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Preliminary results on the distribution and spawning of blue whiting, *Micromesistius poutassou*, off the Portuguese coast.

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This paper presents information on the depth distribution and on the spawning of blue whiting off the Portuguese coast, based on data from six groundfish surveys carried out systematically in three different seasons of the year (winter, summer and autumn) for two consecutive years (1992/93). Length and age distributions by depth range are analysed and seasonal patterns of global abundance are investigated. Preliminary estimates of the proportion of mature fish at length and age are given and spawning season is defined. Information on the pelagic distribution and behaviour of blue whiting, based on data from an echo-survey carried out in 1983, is presented and discussed here for the first time.

Blue whiting is distributed near the bottom, over the deepest half of the continental shelf and on the slope, mainly between 200 and 500 m. An increase on fish length (and age) with depth is observed and the larger individuals (>25 cm) seem to concentrate in the depth stratum 500-750 m. At depths between 200 and 400 m, the blue whiting distribution continues into the oceanic zone where fishes exhibiting diel vertical migrations apparentely related with migrations of their prey organisms. It is suggested that the distribution of blue whiting of the Portuguese coast is closely related with the distribution of the North Atlantic Central Water.

Keywords: *Micromesistius poutassou*, blue whiting, distribution, behaviour, spawning, Portuguese waters

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INTRODUCTION

Blue whiting is a by-catch of bottom trawl fishery in the southern areas of its distribution. Discards are unknown, but probably large and highly variable in time, depending on the availability of more valuable species like hake, monkfish and megrim. Nevertheless, Portuguese blue whiting landings have fluctuated between one and nine thousand tonnes (mean 4228 tonnes) in the period 1986-1995. Blue whiting is usually consummed fresh and the market price for larger individuals (>22 cm) has increased considerably in the last four years.

Blue whiting distribution off the Portuguese southwest and south coast has been studied by Vasconcelos (1987). Some information on the abundance of this species by depth range is given by Cardador (1983) and more recentely by Figueiredo *et al.* (1994) for the southern coast. The work by Cunha (1992a) focus on blue whiting reproductive biology in Portuguese waters (based on 1984/85 data) and Vasconcelos (1982) provide some information on maturity and sex-ratio.

Here we present additional information on the depth distribution and on the spawning of blue whiting off the Portuguese coast, based on data from six groundfish surveys carried out systematically in three different seasons of the year (winter, summer and autumn) for two consecutive years (1992/93). Length and age distributions by depth range are analysed and seasonal patterns of global abundance are investigated. Preliminary estimates of the proportion of mature fish at length and age are given and spawning season is defined. Information on the pelagic distribution and behaviour of blue whiting, based on data from an echo-survey carried out in 1983, is presented and discussed here for the first time. In an introductory note, general information is presented on Portuguese landings and their length composition and on population abundance trends from two series of abundance indices and c.p.u.e. estimates for the trawl fleet.

MATERIAL AND METHODS

Groundfish surveys directed to the study of distribution and abundance of the main demersal fishery resources, have been carried out regularly by IPIMAR (Portuguese Fisheries Institute) since 1989. Two surveys, one between June and August (summer) and another between October and December (autumn), have been carried out each year, except for 1994 when only the autumn survey took place and for 1992 and 1993, when an extra survey was carried out in February/March (late winter).

Sampling design followed a stratified protocol with 97 fixed stations and a variable number of random stations covering all the Portuguese coast in the depth range 20-750 m. The survey area was divided in thirteen sectors in the north/south direction and each sector was further divided into four depth ranges, 20-100 m, 100-200 m, 200-500 m, 500-750 m, generating 52 strata (geographic strata). To the present study, strata were merged by depth range (depth strata) and abundance indices by length class and total in each depth strata were computed as area weighed averages of the geographic strata averages. Mean abundance for the whole area was estimated as an area weighed average of the depth strata abundance indices.

Two series of abundance indices (Kg/hour) corresponding to summer and autumn surveys are presented. These indices are compared with c.p.u.e. values (Kg/hour) of the Portuguese bottom trawl fleet calculated for the corresponding quarters of the year (summer - 3rd quarter, autumn - 4th quarter).

The autumn 92 survey did not cover the area north of 40°25'N at depths greater than 100 m. Abundance indices computed for this survey are not comparable with those estimated for the other surveys (except for the depth stratum 20-100 m) and were therefore excluded from the analysis of abundance trends.

Data selected for the study of blue whiting depth distribution and spawning was collected in the six groundfish surveys carried out in late winter, summer and autumn 1992 and 1993 (Table 1). Subsamples for biological analysis were collected in some of the stations, aiming the coverage of the different depth strata. For each individual, total length was measured, sex and maturity stage determined and otoliths removed. Otoliths were read whole under reflected light on a stereomicroscope, after soaking in sea water for 24 hours.

For the calculation of age frequency distributions, age/length keys were built for each survey and applied to the length frequency distributions. Due to the lack of age readings for the June 93 survey, the age/length key for the June/July 92 survey was used.

Maturity-at-age data was based on individual age readings. Classification of maturity stages followed the scale presented in Anon. (1979). Mature fish were considered to be those on stages II to VII.

The proportion of mature fish by length class and by age group was calculated for males, females and sexes combined using pooled data from the two February/March surveys. Fish in spawning condition were also observed in the summer surveys and in the autumn 93 survey but these surveys were considered to represent the limits of the spawning season and therefore not used to study maturity-at-length/age.

A large number of fishes in length classes 15-18 cm was not sexed (percentages of indeterminate fishes by length class were: 100% of 15 cm, 47% of 16 cm, 48% of 17 cm and 26% of 18 cm). Since these are immature individuals, the percentage of mature fish at length by sex will be severely overestimated if they are not included in the calculations. Maturity ogives based on length for separate sexes were, therefore, calculated for fish in length classes >=19 cm. Male and female maturity ogives based on age include fishes in all length classes. In this case, the effect of indeterminate fishes will be diluted because other length classes contribute to the same age groups. Nevertheless, the percentage of mature fish will be overestimated for ages 1 to 3 but particularly for age 1 fish. Indeterminate individuals were included in the maturity ogives for sexes combined.

L_{50}/Age_{50} and L_{100}/Age_{100} were determined by visual observation of distributions for the first occurrence of >=50% and 100% maturity, respectively.

For the analysis of sexual development in the different seasons, maturity stages I to VII were grouped in five broader stages of development: immature - stage I; first maturity/recovering - stage II; maturing - stages III to IV; spawning - stages V and VI; spent - stage VII.

The proportion of males and females in each stage was computed for each survey. To decrease the influence of large numbers of small fishes which consequentely have a low probability of being adults, only fish >=19 cm (estimated L_{50} for sexes combined) were included in the computations.

Data on the pelagic distribution and behaviour of blue whiting along the Portuguese continental shelf and upper part of slope was collected during an echo-survey carried out in August 1983 (Dias *et al.*, 1983). The main aim of this survey was the study of sardine distribution and abundance but the adopted survey track (equidistant transects perpendicular to the coast) extended the survey area beyond the continental shelf, allowing the observation of blue whiting distribution over the upper part of the slope (150-400 m). This area was crossed 41 times (19 during the day and 22 during the night), and the pelagic distribution of blue whiting was identified by inspection of the echograms and sampled for length distributions by trawling. Twelve samples were collected, six with pelagic net and six with bottom trawl net.

RESULTS

Landings and length compositions by quarter

Portuguese blue whiting landings (tonnes) in the period 1986-1995 are shown in the following table.

1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
8116	9148	5979	3557	2864	2813	4928	1236	1350	2285

Landings decreased from 1987 to 1991, showed some recover in 1992 but decreased again in 1993 to the lowest value of the series. A slight increase is observed in 1994 and 1995.

Length composition of landings by quarters has been very constant in this period: fish range from 12 to 31 cm with the majority between 15 and 23 cm and modal class varying from 17 to 22 cm. Recruits are observed in the 3rd or 4th quarter of the year with a modal length of 15/16 cm. Length compositions by quarter for 1995 are presented in Figure 1.

Indices of abundance

Figure 2 presents abundance indices for summer and autumn surveys and c.p.u.e. values for the corresponding quarters of the year.

Indices of abundance are generally higher in the autumn surveys. This pattern is not observed between the 3rd and the 4th quarter c.p.u.e. series.

A good agreement between abundance indices and c.p.u.e. in the corresponding quarter is observed. This consistence should give credence to the use of any of these estimates as indicators of population abundance. In view of the short time

series presented here, this consistence should be interpreted with care. Furthermore, the two series (summer and autumn) do not give the same picture. The fact that 4th quarter abundance indices and c.p.u.e. can be strongly influenced by recruitment may contribute to this discrepancy.

