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SPATIAL AND TEMPORAL OCCURRENCES OF *LOLIGO* SPP. IN PORTUGUESE WATERS

by

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ABSTRACT

In the last five years (1990-1994), 11 research cruises of R/V "Noruega" were undertaken along the Portuguese coast, directed primarily at obtaining distribution information on several species of groundfish, namely hake, horse mackerel and mackerel. From them it was also possible to study the distribution pattern of *Loligo* spp. (*Loligo vulgaris* and *Loligo forbesi*) as well as estimate indices of abundance for these species occurring in those waters.

Comparisons were made to show relative distribution and abundance between years, seasons, depth layers and geographical areas. The latter of these relied on the distribution of each of the two *Loligo* species themselves, to determine the extent and limits of the areas considered. Estimates of average distribution areas of spawning and recruitment were also included.

With this study a dynamic picture of the distribution and abundance of these two commercially important species may be obtained, favouring future research and laying down a reference for fishermen and policy makers alike.

INTRODUCTION

The most basic reason why man has studied the communities of his fellow Earth inhabitants is no doubt to be able to exploit some of them and thus guarantee his own future. For that reason, basic studies on species taxonomy, distribution and abundance have always been considered important, although often somewhat neglected.

Today other reasons for studying marine communities are pointed out, such as conservation in respect for the right of other species to exist in a way as little unaffected by man as possible. Yet the need for the same basic studies continues.

In Portugal, cephalopods play an important role on the fisheries economy, representing a way of life for some coastal human communities and playing a significant role in the diet of the remaining population (DGP, pers. comm.). Although loliginid squids are not the most important fraction of the cephalopod landings they reach the highest returns per kilogram (Cunha and Moreno, 1994).

The most important loliginid squids in the northeastern Atlantic are *Loligo vulgaris* Lamarck, 1798 and *Loligo forbesi* Steenstrup, 1856, with distributions ranging between 55°N and 20°S for the former and 60° to 20°N for the latter (Roper *et al.*, 1984). The Portuguese continental coast (42° to 36°N) is, in terms of location, an important area, because the distributions of both species overlap.

This study thus comes to complement knowledge on the two most valuable loliginids of the Portuguese coast, by describing their distribution at a time when research on their life histories (Moreno *et al.*, 1994) and population identity (Pierce *et al.*, 1994), both in Portugal and Western Europe is already well underway.

MATERIAL AND METHODS

The R/V "Noruega", a 47.5 m, 495 GRT, 900-1500 HP stern trawler from IPIMAR (Instituto Português de Investigação Marítima), undertook eleven research cruises between 1990 and 1994, along the Portuguese continental coast, directed primarily at obtaining distribution information on several species of groundfish, from which data on *Loligo forbesi* and *Loligo vulgaris* were selected.

Around 90 hauls per survey (Fig.1), following a stratified sampling programme, were conducted with a Norwegian Campell Trawl net, 14 m horizontal by 4 m vertical opening (Leite *et al.* 1990), fitted with a cod-end made of a polyethylene thread tied in a diamond shaped mesh of approximately 20 mm (inside measure).

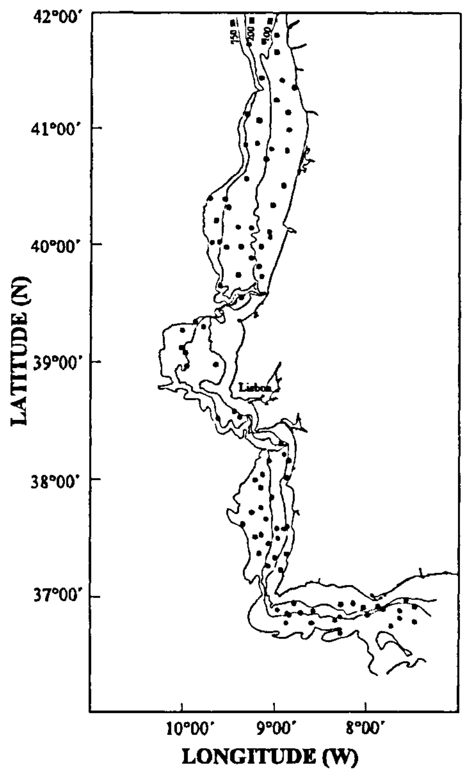

Figure 1 - Sampling stations (fixed) of the groundfish surveys.

