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Cephalopod paralarval distribution in Iberian Atlantic waters

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Abstract

The general distribution of cephalopod paralarvae in Iberian Atlantic waters is described, based in 433 specimens, collected during research cruises in RV "Noruega" and "Mestre Costeiro" (1986-1998). The most abundant paralarvae were the neritic and neritic-oceanic species collected mainly over the NW continental shelf. Among these, loliginid (N=183) and sepiolid paralarvae (N=37) were mostly found in winter and spring, in stations with SST<16°C and over bottoms 50-100m deep. *Octopus vulgaris* paralarvae (N=99) were more abundant in summer (off west coast) and autumn (off south coast), and ommastrephid (rhynchoteuthion) (N=62) in autumn. Higher numbers of these two groups were observed over bottoms 50 to 150m deep, in stations with SST ranging from 17 to 20°C. A tendency of increasing mantle length towards offshore waters was observed in *O. vulgaris* and Sepiolid paralarvae. Paralarvae of oceanic species were collected in offshore waters in the southern sampling area: *Abraliopsis* sp. (N=3), *Pterygioteuthis* spp. (N=8), *Pyroteuthis margaritifera* (N=3), unidentified Pyroteuthidae (N=7), *Helicocranchia pfefferi* (N=2), *Bathothauma lyromma* (N=1), *Leachia* sp. (N=4), *Liguriella* sp. (N=1), *Taonius pavo* (N=6), *Ctenopteryx siculus* (N=1), *Onychoteuthis banksii* complex (N=1), *Mastigoteuthis* sp. (N=6) and unidentified Oegopsidae (N=9). Most oceanic paralarvae were collected during 1998 winter cruises, with the 16°C sea surface temperature isotherm limiting their distribution towards the north. A general overlap was observed in the distribution of the collected paralarvae and the known distribution of their adult phase (neritic, neritic-oceanic or oceanic).

Keywords: Atlantic, cephalopod, distribution, paralarvae

Introduction

Cephalopods represent important fishery resources for Portugal and Spain, but little is known concerning the early stages of their life cycle in the NE Atlantic. The most important cephalopod species in fisheries, which have planktonic paralarvae, are *Octopus vulgaris*, *Loligo vulgaris*, *L. forbesi*, *Illex coindetii* and *Todaropsis eblanae*, however many other species occur in Iberian Atlantic waters, and this area is for many of them the northern limit of their distribution in the NE Atlantic. Upwelling events provide optimum conditions for phytoplankton blooms and consequent zooplankton richness. Upwelling, as indicated by the deviations of the sea surface temperature at the coast, relatively to the central North Atlantic, presents a well defined maxima off the west Portuguese coast in July, August and September (Fiúza *et al.*, 1982). The orientation of the south Atlantic coast of the Iberian Peninsula does not favour upwelling under northerly winds, however, the upwelled waters of the west coast are frequently transported by currents to the south continental shelf and slope (Fiúza, 1983). According to this author, upwelling patterns are also determined by the shelf and upper slope topography. From the 39.5°N parallel to the Portuguese border (42°N) the coastal bathymetry is quite different from the southern area. In the north, the bottom depth increases smoothly and the continental shelf is much wider, thus the upwelled waters have an influence over a wider area. Off the Portuguese coast there are high and steady zooplankton levels in spring, summer and autumn (Cunha, 1993). Sea surface temperature in the Iberian Atlantic area, lower near the coast than offshore (Fiúza *et al.*, 1982), is generally above 12°C (from surface until 200 m depth) and increases about 4°C, from the north to the south. This poster illustrates the general distribution of cephalopod paralarvae in Iberian Atlantic waters and some relationships with the prevailing environmental conditions, based on specimens collected during research cruises carried out to study other marine species.

Materials and Methods

Cephalopod paralarvae (and juveniles) were sorted from around 1000 plankton samples taken during several plankton research cruises, in RV "Noruega" and "Mestre Costeiro" since 1986: monthly ichthyoplankton cruises in 4 transects in the west and south Portuguese shelf (Oct. 1986 to Jan. 1989); seasonal ichthyoplankton cruises under the Project FAR MA-1-203, covering the whole Portuguese coast (Jul. 1990, Mar. 1992,1993); crustacean larvae cruise in the south Portuguese slope (Aug. 1993); Ichthyoplankton cruises under the project SEFOS-AIR2-CT93-1105 in the south (May 1994) and in the south and western (Mar.-Apr.1995) Portuguese shelf and slope; cephalopod cruises in the south (Aug. 1995) and north Portuguese shelf (Aug. and Nov. 1996) and three ichthyoplankton cruises with sampling from western Galicia to the Gulf of Cadiz (Jan.-Feb. 1998). Sampling area as a whole covers latitude 35.75°N to 42.75°N and longitude 6.33°W to 11.50°W in the NE Atlantic. Most sampling was done in oblique tows with Bongo nets (mesh size 335µ and 500µ) and few with a WP2 net (mesh size 200µ). Sampling in the cephalopod cruises was done with Bongo nets in horizontal tows near the bottom floor. The preserved specimens were identified to lowest taxonomic level possible, depending on the preservation state of the specimen and the species paralarvae descriptions available in Sweeney *et al.* (1992) and Young (1991) . Dorsal mantle length (ML) was measured. Sea surface temperature (SST) was measured at each plankton station made during

1986 to 1989 cruises. During the 1998 cruises, temperatures at maximum tow depth (TDT) were also obtain, using a CTD probe at each plankton station.

Results

A total of 433 cephalopod paralarvae and few juveniles were collected in 248 stations. The most abundant were Loliginids (42%), followed by Octopodids (*Octopus vulgaris*) (23%), Ommastrephids (14%), Sepiolids (8.5%), Enoploteuthids (4.5%), Cranchiids (3.2%), Mastigoteuthids (1.4%), Onychoteuthids (*Onychoteuthis banksii* complex) (0.2%) and Ctenopterygids (*Ctenopteryx siculus*) (0.2%). Nine unidentified Oegopsid paralarvae were also collected. Numbers by species, ML range, maximum latitude, bottom depth range, month and SST in stations are described in table 1, as well as the species of which juveniles and adults are known to occur in the study area.