Depth distribution in groundfish surveys

Estimated indices of abundance by depth range and for the whole area are presented in Table 2. Lowest values (zero in all 1993 surveys) occurred in shallow waters (20-100 m) and highest values in the range 200-500 m in all surveys. Abundance was generally higher in the deepest stratum (500-750 m) than in the 100-200 m stratum but differences are small in some surveys.

Total abundance decreased from late winter to summer in both years and increased again in the autumn 1993. Seasonal variations in abundance within each depth stratum are not consistent in the two years.

The length distributions by depth range (Figures 3a and 3b) show that deep waters are related with the largest fishes and shallow waters with the smallest individuals, a pattern that has been referred for different areas of blue whiting distribution (Guichet, 1968; Bailey, 1982; Vasconcelos, 1987;Figueiredo *et al.*, 1994).

Length distributions shift gradually to the right but until 500 m depth most fishes are in the range 15-25 cm and modal length variation is small (one or two cm between 17 and 21 cm). The 500-750 m histograms show a wider range of lengths (15-40 cm) combining fish present at lower depths with larger individuals typical of this stratum. Some of the histograms show a bimodal distribution with the larger mode around 27 cm. Figueiredo *et al.*, (1994) report the ocurrence of these large individuals at lower depths (200-400 m) off the south coast. The abundance of large blue whiting is always very small when compared with that of 15-25 cm fish ocurring in the range 200-500 m.

Age distributions for all surveys are shown in Figures 4a and 4b.
In the depth range 20-500 m, age distributions are dominated by fishes one to four years old with modes of one year old in 1992 surveys and of one to three years old in 1993 surveys. Fishes up to 10 years old occur in the 500-750 m depth stratum and the distribution of age groups is quite variable between surveys.

0-group fish were detected in summer and in autumn surveys but are more abundant in the latter. The comparison of the two years evidences a very low recruitment in 1993. In both 1992 surveys, recruit abundance was higher in the stratum 200-500 m than in the stratum 100-200 m.

Pelagic distribution and behaviour

Like in other North Atlantic areas, a significant part of the blue whiting population off the Portuguese coast exhibits a pronounced pelagic distribution in the depth range 200-400 m, over bottom depths of 250 m and deeper. A striking characteristic of that pelagic distribution is a remarkable diel behaviour: during day-time the pelagic distribution is very well detected acoustically, with relatively dense schools; on the contrary, during night-time, the same distribution is not detected.

There is some evidence (Dias, unpublished data) that the blue whiting that forms the day-time pelagic schools disperses at dawn and ascends to the surface layers; at the sunrise the fish descends schooling at the referred depth range of 200-400 m apparently associated to a thin scattering layer that migrates from the surface to the main "Deep-Scattering-Layers" (400-600 m). In Figure 5, the blue whiting pelagic distributions are represented over the survey track were day-time and night-time periods are identified. The coincidence between the detected distributions and the day-time periods is clearly shown.

In Figures 6 and 7 are shown examples of echograms illustrating the pelagic distribution of blue whiting.

During the echo-survey the blue whiting distribution was sampled for length composition by means of pelagic and bottom trawl stations whose respective positions are indicated in Figure 5. The sampled compositions of the trawl catches are shown in Table 3. The length composition of the survey total catch was very similar to that of the commercial landings in the same year and month in the North of Portugal (Matosinhos).

In an occasion, off Figueira da Foz, it was possible to sample both the pelagic and demersal blue whiting distributions (fishing stations B-41 and P-42, undertaken 1.5 hour apart; see Figure 5 and Table 3). The respective length compositions, represented in Figure 8, are significantly different, with modal lengths of 16 cm (pelagic) and 21 cm (bottom). This difference does not seem to correspond to any length stratification in relation to the different distribution patterns. In fact, in stations P-9 and P-13, both pelagic, the respective samples (Figure 9) shows the simultaneous occurrence of both 16 cm and 20 cm modal lengths.

In conclusion, the described results suggest that, in terms of length composition, the blue whiting with pelagic distribution is the same that distributes near the bottom, in depths not greater than 300 m, and that is caught by the commercial fishing fleet.

Maturity and spawning

Maturity ogives for males, females and sexes combined are presented in Figure 10 (based on length) and in Figure 11 (based on age). It is not possible to define L_{50} values for each sex separately because the proportion of mature fish already equals or exceeds 50% for the first length class (19 cm). A_{50} is 2 years old for males and also not possible to identify for females (the percentage of mature females at age 1 is 51.7). L_{50} and A_{50} values for sexes combined are 19 cm and 2 years old respectively. At a length of 33 cm and an age of 5 years old, 100% of blue whiting individuals are mature.

Ehrich and Robles (1982) reported L_{50} values for northern Spain (ICES Div. IXa+VIIIc) of 18.2 cm for both males and females. The Blue Whiting Assessment Working Group estimated Age_{50} and A_{100} based on these values of 2 and 6 years old respectively (Anon., 1988).

Figures 12a and 12b show the proportion of fish in each maturity stage by sex and survey. Spawning fish are observed in late winter (February/March) and summer (June/July) surveys in 1992 and in all 1993 surveys. However, only in

February/March are the numbers of fish in the midle and late maturing stages (III,IV) relatively important, suggesting as expected, a more intense spawning activity in this time of the year. Mean lengths of spawning fishes in winter and summer surveys were:
winter 92: F=30.0, M=27.1 summer 92: F=32.1, M=27.2
winter 93: F=27.6, M=25.5 summer 93:F=32.3 , M=30.2
indicating that fish spawning in summer are generally larger than those spawning in late winter.

Vasconcelos (1982) observed spawning fish (maturity stages V and VI) only on the 1st and 4th quarters of the year in samples from 1981 landings. This author also analysed samples collected in two groundfish surveys, carried out in March and June of the same year, and found spawning fish only in March. Cunha (1992a), based on pooled samples from commercial landings and several surveys along the year in 1984 and 1985 observed pre-spawning and spawning fish from January to April. Our results suggest that the spawning season was longer in 1992/1993 than in 1981, 1984 and 1985. On the other hand, several factors related to sampling could have contributed for this difference, namely sampling areas, sampling depths and length composition of samples. Its not possible to evaluate the influence of the first two factors. Length composition of samples was considerably different only in the case of commercial samples in 1981.

The autumn 93 survey was carried out from November 24 to December 20, about one and half months later than the autumn 92 survey what may explain why spawning fish are not found in the latter. The large percentage of immatures in this survey, contrasting with the predominance of first maturation/maturing fishes in the autumn 93 survey, also suggests that the spawning season had not yet begun. The larger percentage of males than females in spawning condition suggests that sexual development starts earlier in males.

In summer surveys, the ocurrence of spent fish was expected but instead, a large percentage of stage II/recovering is observed. This may be due to difficulties in the macroscopic separation of spent and recovering fishes, as has been pointed out by Cunha (1992), or may reflect a fast recovery of the gonads also referred by Ehrich and Schöne (1983).

Due to the small number of samples collected in each survey, it is not possible to analyse the distribution of maturity stages by area or depth stratum. Nevertheless, its possible to say that spawning fish occur along all the Portuguese coast in a wide range of depths (100-700 m).

DISCUSSION

Results presented here on blue whiting abundance by depth range are comparable with those reported by Cardador (1983), Vasconcelos (1987) and Figueiredo *et al.* (1994) for other periods of time. A general depth distribution pattern may be outlined: abundance is null or negligible up to 100 m depth, highest abundance is found in the range 200-500 m and much lower values are observed between 100 and 200 m and at depths greater than 500 m. An evident exception to this general pattern is found off the estearn south coast where the batimetry is quite different from the rest of the coast. In this area, the slope becomes very smooth beyond 500 m depth and a deep plateau (500-800 m) extends 40 miles offshore. Figueiredo *et*

al. (1994) report high abundance of large blue whiting in this area at depths of 500-700 m.

The hidroacustic information showed that blue whiting distribution extends into the oceanic zone at depths of 200-400 m, in the continuity of the bottom distribution at the same depths. In this zone fish exhibit diel vertical migrations apparentely following their prey which are part of a migrating thin scattering layer.

Off the Portuguese coast, the "Deep-Scattering-Layers" are found in the vertical transition zone (roughly at 400/500 m depth) between two water masses. The water masses stratification, as well as the mean localisation of the "Deep-Scattering-Layers" off the Portuguese coast, is schematically represented in Figure 13. Under the surface layers, that support the most significant seasonal temperature and salinity variations, lays the North Atlantic Central Water whose temperature-salinity characteristics are very stable in time and space. Following the Central Water deeper limit, extends the Mediterranean Water. The main distribution of blue whiting off the Portuguese coasts is situated, approximately, between 200 m and 400 m depth that corresponds to the North Atlantic Central Water domain. So, the spatial continuity of the blue whiting distribution in the Northeast Atlantic seems to be associated to the North Atlantic Central Water dynamics.