Of the 988 total fishing hauls, 953 were considered valid. Total numbers of squid per fishing hour, in each valid haul, were assigned a geographic position (latitude and longitude) and a bottom depth (in metres), both coincident with the point of first stabilisation of the trawling net. Squid were measured to the nearest 0.5 cm, sexed and attributed a maturity stage on a scale 1-5 (Ngoile, 1987).

The areas where more than 50% of mature specimens (stages 4 and 5) and those where more than 50% of specimens less than 100 mm mantle length (ML) were caught, were mapped as "spawning areas" and "recruitment areas". For each area, two types were defined: "frequent" referring to areas where catches of mature specimens or specimens less than 100 mm ML were usually more than 50% of the total, and "less frequent" referring to areas where these catches were seldom more than 50%.

To prevent over weighing from fishing hauls with zero returns of squid, results of all stations conducted over the maximum or below the minimum depth of recorded occurrence, of either of the two species considered, were discarded. Remaining data were analysed in relation to the research hauls, grouped as in table 1.

Table 1 - Variables considered in the analyses of squid distribution data.

Year		1990, 1991, 1992, 1993 & 1994
Season		Winter, Summer & Autumn
Geographic Area (latitude N)	North	42°00′-39°31′
	Center	39°30′-37°31′
	South	< 37°31′
Depth Layer (m)	0	20-100 (minimum of 38 m for *Loligo forbesi*)
	1	100-200
	2	200-418 (for *Loligo forbesi* only)

Statistical tests consisted of Log-linear analyses (Upton, 1978; Leal, 1986) on average number of squid (number/hour) in each cell of the table (contingency table) resulting from the intersection of the four variables (times the number of levels in each) in table 1, for each of the two species considered. Whenever there were too many zeros in an analysis, 0.5 was added to each cell in the contingency table. The "parsimonious hierarchical model" was considered, examining marginal and partial associations and following a backward elimination procedure. The likelihood ratio chi-square statistic, χ^2_L and a significance level of 5% were considered when judging the model's fit.

Graphical representations of number of squid per hour (Ind./h) in each of the three depth layers described in table 1 were made per ICES statistical square for the whole Portuguese coast (Division IXa).

RESULTS

Figure 2 shows the average distribution along the continental coast of Portugal of all squid specimens of the two species (*Loligo vulgaris* and *Loligo forbesi*) obtained from the 953 valid research hauls undertaken throughout the study period.