Figure 1 displays the sampling stations and the paralarvae with distribution in neritic (Loliginids, Octopodids and Sepiolids), neritic-oceanic (Ommastrephids) and oceanic (Cranchiids, Ctenopterygids, Enoploteuthids, Mastigoteuthids and Onychoteuthids) waters. A general overlap was observed in the distribution of the collected paralarvae and the known type of distribution of their adult phase. Neritic and neritic-oceanic paralarvae were more frequent off the NW Portuguese coast. Oceanic paralarvae were mainly collected in the offshore stations of the southern sampling area, with the exception of a *Helicocranchia pfefferi* paralarvae found north of the 40°N parallel (fig. 2). However, some of their adult stage are known to have a distribution extending further north (e.g. most of *Mastigoteuthis* species, *Perygioteuthis giardi*, *Leachia atlantica*, *Helicocranchia pfefferi* and *Taonius pavo*).

A cranchiid paralarvae, identified as *Liguriella* spp., was collected at 36.37°N, yet the species is not referred in Atlantic Iberian waters (Guerra, 1992). *Abraliopsis* sp. paralarvae and a juvenile were found in 3 stations close to each other, the juvenile over deeper waters than paralarvae. Among Pyroteuthidae paralarvae, *Pterygioteuthis* sp. presented a distribution closer inshore than *Pyroteuthis margaritifera* (fig. 3).

Most oceanic paralarvae were collected during the winter cruises in 1998. Their distribution were confined to the warmer temperatures, limited by the 16°C surface isotherm to the north, the sampling area to the south, and between the 14 and 15°C maximum tow depth isotherms, respectively to the west and east (fig 4).

Some of the most abundant squid paralarvae were not possible to identify to species level. The early young stages of the 4 loliginid species, which occur and spawn in the study area (see table 1) are nearly indistinguishable, specially in preserved condition where cromatophore patterns fade or disappear. Similar constraints exist for Ommastrephids (all in rhynchoteuthion stage), however they are likely to be *Illex coindetii* and *Todaropsis eblanae* specimens. These species are known to occur from juveniles to mature adults (and probably spawn) in Iberian Atlantic waters, but paralarvae were not identified to species, since paralarvae of *T. eblanae* were never described.

Loliginid paralarvae were collected in hi[illegible] numbers in the NW coast (latitude > 40°N) (fig. 5), where *L.vulgaris*, *L. forbesi* and *Alloteut*[illegible]p. adults and juveniles are more abundant (Cunha *et al.*, 1995; Moreno, 1995). In the so[illegible] however, few loliginid paralarvae were collected, although the abundance of post-paral[illegible] *L. vulgaris* and *Alloteuthis* spp. in this area is significant and where an important area [illegible] *vulgaris* spawning is known to be located (Cunha *et al.*, 1995, Villa *et al.*, 1997). Small [illegible]arvae (ML < 4 mm) occurred along the sampled continental shelf, although larger paral[illegible] were found only in two areas of the continental shelf, in latitudes between 39.5 and 41.[illegible]d 37.5 to 38.5°N. No significant relation was found between the size of paralarvae and [illegible] depth. Paralarvae were found throughout the sampled SST range, but more frequen[illegible]tations with SST between 13 and 16°C (fig. 6). Distribution in summer and autumn was [illegible] to the coast, where SST was lower. In the south they were found mainly during winter [illegible] (the period when local SST is generally below 16°C). Most specimens were collecte[illegible]bottoms 50-100 m deep, overlapping the main spawning area of *L. vulgaris* (40 to 70 m [illegible] unpublished data). Seasonally, these paralarvae were more abundant in winter and spri[illegible]xpected result from the *L. vulgaris* and *L. forbesi* main spawning activity, which is from [illegible]mn to winter in Portuguese and Galician waters (Moreno *et al*, 1994; Guerra and Roch[illegible]. The specimens with ML< 2 mm, most likely all newly hatched *Alloteuthis* spp., were c[illegible] mainly in August, also as a result from the late spring-summer main spawning season [illegible]*uthis subulata* (Moreno, 1995).

Octopus vulgaris paralarvae were m[illegible]dant in summer samples (in the north) and in autumn (in the south), close to the [illegible]where abundance of juveniles and adults in Portuguese waters is higher (persona[illegible]ation). Newly hatched paralarvae (ML< 2 mm) occurred mostly from nearshore to th[illegible] isobath, and larger specimens more frequently over deeper waters (fig. 7). Fully ma[illegible]les of *O. vulgaris* are rare in trawling sampling (personal observation), probably due [illegible] for spawning into very inshore grounds, outside of sampling coverage. Thus, parala[illegible] very close to the coast and start migrating towards offshore waters, as evidence[illegible]served tendency of increasing ML of paralarvae with distance to the coast, and propor[illegible]her abundance offshore, in relation to the main distribution of adults and juveniles. I[illegible] paralarvae occurred more offshore in summer than in autumn (fig. 8), however it w[illegible]mn (and spring), when three paralarvae were found over the deepest bottoms (50[illegible]). Higher numbers of paralarvae were found in stations with SST ranging between 1[illegible]. Only newly hatched *O. vulgaris* were collected in stations with SST below 16°C and [illegible].

Higher numbers of Ommastrephid p[illegible] were collected north of 40°N, within the main distribution area of *Illex coindetii* and [illegible]*sis eblanae* (fig. 9). No relation was observed between size of paralarvae and bottom [illegible]he spawning area of these species is unknown, however mature females occur most [illegible] offshore part of the species distribution (pers. obs.). Nevertheless, rhynchoteuthions [illegible]tributed mainly inshore, in stations between 50 and 150 m deep (fig. 10), meaning [illegible] masses are released offshore, they may be subject to offshore-inshore transporta[illegible]choteuthions were collected more frequently in summer and autumn, which is durin[illegible]n after the main spawning season of both *I. coindetii* (González and Guerra, 1996[illegible]*blanae* (Rasero, 1996) in Galician waters (and most likely also in Portuguese wate[illegible] summer, rhynchoteuthions were only found offshore of the 100 m isobath, althou[illegible]mn, when higher numbers were collected, they were distributed also further inshore. [illegible] paralarvae were found from the coast until the 3000 isobath. Smaller paralarvae (M[illegible]m) were collected at all seasons, which is in accordance with the all year round spawning of *Illex coindetii* and *Todaropsis eblanae*. Paralarvae were found in areas with SST > 13°C, with higher numbers between 18 and 20°C. Larger animals (ML ≥ 4mm) were associated to the warmer waters (SST > 18°C).

Sepiolid paralarvae occurred in two discrete geographic areas: 37 to 38°N and 40 to 42°N (fig. 11). A tendency of increasing size (ML) with distance to the coast was observed in the northern area. This was not verified in the southern area of distribution. In the north, paralarvae occurred mainly from November to April in stations with SST between 13 and 14.5°C. Distribution in the south was verified mainly from June to September in stations with SST between 17.5 and 18.5°C. This difference can be due to distinct species composition between the north and the south areas.