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Survey	Date	Hauls	Biological samples	Fish sampled
winter 92	14/02-20/03	88	11	440
summer 92	07/07-30/07	81	9	393
autumn 92	15/10-05/11	59	10	439
winter 93	09/02-11/03	76	9	513
summer 93	25/06-18/07	66	11	519
autumn 93	24/11-20/12	65	13	327

Table 1 - Characteristics of groundfish surveys used for the study of blue whiting depth distribution and spawning.

Year	Season	Depth strata				
		20-100 m	100-200 m	200-500 m	500-750 m	20-750 m
1992	winter	7.3	42.8	249.2	73.3	67.7
	summer	1.4	29.0	215.5	26.8	46.8
	autumn	0.7	-	-	-	-
1993	winter	0.0	18.6	104.5	36.2	42.3
	summer	0.0	3.0	150.7	55.3	34.3
	autumn	0.0	90.3	188.6	5.8	85.8

Table 2 - Abundance indices (number of fish/hour) by depth range and for the whole area for winter, summer and autumn 1992 and 1993 surveys.

	STATIONS No.											
L ength Class (cm)	**B-1**	**P-4**	**B-8**	**P-9**	**P-13**	**P-15**	**P-21**	**B-23**	**B-30**	**B-39**	**B-41**	**P-42**
14 -	11				19	2	71	40	17			
15 -	78	20		66	35	34	128	103	104	30		49
16 -	30	54		96	14	97	22	60	73	131		118
17 -	15	94		70	6	79		17	16	22	5	71
18 -	18	63		20	7	22		4	6	3		14
19 -	8	16		2	45			1	1		5	
20 -	4	2		11	68	1			1		33	2
21 -	1			7	17	1			2	8	54	
22 -		1		5	3	1			2	1	13	
23 -						2					3	
24 -											2	
25 -												
26 -											1	
27 -												
28 -			1									
29 -			2									
30 -			6									
31 -			11									
32 -			30									
33 -			21									
34 -			15									
35 -			15									
36 -			8									
37 -			7									
38 -			2									
39 -			2									
Total	165	250	120	277	214	239	221	225	222	195	116	254
Date:	08/04	08/06	08/07	08/08	08/09	08/12	08/13	08/14	08/16	09/07	09/08	09/08
Hour:	12 30	11 30	13 00	10 00	18 00	12 30	19 30	11 00	04 00	19 00	16 00	17 30
Depth -												
- Trawl:		355		265	360	365	120					205
- Bottom:	70	>500	580	300	470	>500	130	110	175	150	270	275

B-(n) Bottom trawl P-(n) Pelagic trawl

Table 3 - Length distributions of blue whiting caught by N.I."Noruega" off the Portuguese coast in August/September 1983.

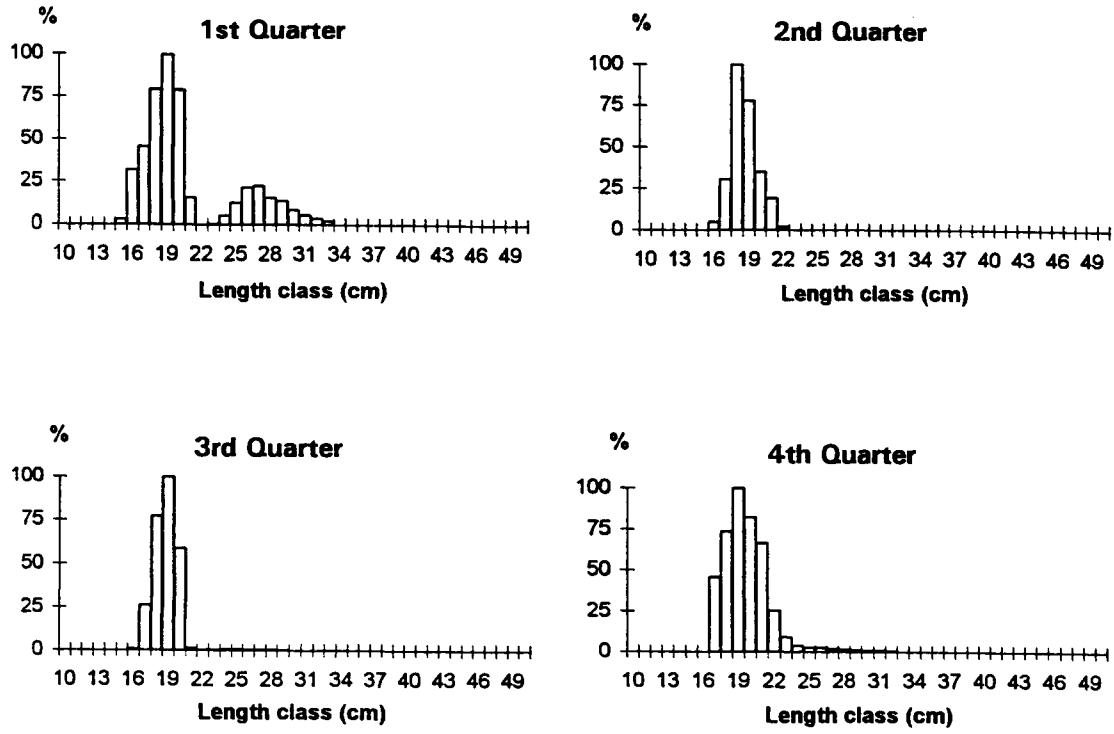

Figure 1 - Length composition of blue whiting landings from the Portuguese bottom trawl fleet, by quarters in 1995 (100% corresponds to the modal length class).

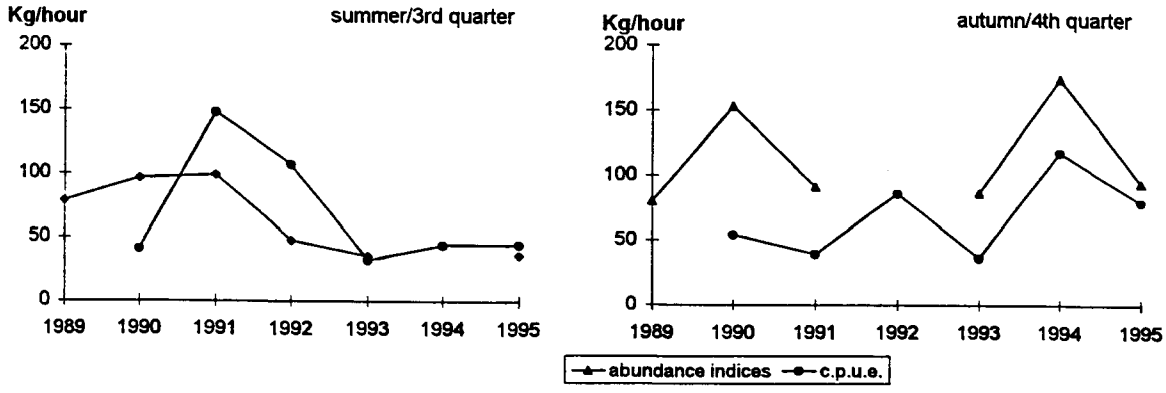

Figure 2 - Comparison of blue whiting abundance indices in groundfish surveys and c.p.u.e. of the bottom trawl fleet in the corresponding quarters of the year.