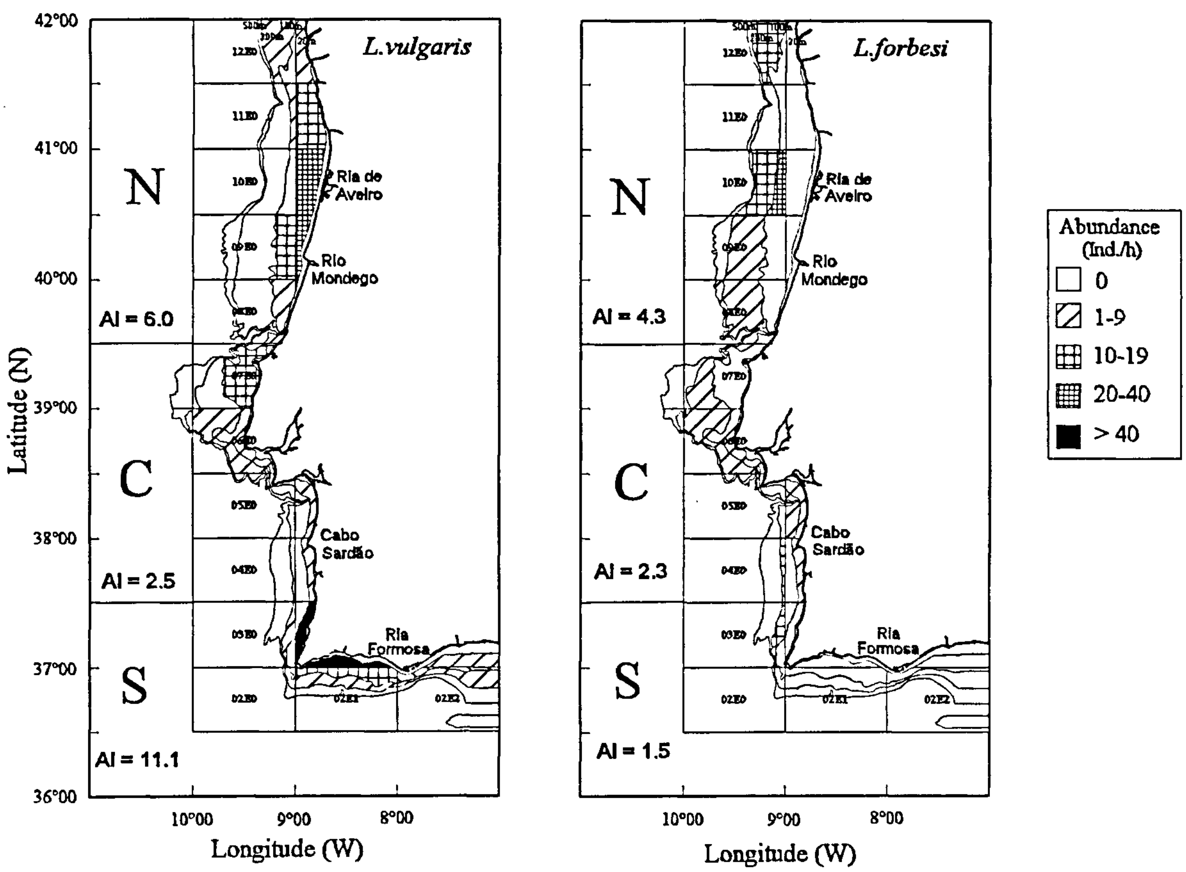

Figure 2 - Distribution and mean abundance, from 1990 to 1994, of the two squid species per depth layer, ICES statistical square and geographic area (N = North, C = Centre, S = South; AI = Abundance Index).

Although variations between and within years do exist, these average images suggest the location of the species, giving a feeling as to their preferred sites of occurrence.

L. vulgaris is caught along the Portuguese coast, predominantly, inshore of the 100 m isobath, although it extends outwards to the 200 m isobath especially in the south. Areas of greater concentration can be found between '"Ria de Aveiro" and the Mondego river mouth, in the north, and between Cape Sardão and the beginning of "Ria Formosa", in the center and south.

L. forbesi occurs less regularly than *L. vulgaris* along the west coast while it only shows up accidentally in the south coast. Its distribution is predominantly offshore of the 100 m isobath, although the highest concentration can be found just inshore of it, in the same area as for *L. vulgaris*, off the "Ria de Aveiro" (ICES Statistical square 10E0). In the center, the species can also be found inshore of the 100 m isobath.

The offshore limit of the distribution of these two loliginids, along the Portuguese coast, is the 500 m isobath, although *L. vulgaris* was never found offshore of the 200 m isobath and *L. forbesi* only seldom occurs beyond the 400 m isobath.

Figure 3 represents the number of *L. vulgaris* per hour as used in the Log-linear analyses, both for the 20-100 m and the 100-200 m depth layers.

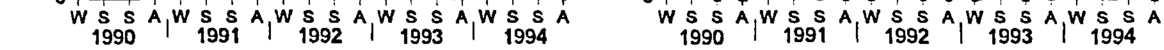

Figure 3 - Seasonal abundance of *L. vulgaris* from 1990 to 1994. Geographic and bathymetric variation.

As can be seen from figure 3, in the north area, there is an increase in abundance from summer to autumn followed by a decrease from autumn to winter. In the centre, the species also increases in abundance between summer and autumn but carries on increasing to winter. In the south, from 1990 to 1992, there was a decrease in abundance from summer to winter, but in 1993, the trend was opposite. In winter and summer *L. vulgaris* is located mainly inshore but in autumn the distribution, sometimes, extends further offshore.

These between-year differences result in hard to explain influences of the factors in analysis, which are reflected in the results of the Log-linear analysis, suggesting the "saturated model" to be the one that best explains the patterns observed (i.e. the factors in analysis are either not the best or not the only ones to explain the variation observed).

A different approach was tried, analysing the years separately with three variables in analysis (season, geographic area and depth layer), except for 1994, when only one season was sampled. Table 2 represents, for each year, the best model resulting from the analyses.