Comments

Some relationships have been made between the distribution and abundance of cephalopods and upwelling (e.g. Rasero, 1994; Rowell and Trites, 1985). The western coast of Iberian Peninsula is characterised by important upwelling conditions and a high productivity and, was shown to be an important spawning area for many cephalopod species, considering the abundance of the early young stages. The main distribution of cephalopod paralarvae was observed off the Northwest Portuguese coast, within the area where upwelled waters have a wider extension. Additionally, paralarvae were abundant off the Southwest corner of Iberian Peninsula. Here, upwelling is intense on the western coast and upwelled waters are transported by currents to the southern coast. On the other hand, ommastrephid and *Octopus vulgaris* paralarvae occurred mainly in summer and autumn, during and soon after the upwelling peak (summer), although loliginid paralarvae appeared mainly in winter and spring, before the upwelling peak. This upwelling related seasonal pattern has two main implications: 1) higher food availability, since paralarvae feed on zooplankton (Boucher-Rodoni *et al.*, 1987), and zooplankton availability is increased in relation to upwelling events (thus survival chances of ommastrephid and *Octopus vulgaris* paralarvae increase, since they occur mainly within the period of higher food availability); 2) decreased growth rates in the colder waters associated with upwelling. It was however observed that, during summer, paralarvae presented a distribution further north and offshore than in autumn (period of downwelling), "avoiding" the northern colder coastal waters. In general, those paralarvae were found mainly in areas and seasons with warmer surface water temperature (SST>17°C), especially the larger ommastrephids.

In opposition to ommastrephid and *Octopus vulgaris*, loliginids occurred mainly during a period of lower food availability, and associated to relatively colder water temperatures. This may be related to: firstly, lower food requirements for these species, immediately after hatching although zooplankton levels in the Portuguese coast are high troughout the year, despite being higher and steady in spring, summer and autumn (Cunha, 1993); secondly, the most abundant loliginids in the study area (*Loligo vulgaris* and *Alloteuthis subulata*) are known to spawn through a wide range of temperatures, to which they are exposed through their extended geographical distribution and due to their year round spawning. Additionally, it is interesting to note that loliginid (*Loligo* spp.) main spawning season is in synchrony with many abundant finfish species in the area, such as horse mackerel (Borges and Gordo, 1991), mackerel (Gordo and Martins, 1984), Spanish mackerel (Martins, 1996) and hake (Pérez and Pereiro, 1985), with which they have strong trophic relationships.

Although the information presented on the distribution of Loliginids and Ommastrephids can be useful, the distinction between species is still needed to infer on the specific paralarval distribution and ecology. In the future, attempts should be made to describe the morphology of early young stages in greater detail, and examine plankton samples as fresh as possible, to enable species identification through cromatophore patterns.

As most sampling was done by oblique tows, no information was available on the distribution of species in the water column, although vertical migrations have been observed for some species in Portuguese waters (Reis, 1989), and some (Loliginids, for instance) are usually found in the vicinity of the bottom. In this case, it must be born in mind that the relationships between species distribution and water temperature were based mainly on SST data.

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Table 1 - Number of collected paralarvae, mantle length (ML) range, maximum latitude, bottom depth, month, sea surface temperature (SST) range and species which juveniles and adults with known distribution in the sampled area.

FAMILY AND SPECIES	N	ML (mm)	LAT. max.(°N)	BOTTOM DEPTH (m)	MONTH	SST (°C)	POSSIBLE SPECIES
(total sampling)	433	0.9-28.0	42.75	12-4910	1 to 12	11.8-23.4	-------------
Cranchiidae							
Bathothauma lyromma	1	23	37.75	3100	2	16.2	*B. lyromma*
Helicocranchia pfefferi	2	4.4-5.4	40.25	1386-3850	2	?	*H. pfefferi*
Leachia spp.	4	7.8-52.0	37.25	2043-3400	1	16.9-17.3	*L. atlantica*
Liguriella spp.	1	9.6	36.37	800	2	?	?
Taonius pavo	6	4.4-12.2	36.57	800-4000	1, 2	17.3-17.7	*T. pavo*
Ctenopterygidae							
Ctenopteryx siculus	1	2.1	36.00	2000	4	17.0	*C. siculus*
Enoploteuthidae							
Abraliopsis spp.	3	2.4-28.0	36.63	830-930	2, 3	17.2	*A. pfefferi*
Loliginidae	183	1.6-9.6	42.75	17-500	1 to 12	13-22.7	*L.vulgaris, .subulata, L.forbesi, A.media*
Mastigoteuthidae							
Mastigoteuthis spp.	6	4.1-6.1	37.25	527-3000	1, 2, 4	17.3-17.7	*M.grimaldii, M.schmidti, M.talismani*
Oegopsida unidentified	9	2.0-6.8	40.08	98-3000	1, 2, 8	17.2-19.7	Several
Octopodidae							
Octopus vulgaris	99	1.3-4.2	41.83	20-900	1 to 12	14.3-22.7	*O. vulgaris*
Ommastrephidae	62	0.9-6.2	42.75	20-3000	1 to 12	13.2-19.9	*I. coindetii, T.eblanae*
Onychoteuthidae							
Onychoteuthis banksii	1	6.8	36.80	230	8	-	*O. banksii*
Pyroteuthidae							
Pterygioteuthis spp.	8	1.7-3.4	38.00	65-2000	1, 2, 4, 7	16-17	*P.giardi, P.gemmata*
Pyroteuthis margaritifera	3	2.1-13.3	36.57	800-2043	1, 2	17.3	*P. margaritifera*
Pyroteuthidae unidentif.	7	1.5-2.9	36.87	132-3000	1	16.8-17.6	
Sepiolidae	37	1.4-4.4	41.83	27-275	1 to 12	13.2-19.9	Several

