced by descriptions of a similar relationship between depth of mackerel (*Scomber scombrus*) eggs and thermal structure in the same sampling area (Coombs *et al.*, 1981) and by examples of a thermocline acting as an upper depth limit to the distribution of eggs (e.g. Haug *et al.*, 1986).

Estimation of the stock size of horse mackerel based on egg abundance in the Biscay/Celtic Sea region has been a supplementary aspect of surveys designed primarily to sample eggs of mackerel (Eaton, 1989; Anon, 1994). In these surveys various modifications have been introduced to ensure the full depth range of mackerel eggs have been sampled without undue time being spent sampling below their depth of occurrence, particularly later in the season when most mackerel eggs are above the thermocline (Anon, 1994; Coombs *et al.*, 1981). This strategy, essentially sampling to 200m depth or 20m below a thermocline of 2.5C° or more, would be at least as effective in sampling eggs of horse mackerel.

Fish larvae are generally more restricted in vertical range than are eggs and, as observed for larvae of horse mackerel, often have sub-surface peaks of abundance (e.g. Conway *et al.*, in press; Boehlert *et al.*, 1985). There may also be a pattern of diel migration, reflecting behavioural responses to preferenda of physical or biological stimuli such as light, temperature or food availability. Such migratory behaviour tends to develop only with with increased locomotory capability of larvae >6mm in length, therefore it is not unexpected that the small larvae taken in the present study showed no diel variation in depth distribution. Both Russell (1930) and Olivar (1990) also found no evidence for vertical migration of small horse mackerel larvae .

Results from the present study, with respect to considerations of larval drift, show that larvae of horse mackerel in the main area of spawning in Biscay and the Celtic Sea are mostly in the wind-driven surface Eckman layer to a depth of about 40m. Similar conclusions were incorporated by John and Ré (1993), John *et al.* (1991) and Olivar (1990) in studies of larval transport off Portugal and west Africa. In such areas John (1985) considered that the distribution of the majority of larvae of horse mackerel in the upper 60m of the water-column might reflect some upwards displacement due to upwelling. It is unlikely that any such effect was of any significance since the present results, from an area of negligible upwelling and similar degree of thermal stratification, show larvae with a somewhat more superficial distribution.

Acknowledgements

The authors gratefully acknowledge the assistance given by the Institute for Marine Research, Bergen and by the Fisheries Laboratory, Lowestoft of the UK Ministry of Agriculture Fisheries and Food for the opportunity to participate in their cruises. Funding for the work has been provided in part under EU contract AIR2-CT93-1105.

References

Ahlstrom, E.H. 1959. Vertical distribution of pelagic fish eggs and larvae off California and Baja California. Fish. Bull. U.S. 60, 107-143.

Anon. 1994. Report of the mackerel/horse mackerel egg production workshop. ICES CM 1994/H:4, 58pp.

Boehlert, G.W., Gladomaski, D.M. and Mundy, B.C. 1985. The vertical distribution of ichthyoplankton off the Oregon coast in spring and summer months. Fish. Bull. U.S. 83, 611-622.

Conway, D.V.P., Coombs, S.H. and Smith, C. In press. Vertical distribution of fish eggs and larvae in the Irish Sea and southern North Sea. ICES J. Mar. Sci.

Coombs, S.H., Pipe, R.K., and Mitchell, C.E. 1981. The vertical distribution of eggs and larvae of blue whiting (*Micromesistius poutassou*) and mackerel (*Scomber scombrus*) in the eastern North Atlantic and North Sea. Rapp P.-v. Réun. Cons. perm. int. Explor. Mer. 178, 188-195.

Coombs, S.H. 1981. A density-gradient column for determining the specific gravity of fish eggs, with particular reference to eggs of the mackerel *Scomber scombrus*. Mar. Biol. 63, 101-106.

Coombs, S.H., Pipe, R.K. and Mitchell, C.E. 1979. The vertical distribution of fish eggs and larvae in the eastern North Atlantic, and North Sea. ICES, Early Life History Symposium, Woods Hole, 2-5 April 1979, DA:3, 24pp.

Eaton, D.R. 1983. Scad in the North-East Atlantic. Lab. Leafl. MAFF Direct. Fish Res., Lowestoft No. 56, 20 pp.

Eaton, D.R. 1989. Spawning-stock biomass of scad (*Trachurus trachurus* L.) to the west of the British Isles, as indicated by egg surveys. J. Cons. Int. Explor. Mer 45, 231-247.

Franco, C., Motos, L., Sola, A. and Lago de Lanzos, A. 1993. Horse mackerel (*Trachurus trachurus* L.) egg distribution and stage I egg production estimates in division VIIIb, c and IXa N in 1988, 1990 and 1992. ICES CM 1993/ H:43, 11pp.

Haug, T., Kjørsvik, E. and Solemdal, P. 1986. Influence of some physical and biological factors on the density and vertical distribution of Atlantic halibut *Hippoglossus hippoglossus* eggs. Mar. Ecol. Prog. Ser. 33, 217-229.

John, H.C. 1985. Horizontal and vertical distribution patterns of fish larvae off N W Africa in relation to the environment. In: Bas, C., Margalef, R., Rubies, P. (eds.) International symposium on the most important upwelling areas off Western Africa (Cape Blanco and Benguela). Instituto Investigaciónes Pesqueras Barcelona 1, 489-512.

John, H.C., Klenz, B. and Hermes, R. 1991. Distribution and drift of horse mackerel larvae (genus *Trachurus*) off Mauritania January to April 1983. ICES CM 1991/H:3, 22pp.

John, H.C. and Ré, P. 1993. Cross-shelf zonation, vertical distribution, and drift of fish larvae off northern Portugal during weak upwelling. ICES CM 1993/L:33, 17pp.

Nellen, Von W. and Hempel, G. 1970. Beobachtungen am Ichthyoneuston der Nordsee. Ber. Dt. Wiss. Kommn. Meeresforsch. 21, 311-348.

Olivar, M.P. 1990. Spatial patterns of ichthyoplankton distribution in relation to hydrographic features in the northern Benguela region. Mar. Biol. 106, 9-48.

Pipe, R.K., Coombs, S.H. and Clarke, K.R. 1981. On the sample validity of the Longhurst-Hardy Plankton Recorder for fish eggs and larvae. J. Plankton Res. 4(3), 675-683.

Pipe, R.K. and Walker, P. 1987. The effect of temperature on the development and hatching of scad (*Trachurus trachurus*, L.) eggs. J. Fish Biol. 31, 675-682.

Russell, F.S. 1930. The vertical distribution of marine macroplankton. IX. The distribution of the pelagic young of teleostean fishes in the daytime in the Plymouth area. J. Mar. Biol. Assoc., UK, 16, 639-670.

Southward, A.J., Barrett, R.L. 1983. Observations on the vertical distribution of zooplankton, including post-larval teleosts, off Plymouth in the presence of a thermocline and a chlorophyll-dense layer. J. Plankton Res. 5(4), 599-618.

Sundby, S. 1983. A one-dimensional model for the vertical distribution of pelagic fish eggs in the mixed layer. Deep Sea Res. 30(6A), 645-661.

Williams, R., Collins, N.R. and Conway, D.V.P. 1983. The double LHPR system, a high speed micro- and macroplankton sampler. Deep-Sea Res. 30, 331-342.

Zaitsev, Y.P., 1971 "Marine Neustonology". 207 pp. Israel Program for Scientific Translations, Jerusalem.