Table 2 - Results of the Log-linear analyses for the distribution and abundance of *L. vulgaris* on the Portuguese coast.

Year	Matrix: Variable(Number of Levels)	Best Model	probability
1990	Season(2)*Area(3)*Depth(2)	AS,DS,DA	0.31
1991	Season(2)*Area(3)*Depth(2)	Saturated	N/A
1992	Season(3)*Area(3)*Depth(2)	AS,D	0.59
1993	Season(3)*Area(3)*Depth(2)	AS,D	0.54
1994	Area(3)*Depth(2)	Saturated	N/A

S = Season (2 = summer and autumn; 3 = winter, summer and autumn)
A = Geographic Area (3 = North, Center, South)
D = Depth layer (2 = 20-100, 100-200 m)

Figure 4 represents the number of squid per hour as used in the Log-linear analyses for *L. forbesi*. The catches of this species, obtained throughout the study period, were generally low.

The most striking observation is that throughout the study period there was a decrease in the abundance of the species (almost disappearing since 1993), regardless of season, geographical area or depth, although other underlying variations may be seen. In the north, abundance increases from summer to autumn, decreasing to winter. In the centre and south abundance is variable except in the 100-200 m layer, where it increases from summer to autumn, decreasing to winter. In autumn and winter the range of distribution, in the west coast, extends from 38 up to 500 m.

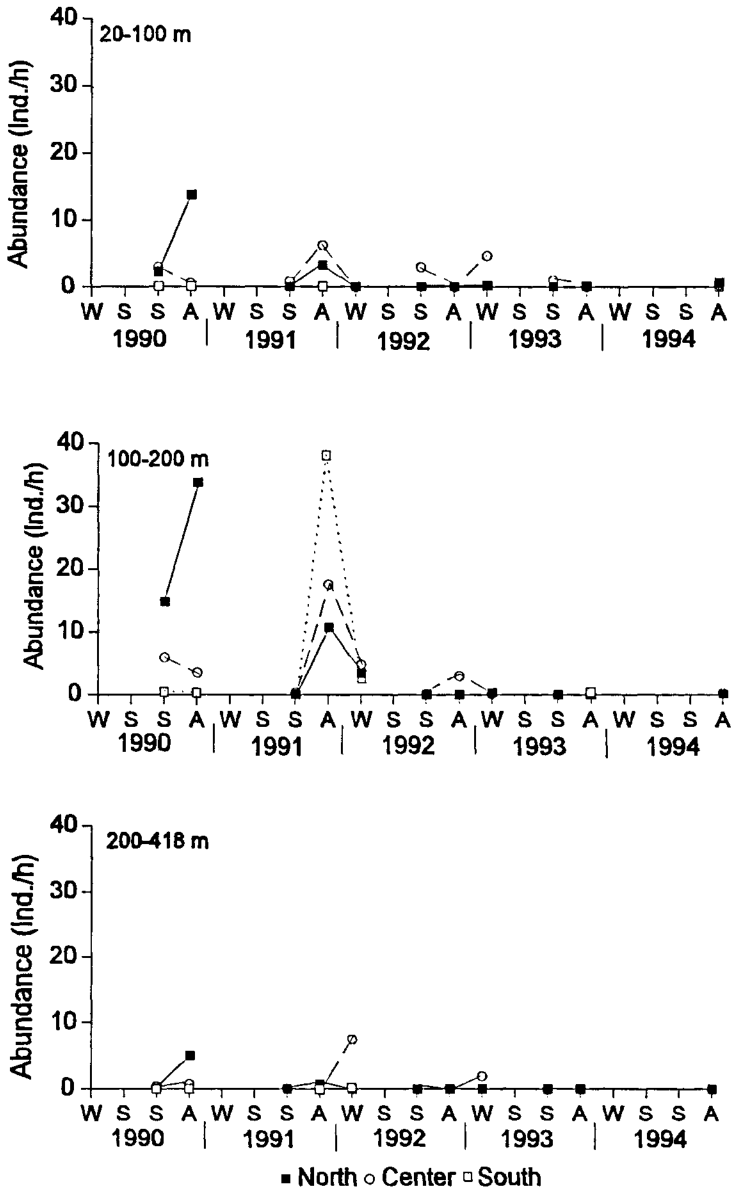

Figure 4 - Seasonal abundance of *L. forbesi* from 1990 to 1994. Geographic and bathymetric variation.