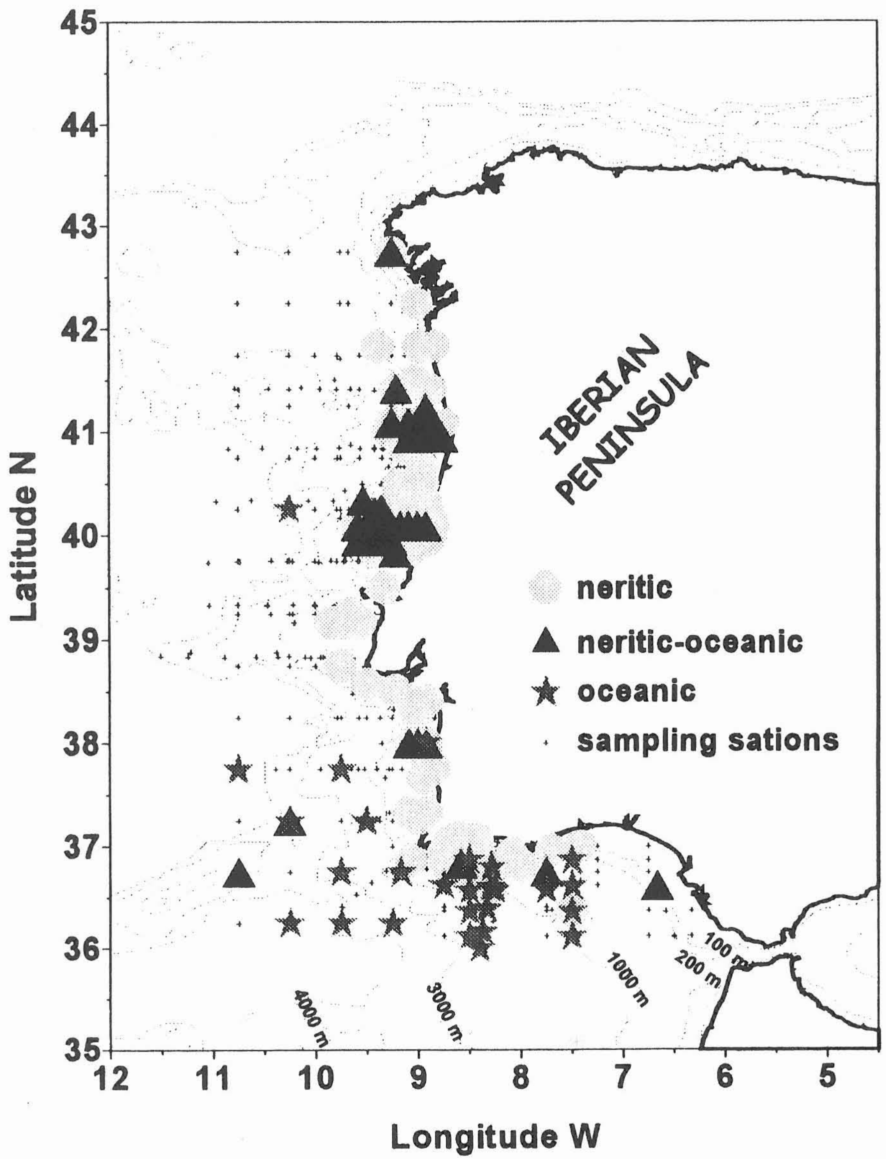

Figure 1 – Position of plankton stations and distribution of paralarvae of neritic, neritic-oceanic and oceanic species (small symbols: < 5; large symbols: ≤ 10 specimens).

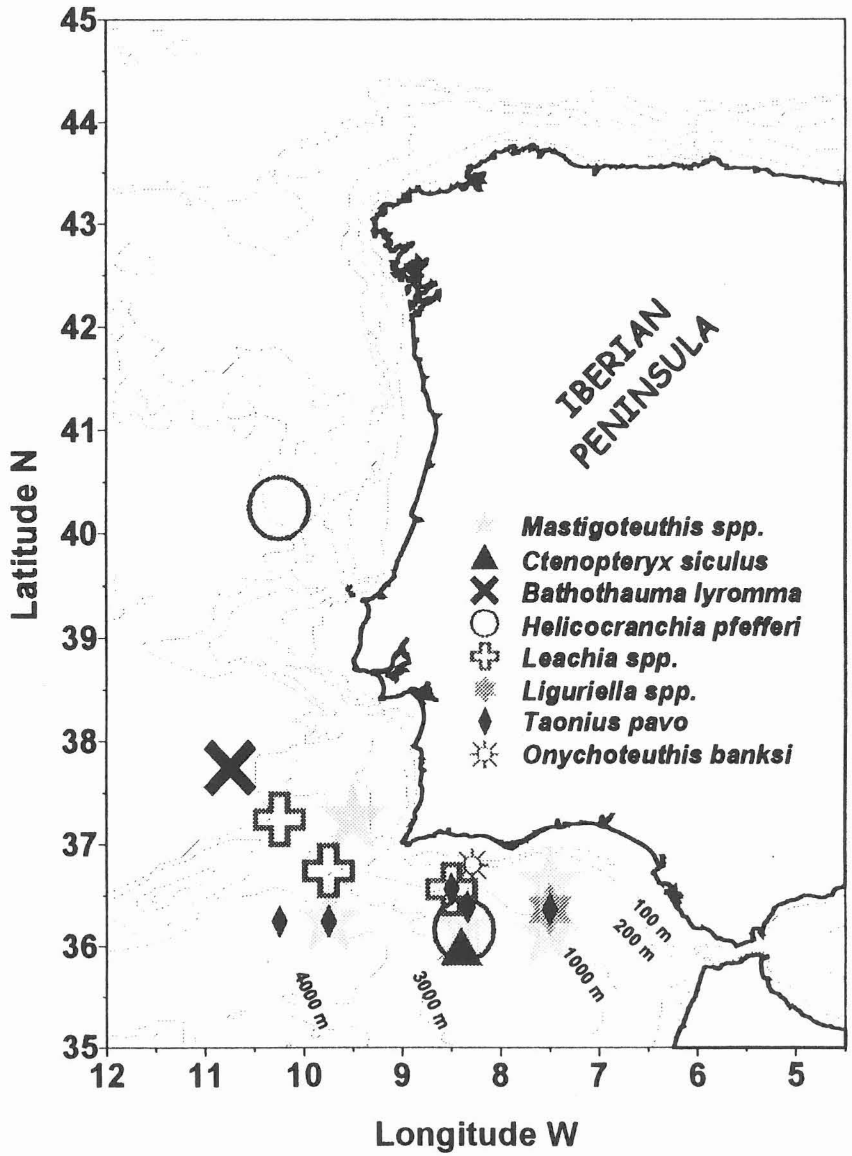

Figure 2 - Distribution of Mastigoteuthid, Onychoteuthid, Ctenopterygid and Cranchiid paralarvae.