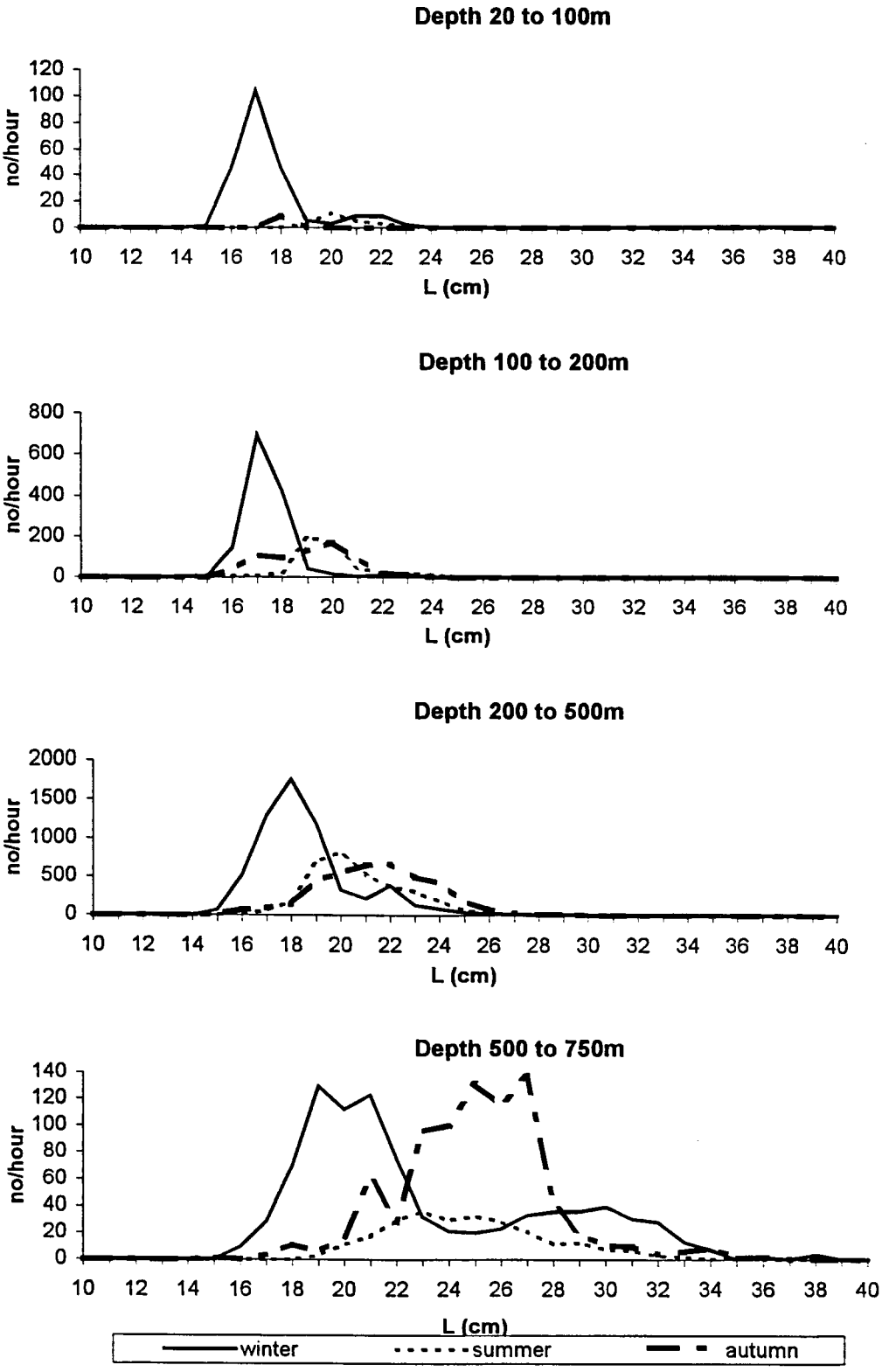

Figure 3a - Blue whiting length distributions in each depth stratum for 1992 groundfish surveys.

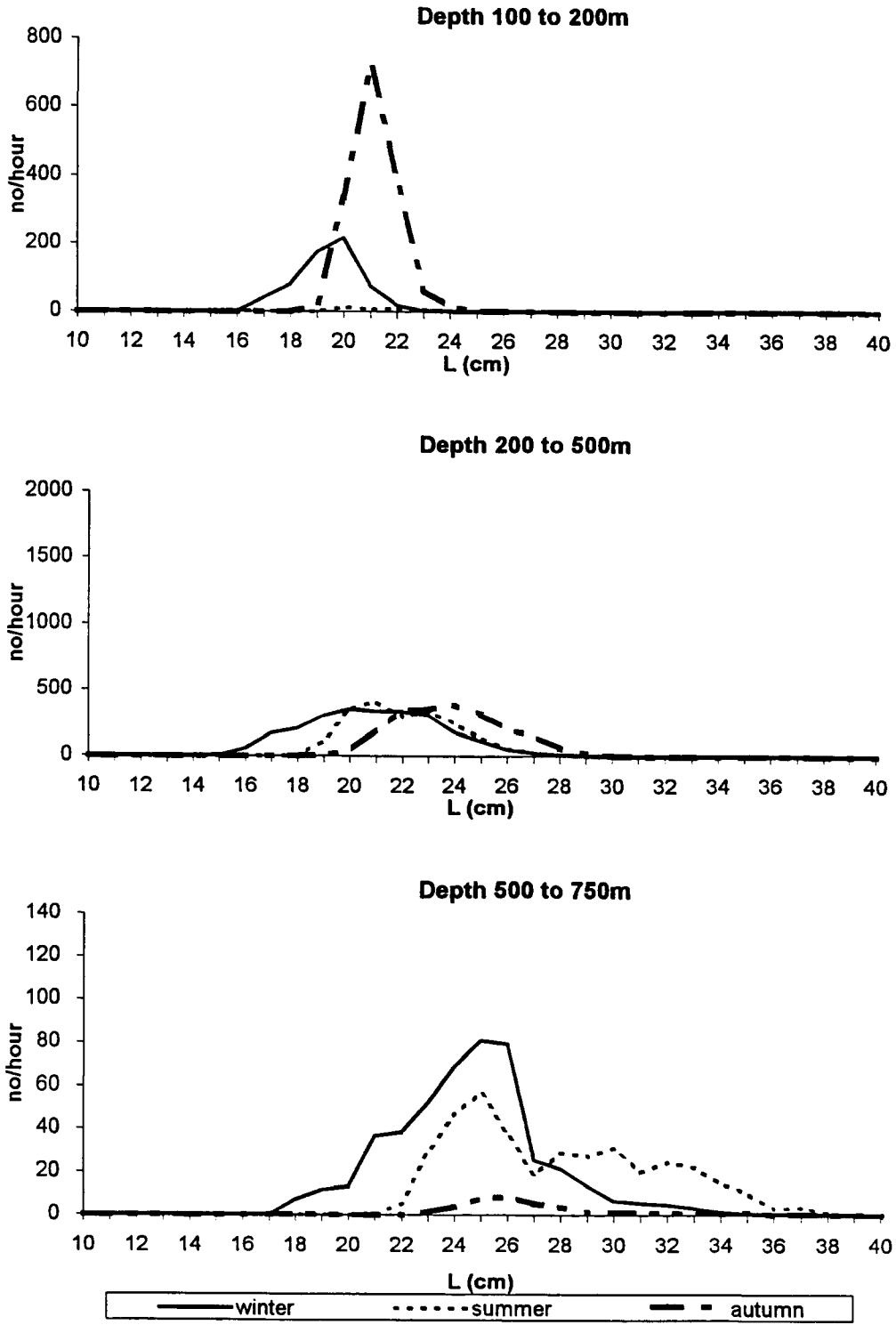

Figure 3b - Blue whiting length distributions in each depth stratum for 1993 groundfish surveys.

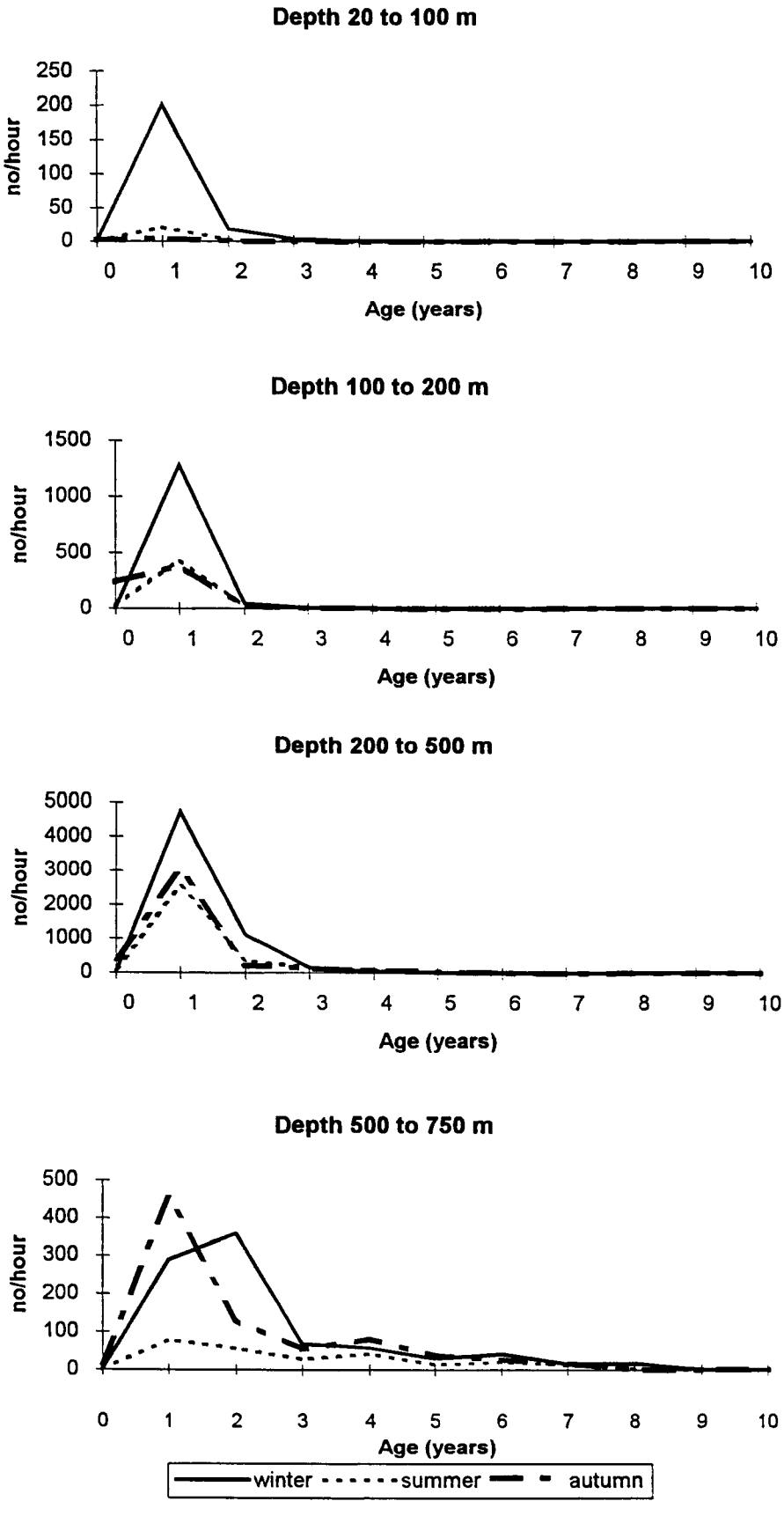

Figure 4a - Blue whiting age distributions in each depth stratum for 1992 groundfish surveys.