Due to the small amounts of squid caught, resulting in very low contingency table cell entries, a correction was made to the years 1992 and 1993 by adding 0.5 to every cell entry. The Log-linear analysis results are represented in table 3.

Table 3 - Results of the Log-linear analyses for the distribution and abundance of *L. forbesi* on the Portuguese coast.

Year	Matrix: Variable(Number of Levels)	Best Model	probability
1990	Season(2)*Area(3)*Depth(3)	S,A,D	0.33
1991	Season(2)*Area(3)*Depth(3)	DA,DS	0.96
1992	Season(3)*Area(3)*Depth(3)	S,A	0.71
1993	Season(3)*Area(3)*Depth(3)	A	≈ 1.00
1994	Area(3)*Depth(3)	Saturated	N/A

S = Season (2 = summer and autumn; 3 = winter, summer and autumn)
A = Geographic Area (3 = North, Center, South)
D = Depth layer (3 = 20-100, 100-200, 200-418 m)

Figure 5 shows the main distribution areas of mature specimens ("spawning areas"), for both *L. vulgaris* and *L. forbesi.*

L. vulgaris spawns throughout the year, all along the coast although there are some localized areas in the north, center and south, where spawning specimens seem to occur more often (Fig.5a). During winter and summer mature specimens were found mostly in the main spawning areas, but in autumn spawning seems to occur from north to south without preferential areas.

Mature specimens of *L. forbesi,* were found in low proportions during the sampling periods (especially in summer), the main spawning areas being located in the center (Fig.5b).

Egg masses of *Loligo* spp. were collected in the field, in grounds from 31 to 80 m (Fig. 6), from February to July, most of which within the "spawning areas" suggested for *L. vulgaris*.

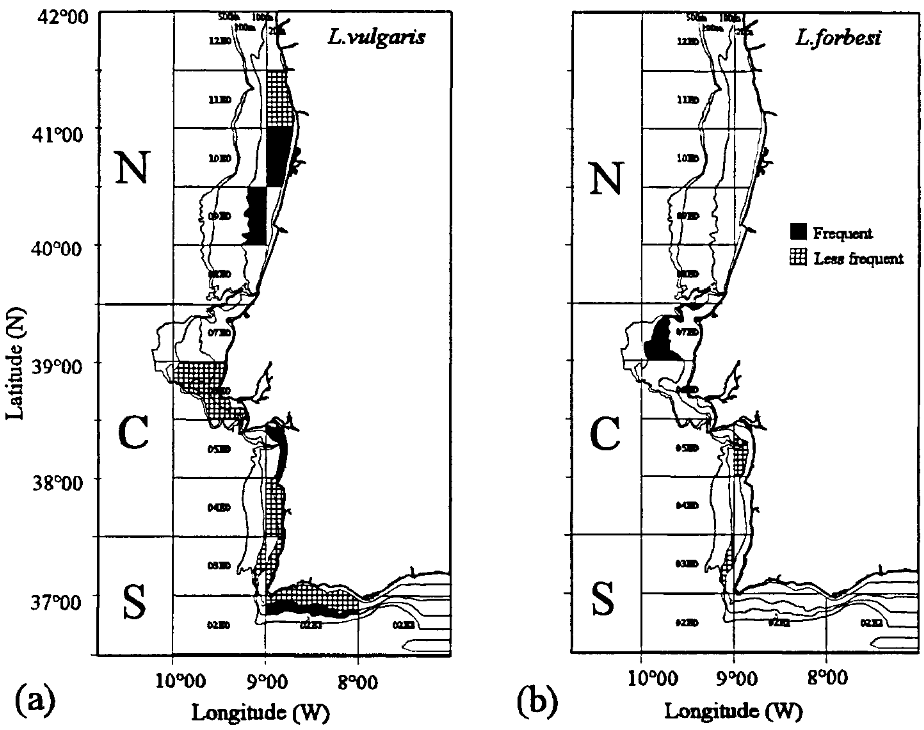

Figure 5 - Main spawning areas of *L.vulgaris* (a) and *L. forbesi* (b).