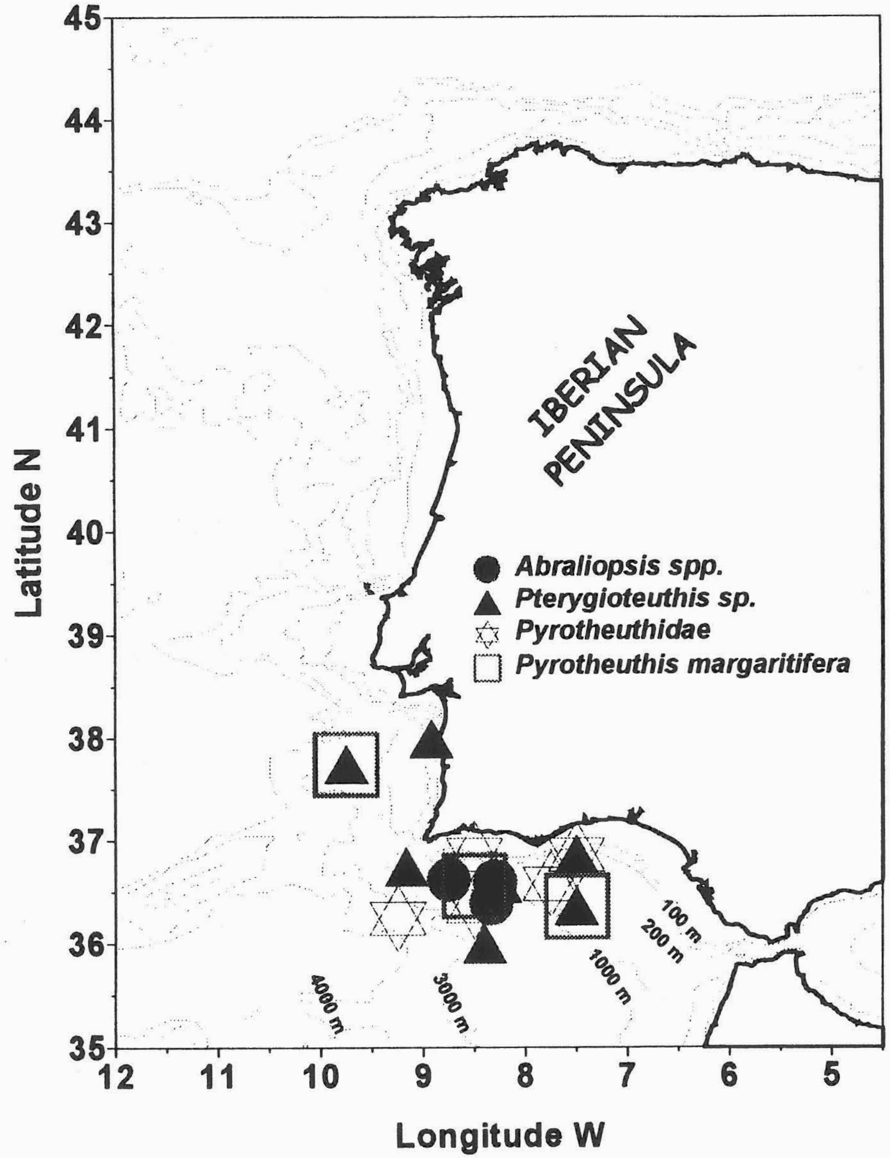

Figure 3 - Distribution of Enoploteuthid and Pyroteuthid paralarvae.

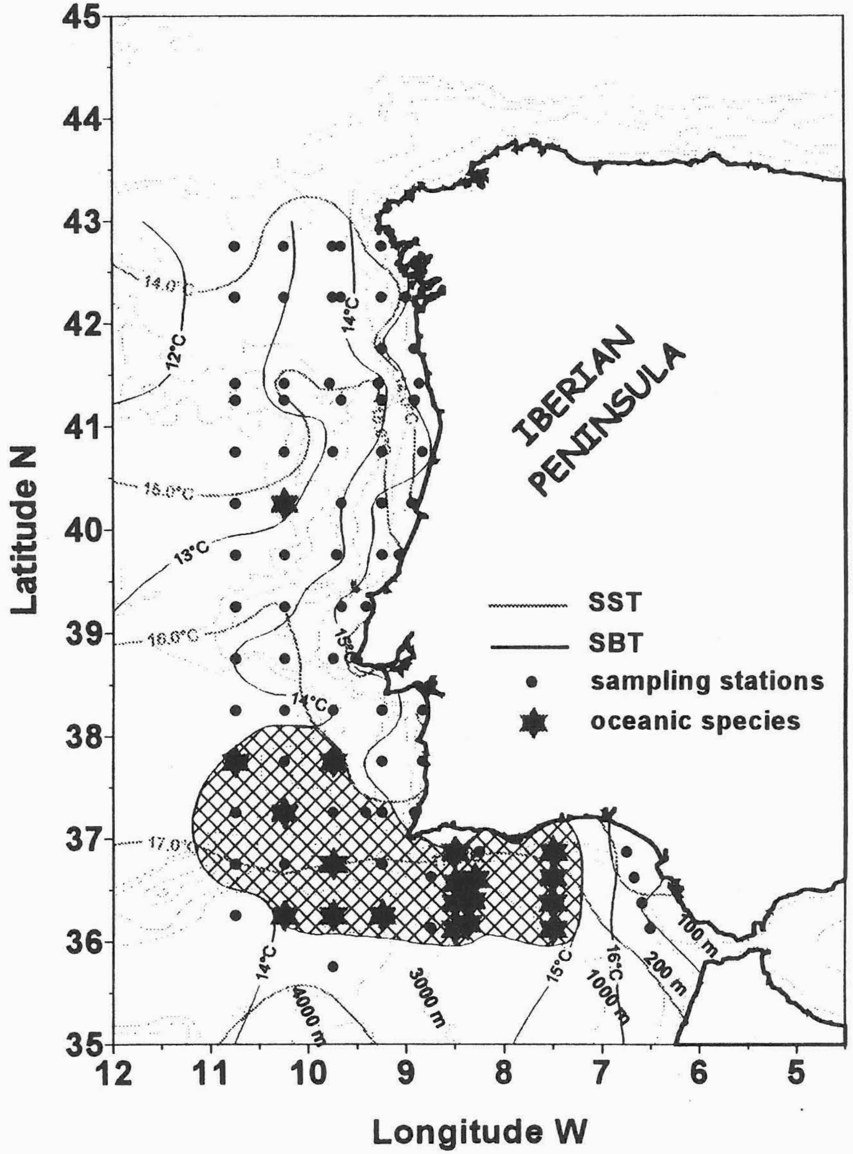

Figure 4 - Distribution of oceanic paralarvae collected in the 1998 cruises in relation to sea surface temperature (SST) and temperature at maximum towing depth (SBT).