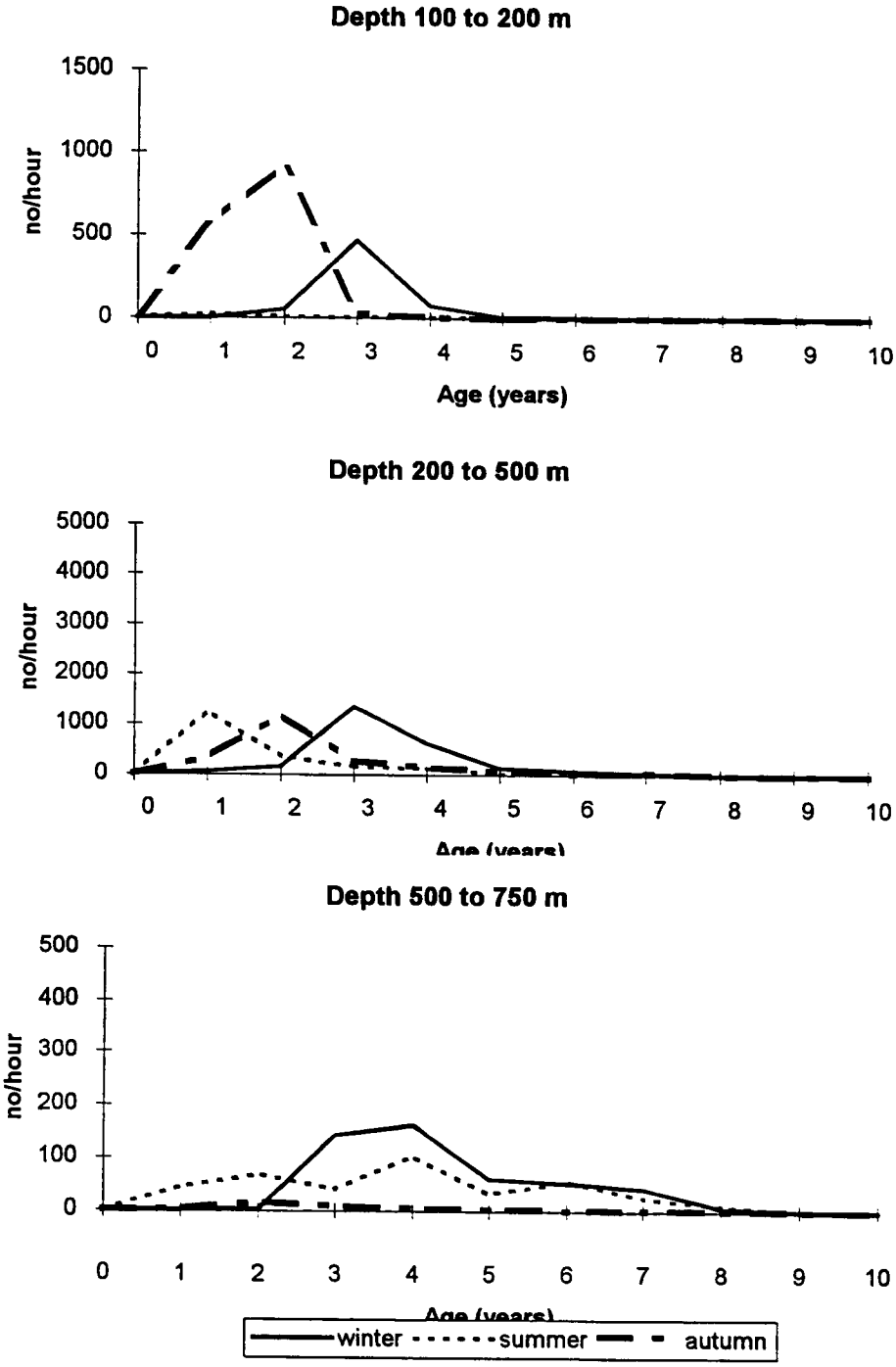

Figure 4b - Blue whiting age distributions in each depth stratum for 1993 groundfish surveys.

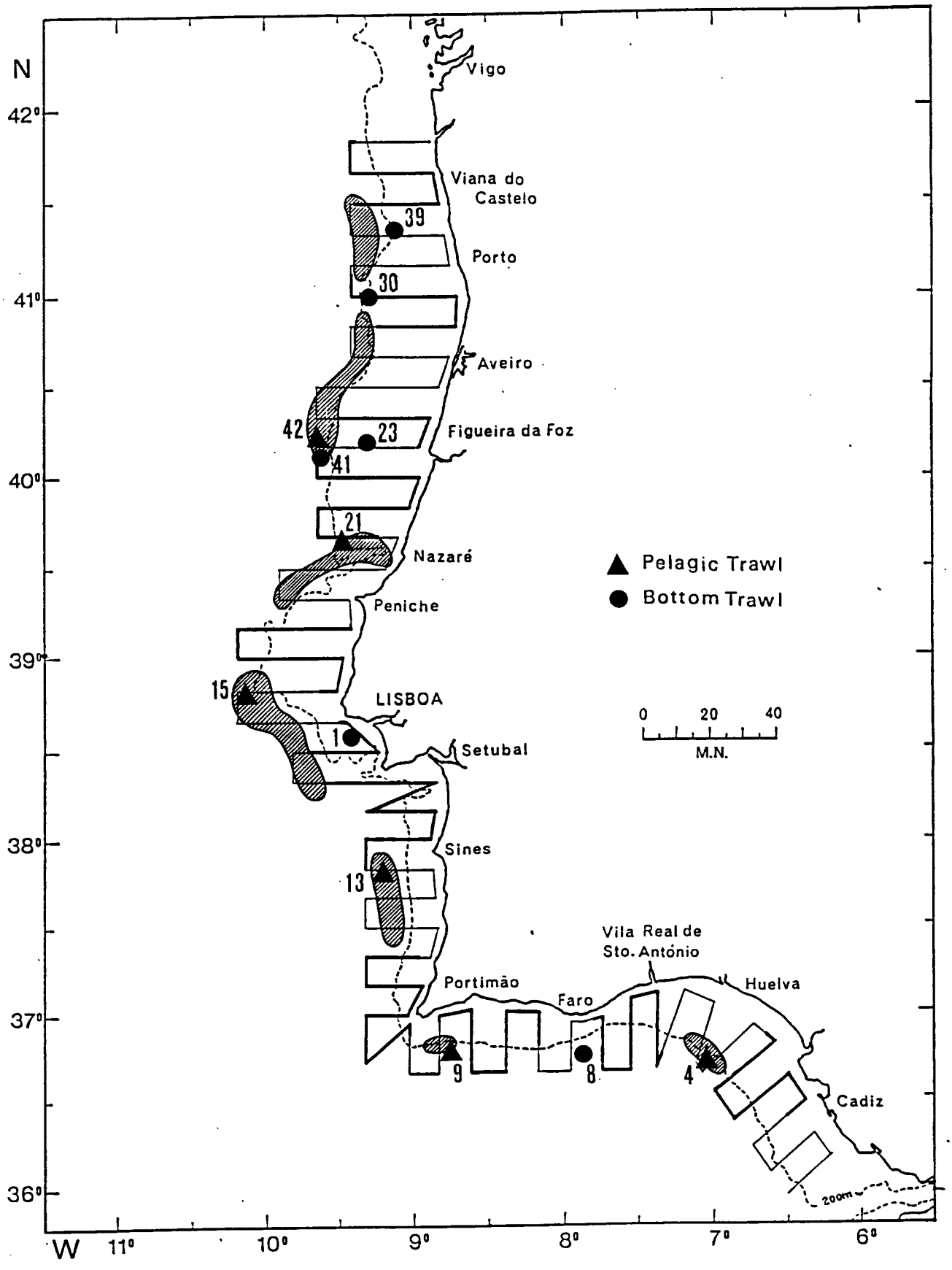

Figure 5 - August 1983 echo-survey track (thin traces: day-time; heavy traces: night-time), detected blue whiting distributions (hatched areas) and sampling stations. (the 200 m bathymetric is represented).