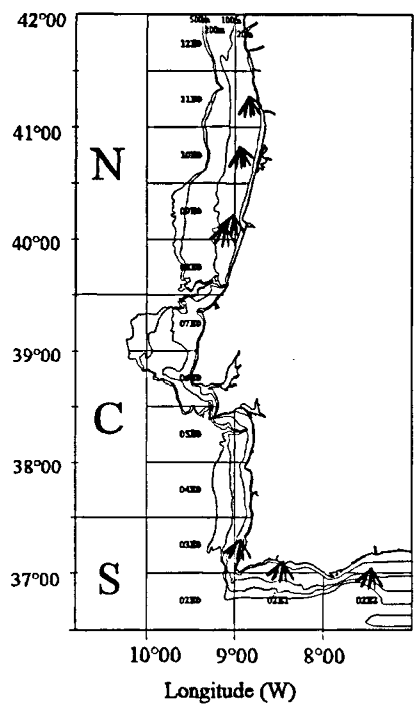

Figure 6 - Records of *Loligo* spp. egg masses.

L. vulgaris pre-recruits (<100 mm ML) occur mainly in the north and south areas, where the most important "recruitment areas" are located close inshore (Fig.6a). During summer the whole coast (mainly the 20-100 m depth layer) could be considered a "recruitment area", due to the great proportions of small specimens in the population. In autumn and winter pre-recruits were found more restricted to the main recruitment areas, although in autumn some high proportions were also observed (in particular in 1994) in the 100-200 m depth layer.

The specimens of *L. forbesi* found in the Portuguese coast were mainly juveniles. For this reason most of its distribution area can be considered a "recruitment area", although some regions, in the north and center, present higher proportions of small animals, those being the main "recruitment areas" (Fig.6b).

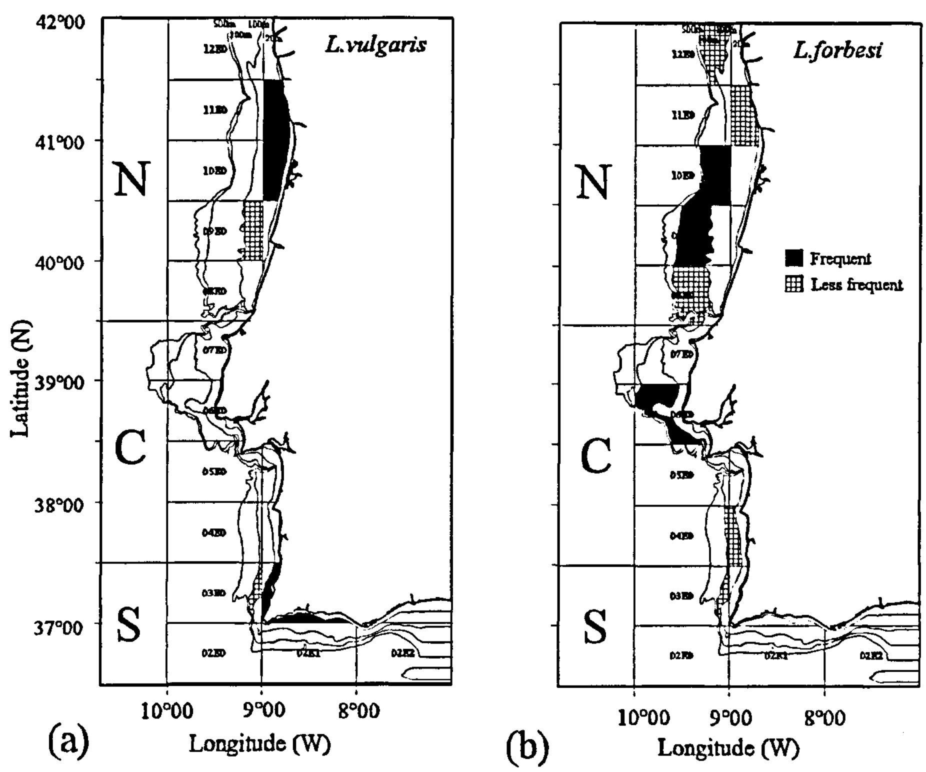

Figure 6 - Main recruitment areas of *L. vulgaris* (a) and *L. forbesi* (b).

DISCUSSION

It is never a straightforward task to interpret biological data in relation to abiotic factors, but it is particularly difficult in marine systems and especially so in relation to cephalopods. Distribution data is very variable, being conditioned, as it is, by many different factors, not all of which are always apparent. So, along with real fluctuations and trends, there are always discrete influences of specific factors, shaping the final picture in a way that effectively forbids perception from mere observation.