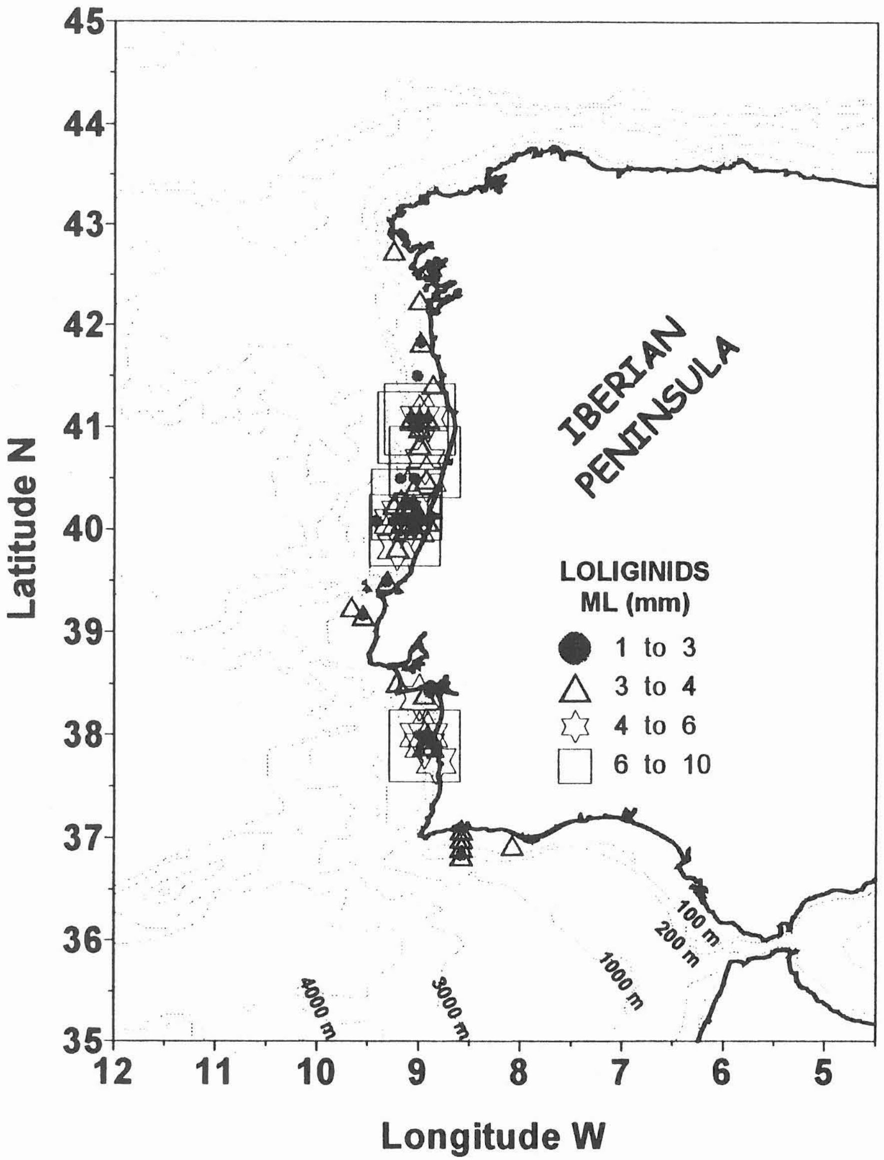

Figure 5 – Distribution of Loliginid paralarvae according to mantle length (ML).

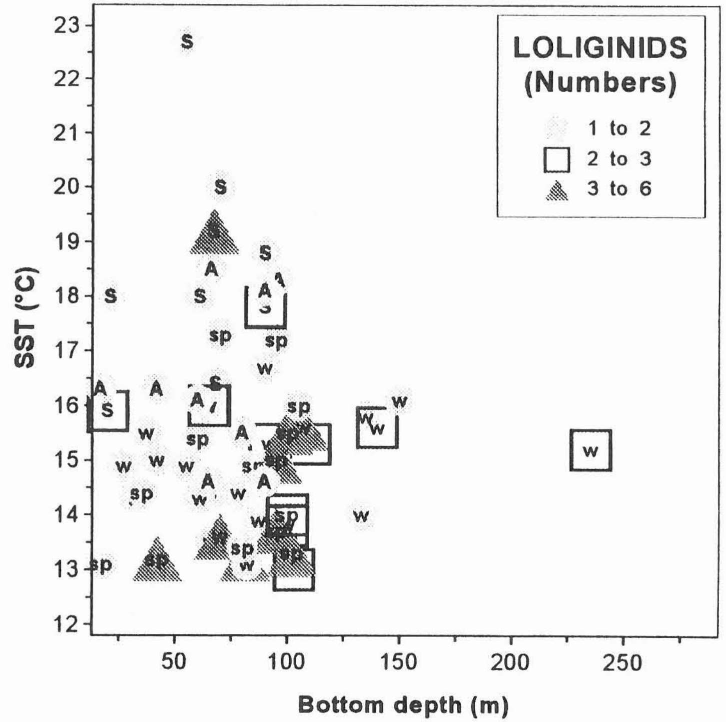

Figure 6 - Distribution of Loliginid paralarvae in relation to sea surface temperature and bottom depth and season (w = winter, sp = spring, S = summer, A = autumn).