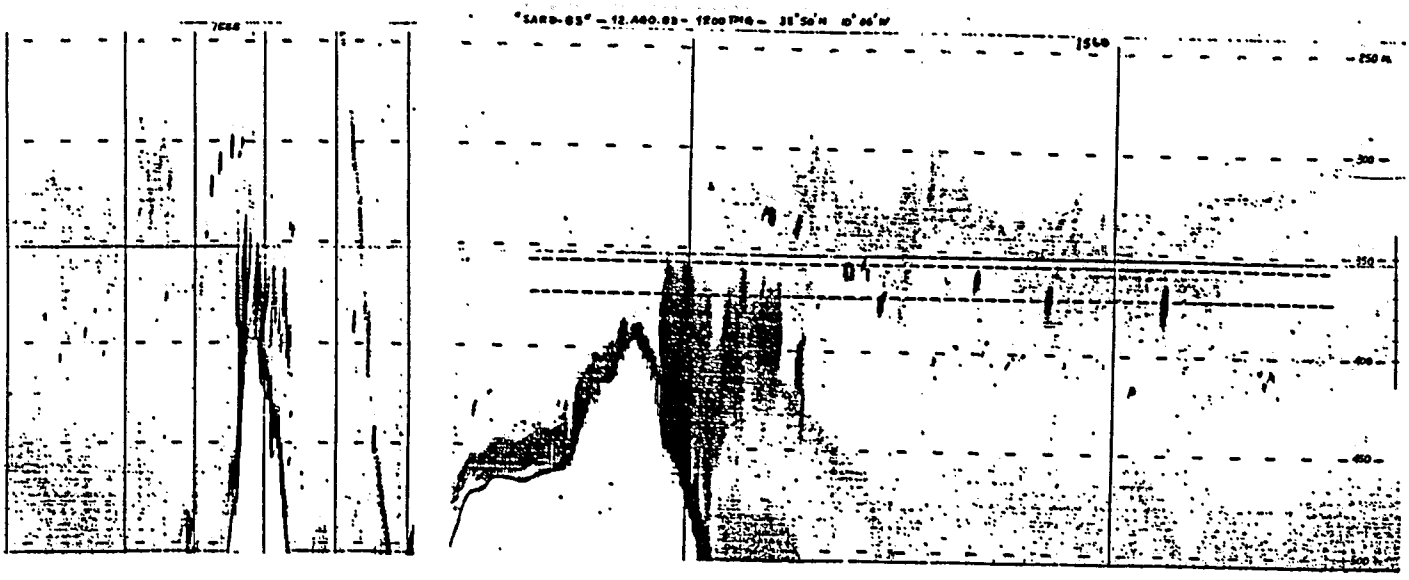

Figure 6 - Echo-recording of pelagic blue whiting schools, before and during the trawling at station P-15. The interrupted lines represent the pelagic trawl opening.

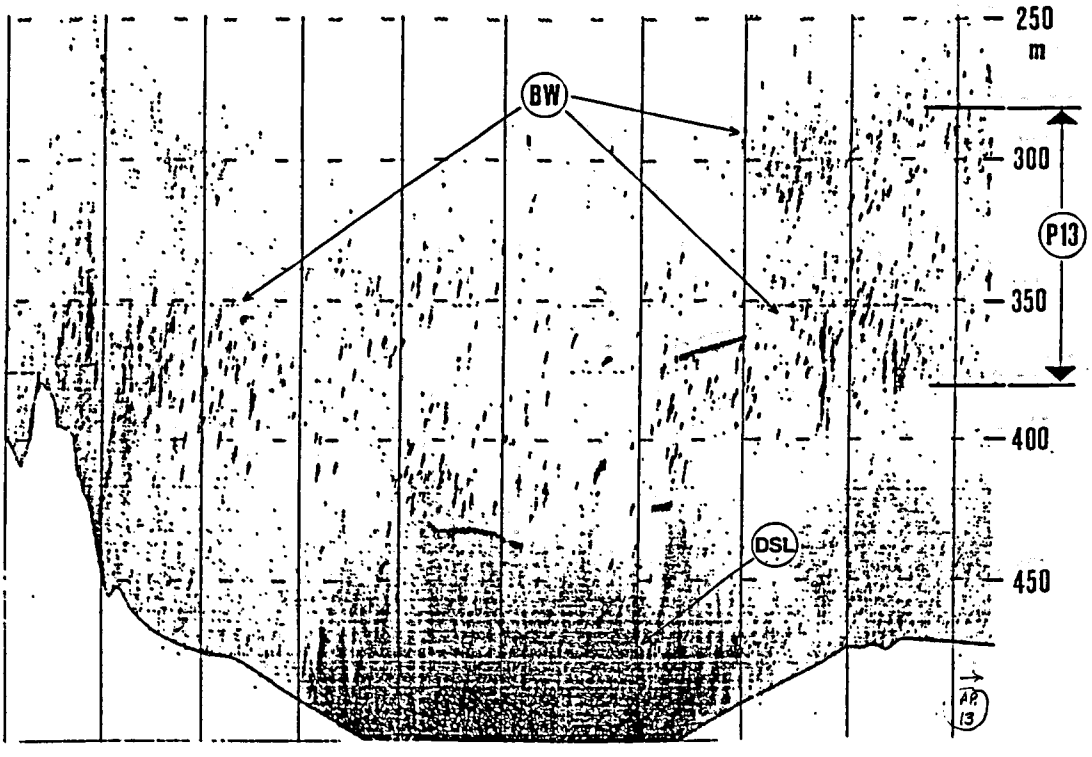

Figure 7 - Pelagic blue whiting distribution (BW) sampled at P-13 fishing station. The the upper part of the "Deep-Scattering-Layer" (DSL) is indicated.

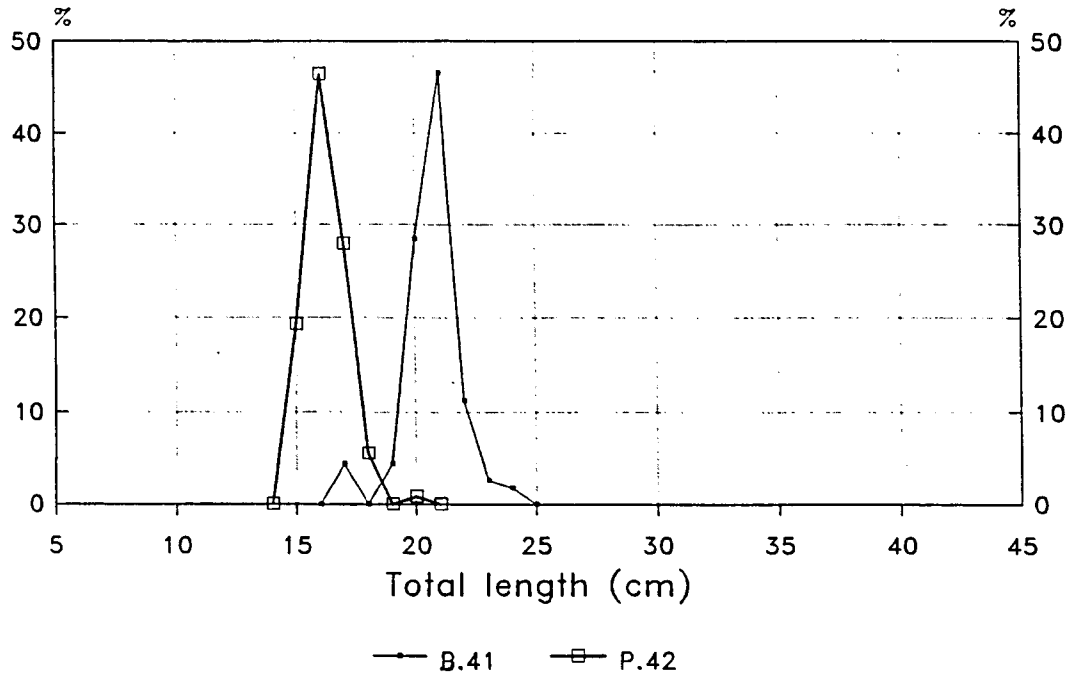

Figure 8 - Length composition of blue whiting caught in B-41 and P-42 fishing stations (see localisation in Figure 5).