The average distributions and abundances shown in figure 2 are misleading in that they smooth out the areas of greater and lesser abundance producing a picture with little contrast between favoured and unfavoured areas. Nevertheless, areas with the greatest abundances are, for the same reason a guarantee of the presence of the species. Areas of intermediate abundances may hide seasonal or occasional peaks.

The case of *Loligo forbesi* is particularly striking. The species has been constantly decreasing in abundance since 1991, having reached an all time low in 1994, which results in a low average abundance. In 1990 and 1991 however, average abundance per ICES statistical square and depth layer in the autumn was greater than 60 specimens per hour in 12E0, 10E0 and 03E0 in the 200-500 m depth layer.

To test the significance of the differences between average abundances in any of the areas considered would, for the above mentioned reasons, be as misleading, if not more, than to just describe the patterns observed. Average distribution and abundance of *L. vulgaris* and *L. forbesi* were thus analysed and then Log-linear analyses applied to attempt to unveil a pattern of influences in the distributions and abundances observed, from the variables analysed.

From the Log-linear analyses, it can be concluded that the strongest influences vary from year to year, there being only two years (1992 and 1993) for *L. vulgaris* when the best model found is the same. Additionally, most best models include second order interactions meaning that the factors considered cannot by themselves justify the distributions, but they do so in combination. In three cases, the years 1991 and 1994 for *L. vulgaris* and the year 1994 for *L. forbesi*, the best model would be one with different variables from the ones analysed, i.e. the variables employed do not contribute significantly to the distribution (and abundance) observed. In 1994 this could be due to the lack of the variable season, which isn't surprising, since it is present in the majority of the remaining models, but for *L. vulgaris* in 1991, when abundance was the highest, some other factor must have had a determining influence. An attempt to analyse the data by season, rather than by year resulted in saturated best models for most seasons, an indication that the factor season, itself, is one of the most important in influencing the abundance patterns observed.

Despite the variability in abundance which seems to be mostly related to season, it is possible to conclude that *L. vulgaris* is more abundant in depths between 20 and 100 m and mainly in the south area and *L. forbesi* in depths between 100 and 200 m and mainly in the north. The general pattern of spatial distribution of this necktobenthic species is thus no doubt also influenced by the variability, intrinsic to the two factors geography and depth.

Although both species occur along the whole Portuguese coast, they seem to be associated with specific areas that Fiúza (1984) found to be hydrologically different and to which are associated characteristic faunal and floral communities (Serrão, 1989), one corresponding to the north area and another grouping center and south areas.

In terms of bathymetry, there are considerable differences in the prevailing types of bottom sediment, between the 20-100 m (mostly sandy) and the 100-200 m (mostly muddy) depth layers (Monteiro *et al.*, 1980). An analysis of the relationship between the distribution of *L. vulgaris* and the type of bottom sediment revealed that the species is associated with sandy bottoms, in particular coarse sand (Pereira *et al.*, 1995), where suitable grounds for the fixation of the egg masses exist. This association is also consistent with the location of the main spawning areas observed for both species, in particular for *L. forbesi* which is distributed mainly over muddy bottoms but with the main spawning areas in sandy grounds.

The intra-annual pattern of abundance, on the other hand, reflects their life cycle in Portuguese waters (Coelho *et al.*, 1994; Moreno *et al.*, 1994). This temporal pattern is also consistent with the distribution of commercial catches (Cunha and Moreno, 1994).

Inter-annual variations in the abundance in time and space may be related with fluctuations in the prevailing environmental conditions affecting the animals from the embryonic and paralarval stages and thus influencing recruitment success (Anon., 1994).

In general, it may be concluded that the ocurrence of these species is related to and affected by "persistent features" of the environment as well as the "average patterns" of the other features. The prevailing characteristics of the sites with the greatest concentrations of these two species, are thus an indication of the best environment for each of them, in this case ICES statistical squares 10E0 for *L. forbesi* and 03E1 for *L. vulgaris*. On the other hand, the variations in their relative abundance are probably a consequence of discrete fluctuations in the most unstable environmental characteristics, which result in seasonal and inter-annual modifications to that environment.

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