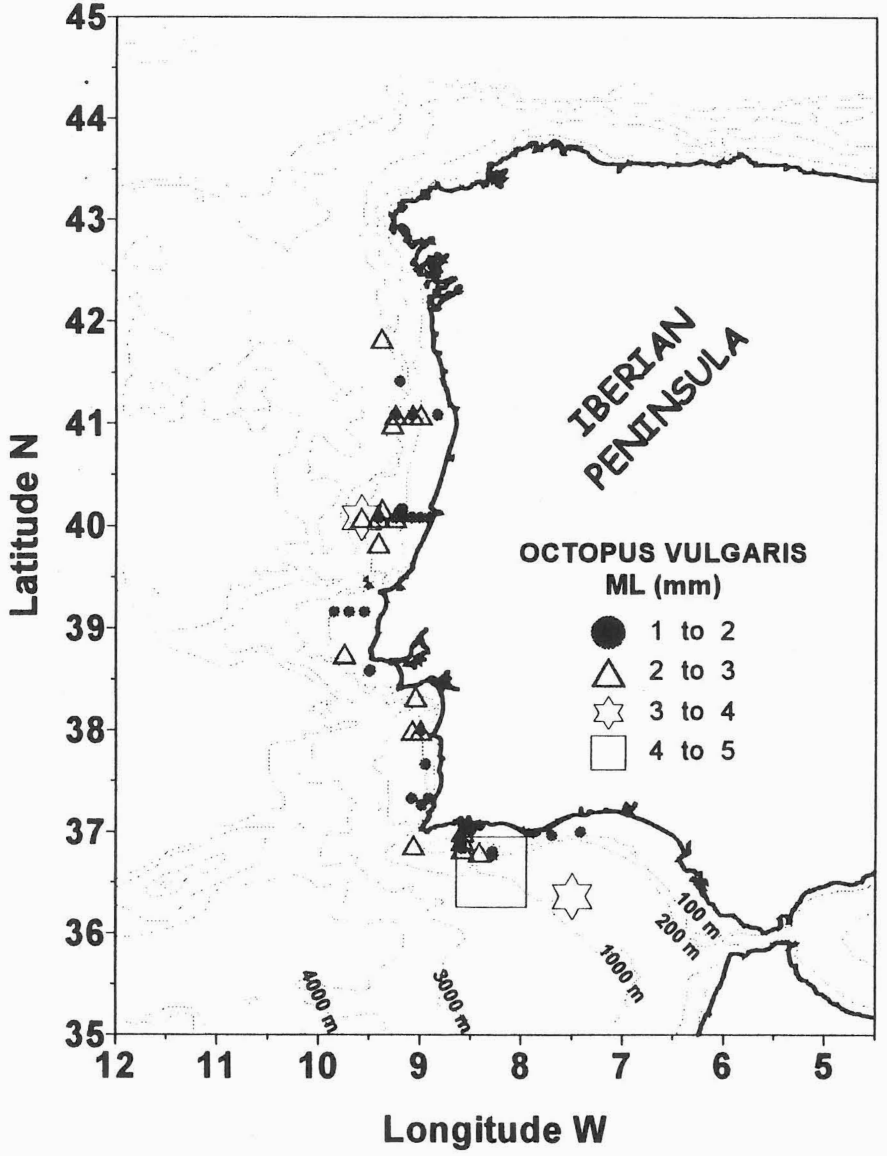

Figure 7 – Distribution of *Octopus vulgaris* paralarvae according to mantle length (ML).

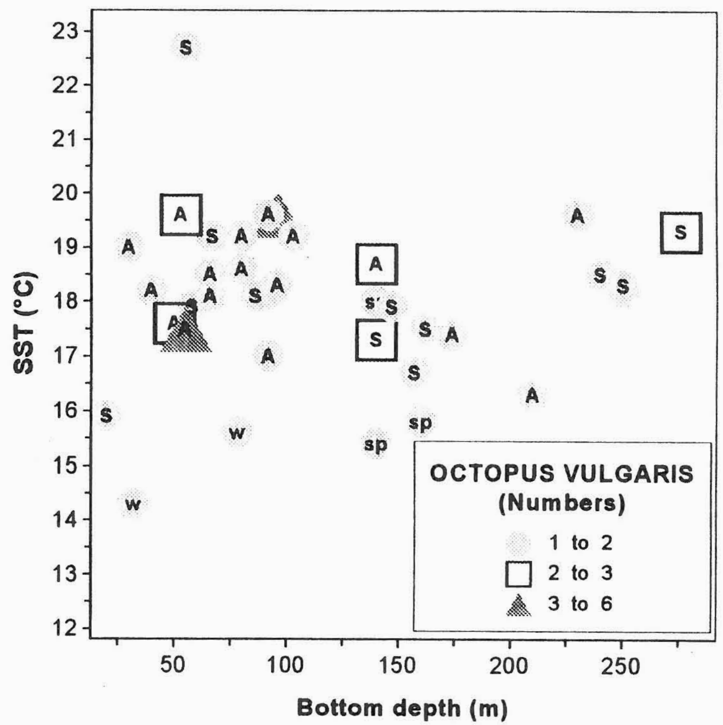

Figure 8 - Distribution of *Octopus vulgaris* paralarvae in relation to sea surface temperature and bottom depth and season (w = winter, sp = spring, S = summer, A = autumn).