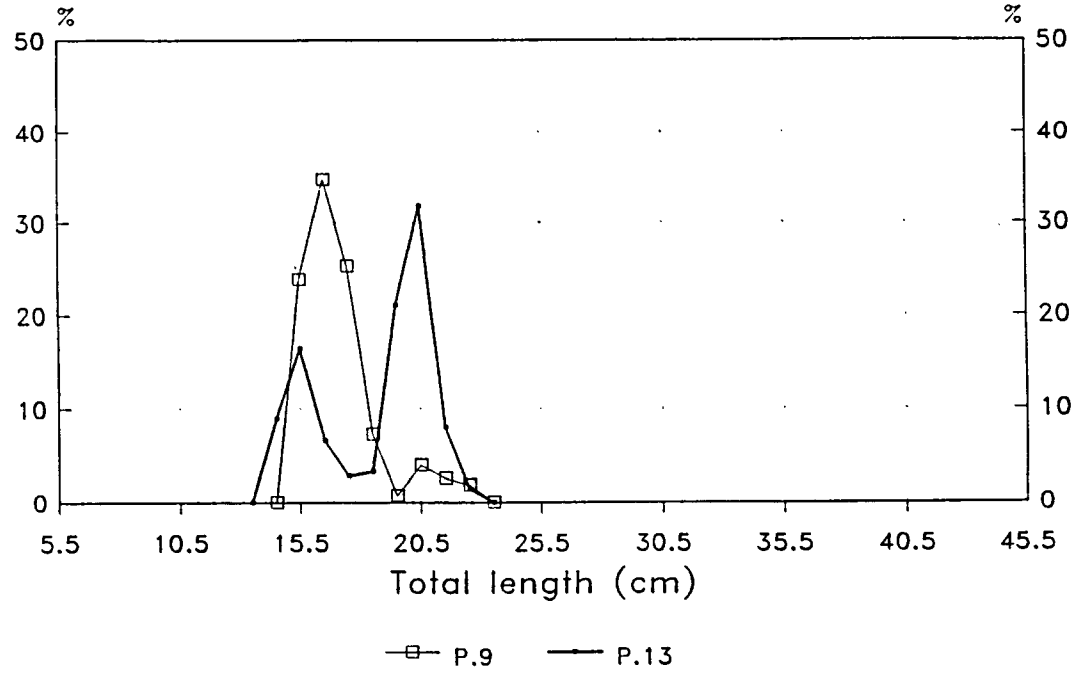

Figure 9 - Length composition of blue whiting caught in P-9 and P-13 fishing stations (see localisation in Figure 5).

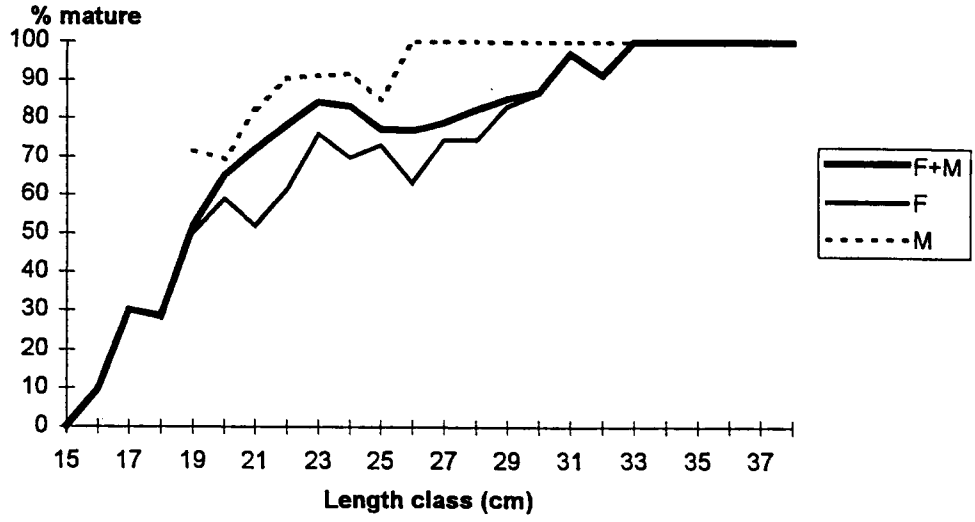

Figure 10 - Blue whiting maturity ogives, based on length, for males, females and sexes combined using pooled data from February/March 1992/1993 groundfish surveys.

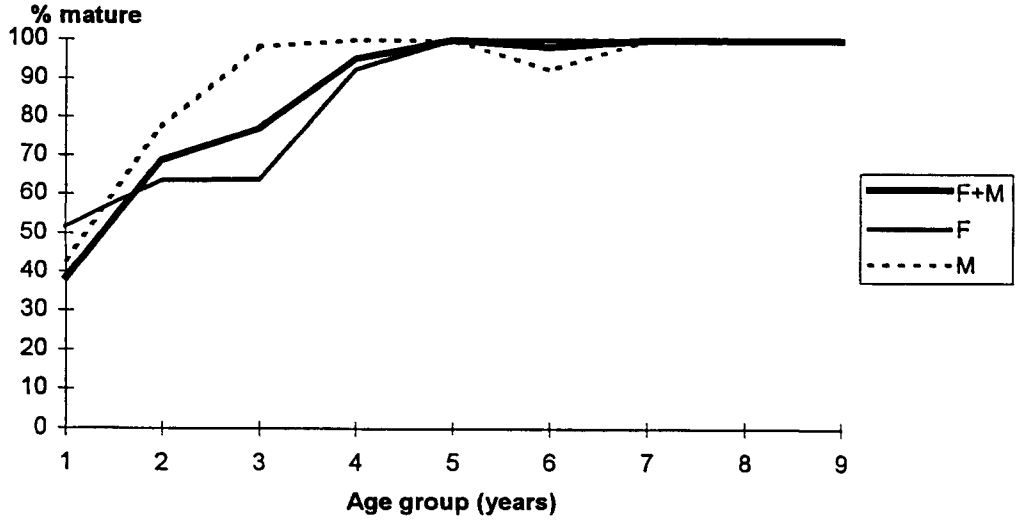

Figure 11 - Blue whiting maturity ogives, based on age, for males, females and sexes combined using pooled data from February/March 1992/1993 groundfish surveys.

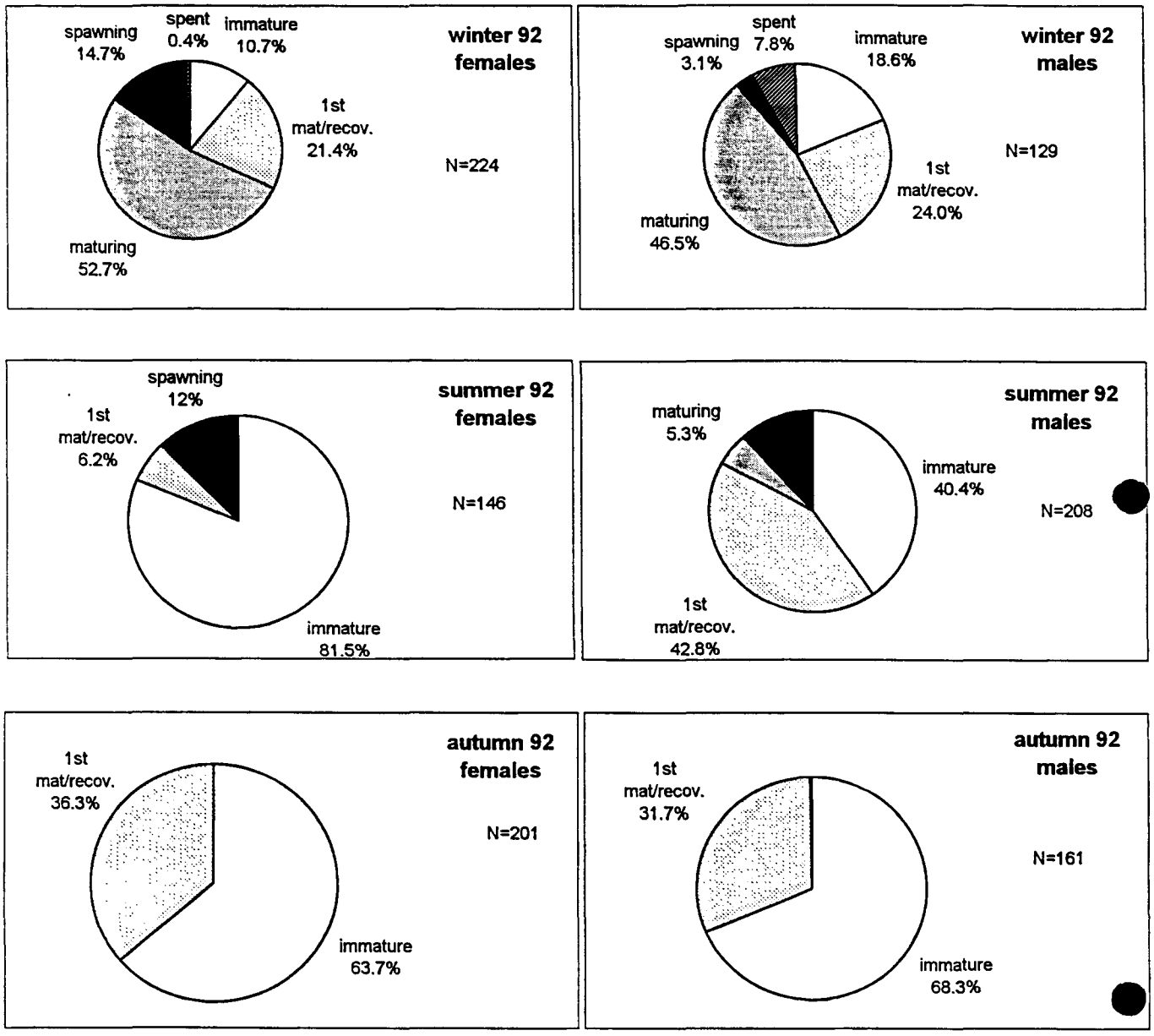

Figure 12a - Proportion of blue whiting in each maturity stage, by sex, observed in 1992 groundfish surveys.