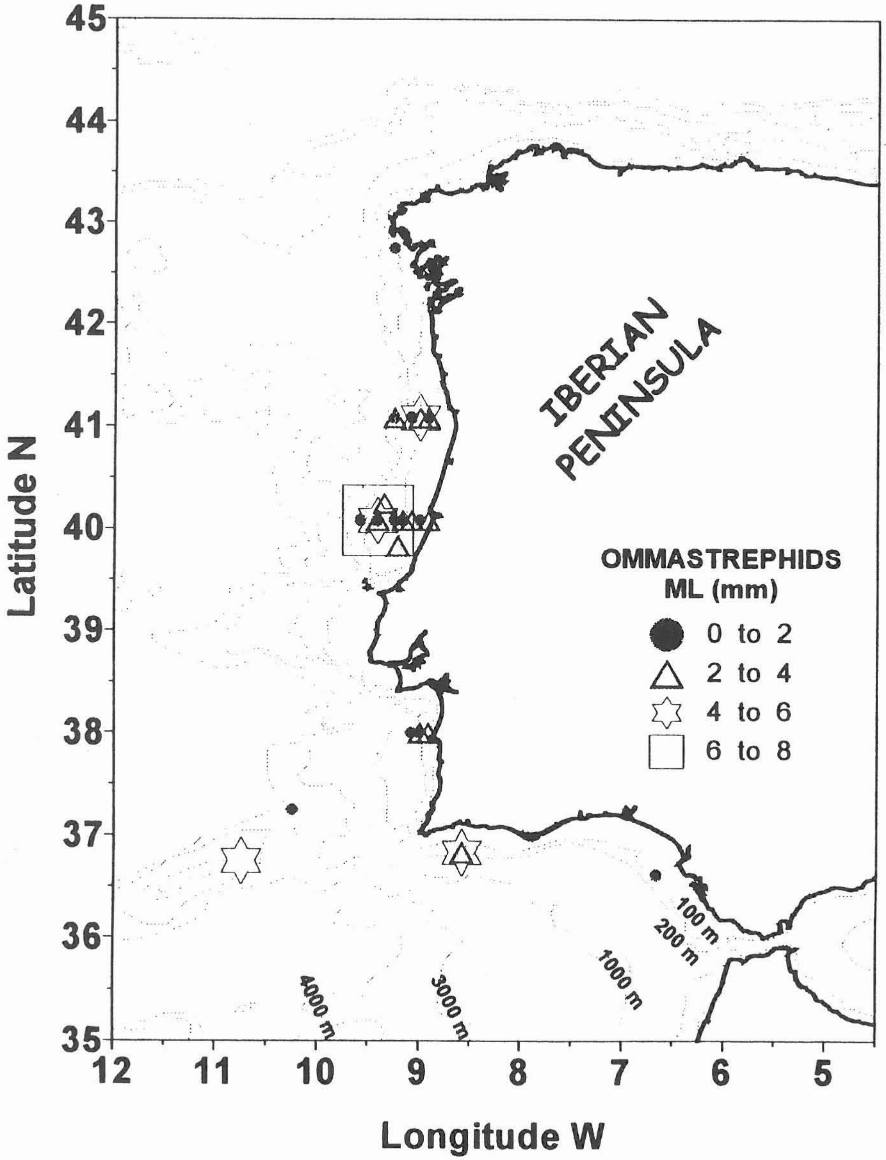

Figure 9 – Distribution of ommastrephid paralarvae according to mantle length (ML).

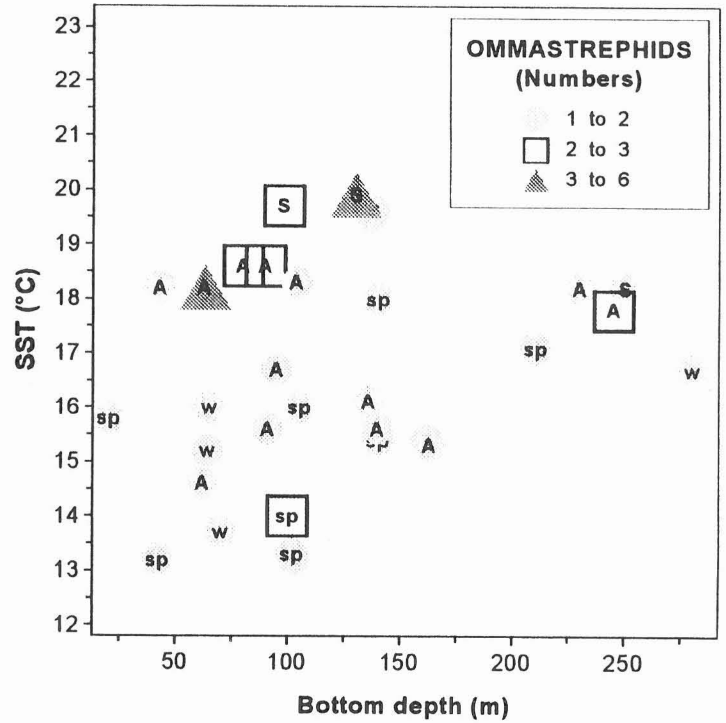

Figure 10 - Distribution of Ommastrephid paralarvae in relation to sea surface temperature and bottom depth and season (w = winter, sp = spring, S = summer, A = autumn).

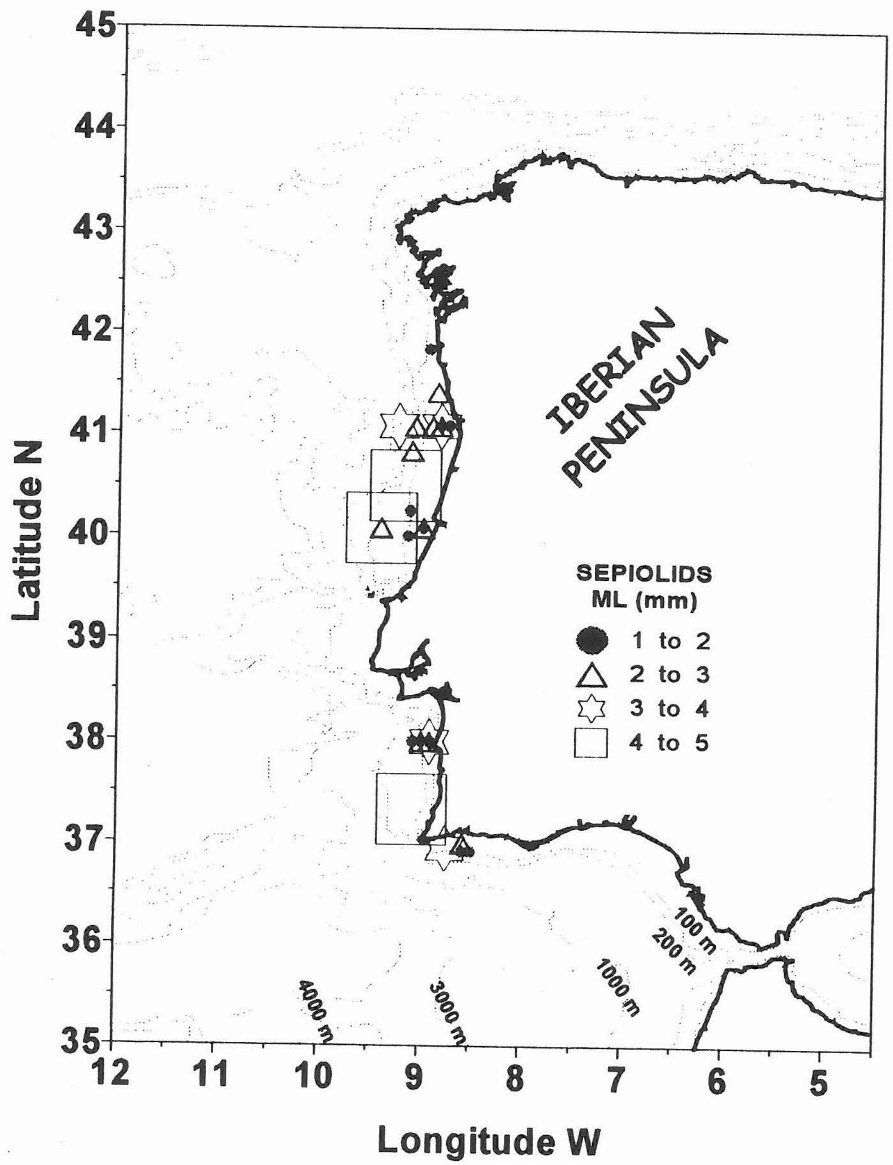

Figure 11 – Distribution of sepiolid paralarvae according to mantle length (ML).