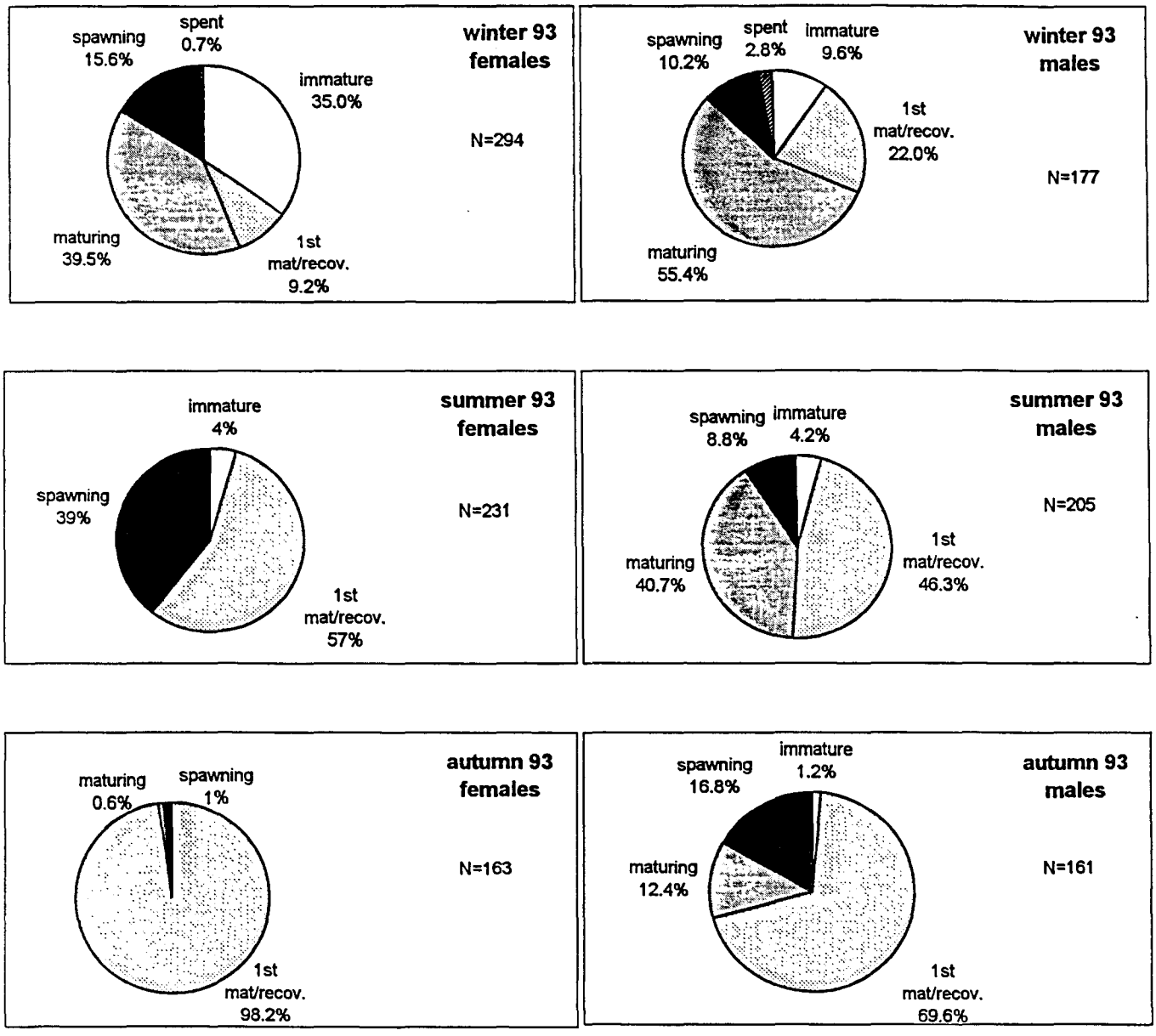

Figure 12b - Proportion of blue whiting in each maturity stage, by sex, observed in 1993 groundfish surveys.

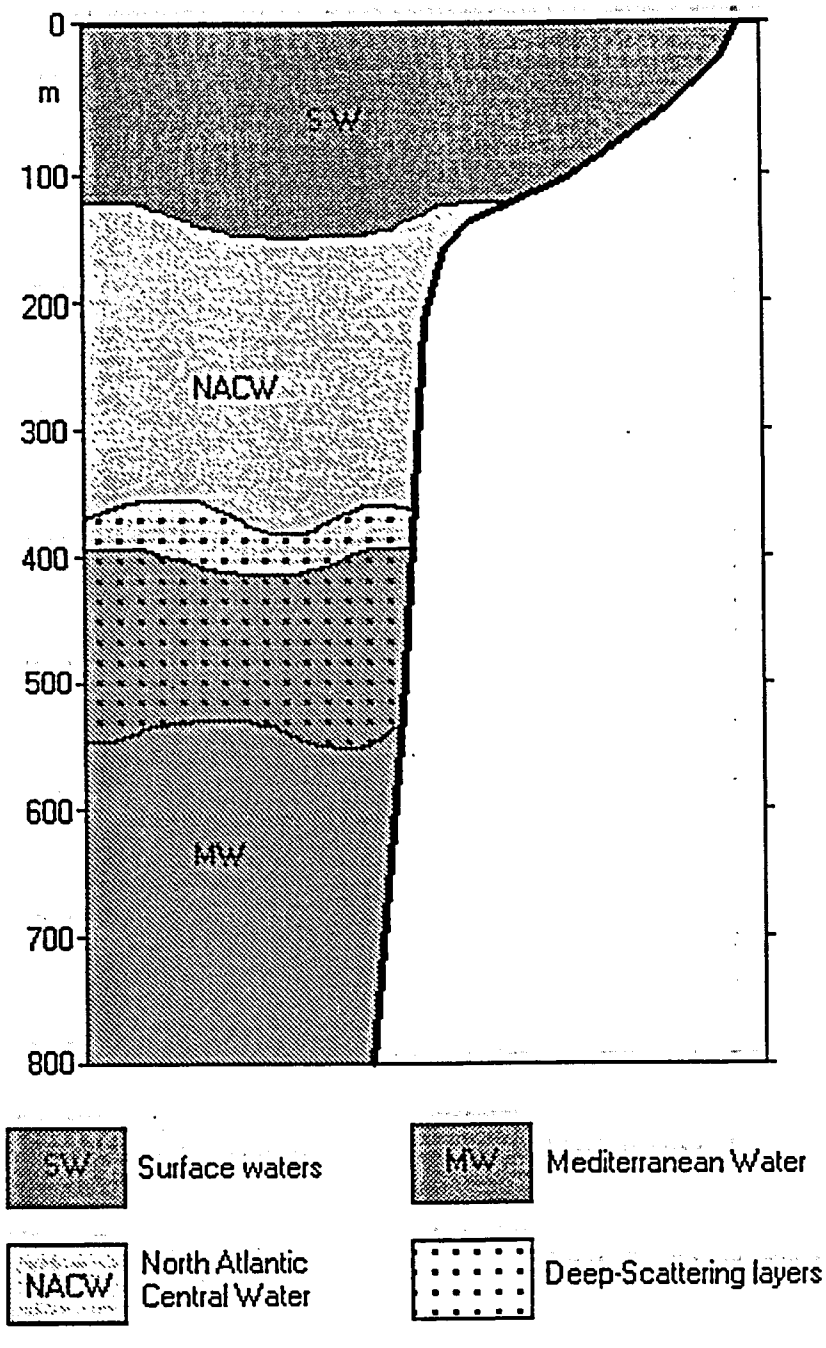

Figure 13 - Schematic representation of water masses vertical distribution and localization of the "Deep-Scattering-Layers" off the Portuguese coast.