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## Maturation pattern and recruitment of the squid *Loligo vulgaris* from North West African coast

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**ABSTRACT.** *Loligo vulgaris* (Cephalopoda: Loliginidae) is a commercially important squid species of the cephalopod fishery in the Saharan Bank (21°N-26°N). This study on squid in Central Eastern Atlantic waters aims to examine some important aspects of the reproductive cycle. In the period from May 1993 to April 1994 samples of *Loligo vulgaris* were collected from this commercial trawl fishery. Sex ratio and the dorsal mantle length-body weight relationship were determined. Spawning seasons were estimated using a range of reproductive indices derived from the morphometrics of the somatic and reproductive systems. The timing of recruitment and maturation of *L. vulgaris* was described from the proportion of immature and mature animals in commercial landings (1983-1993). The analysis of data on size and maturity has provided results on size at first maturity in *L. vulgaris* from the Saharan Bank. Results are compared with information on this species in European Continental Shelf waters.

### INTRODUCTION

*Loligo vulgaris* Lamarck, 1798 is a commercially important neritic and semi-pelagic species occurring from the North Sea (55°N) to the African coast (20°S) and in the Mediterranean Sea (Roper *et al.*, 1984). Previous studies on reproductive biology of *L. vulgaris* have covered various parts of its range, including the western Mediterranean (Mangold-Wirz, 1963), Portuguese coast (Coelho *et al.*, 1994) and North West Spain (Guerra and Rocha, 1994; Rocha, 1994). No specialized fishery exists in the northeastern Atlantic where *Loligo vulgaris* is mainly a by-catch of multi-species trawling fisheries (Worms, 1983). Research on some aspects of the life cycle has been carried out on the Moroccan coast (30°N) (Baddy, 1988) but there

have been no studies of reproduction on the Saharan Bank (21°N -26°N) except general fishery studies (Cort and Pérez-Gándaras, 1973).

This loliginid species is one of the most important in the landings of the Spanish cephalopods freezing-trawler fleet operating between Cape Bojador (26°N) and Cape Blanc (21°N). *Loligo vulgaris* contributed 2605 t in 1992 and 4329 t in 1993 (10% of the total cephalopod catches).

The present study on *Loligo vulgaris* aims to examine some important aspects of reproductive biology and recruitment. These results are compared with those obtained in European Continental self waters.

## MATERIAL AND METHODS

Frozen samples of *Loligo vulgaris* were taken from the Spanish commercial trawl fishery in the Saharan Bank, from June 1993 to January 1994. Some data were also collected in survey cruises (R/V Charif al Idrissi) carried out in May 1993 and April 1994.

Specimens were sexed and dissected in the laboratory, recording dorsal mantle length (DML) to the nearest millimetre, the wet body weight (BW) to the nearest 0.1 g and, for maturing and mature individuals, gonad weight (GW). For males, spermatophoric complex weight (SCW) and penis length (PL) were recorded. Spermatophoric complex includes the spermatophoric organ, spermatophoric sac and penis. For females, primary and accessory nidamental gland weight (NGW1 and NGW2 respectively) were also recorded. The maturity stages of males and females were assessed using a maturity scale of five stages (Lipinski, 1979).

For the study of the sex ratio, the percentages of males and females were calculated for the period considered, and separately for each DML class. Spawning period was established both by calculating the percentages of mature females (stage IV and V) in different periods of the year, and using several reproductive indices throughout the sampled period (table I).

<p><b>FEMALES</b></p> <ul style="list-style-type: none"><li>- Gonado-Somatic Index (GSI) = <math>GW \times 100/BW - GW</math></li><li>- Nidamental gland-Somatic Ratio (NSR) = <math>NGW1 \times 100/ BW - (GW+NGW1+NGW2)</math></li><li>- Reproductive-Somatic Ratio (RSR) = <math>(GW+NGW1+NGW2) \times 100/BW-(GW+NGW1+NGW2)</math></li></ul> <p><b>MALES</b></p> <ul style="list-style-type: none"><li>- Gonado-Somatic Index (GSI) = <math>GW \times 100/BW - GW</math></li><li>- Spermatophoric-Somatic Ratio (SSR) = <math>SCW \times 100/BW - (GW+SCW)</math></li><li>- Penis length/DML Ratio (PL/DML) = <math>PL/DML</math></li></ul>
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**Table I.** Reproductive indices used in assessing maturation in *Loligo vulgaris*.

Size at maturity was established separately for males and for females by calculating the percentages of mature animals in each DML class. The mean size at which 50% of the individuals are mature was estimated graphically.

In the commercial fishery, squid are sorted into categories depending on their size. Squid landed each month can be assumed to have been caught within the previous two months. Fishery data on squid landings by commercial category from 1983 have been employed to identify the yearly periods of recruitment and to confirm the spawning season previously established on the basis of laboratory sampling data. Each commercial size category (from CA00 to CA5, see table II) is associated with a specific length range (table II). The percentage of matures and immatures in those length classes was calculated for the sampling period from May 1993 to April 1994. Arbitrarily, the commercial length categories with more than 60% of mature animals were considered as representing the 'spawners' (CA00, CA0, CA1) and commercial categories with more than 60% of immatures were assumed to represent the 'recruits' (CA5 with DML < 11 cm, see table II). Assuming a stable population structure, recruits can also be defined as those animals below the previously calculated modal body size (Pierce *et al.*, 1994). In *Loligo vulgaris* from Saharan Bank this modal size was 11-12 cm DML.

A monthly recruitment index was calculated for the 1983-1993 period considering the catch per unit effort (tons x 100/fishing days) of individuals with less than 11 cm DML (commercial category CA5).

Category	DML range (cm)	% IMMATURE	% MATURING	% MATURE	TOTAL %
CA5	<11	84.8	14.8	0.4	100
CA4	11-15.9	38.1	57.0	4.9	100
CA3	16-20.9	1.3	69.9	28.8	100
CA2	21-25.9	0.0	46.0	54.0	100
CA1	26-30.9	0.0	21.1	78.9	100
CA0	31-40.9	0.0	6.5	93.5	100
CA00	>41	0.0	0.0	100.0	100
TOTAL NUMBER					1217

Table II. Percentages of immature, maturing and mature individuals in each commercial category of *Loligo vulgaris* in Saharan Bank.

## RESULTS

Of the 1281 squid of known sex collected between May 1993 and April 1994, 621 were males and 660 were females (overall sex-ratio close to 1:1). However, the monthly sex ratios varied through the year and females were more abundant from September 1993 to December 1993 while males dominated in January 1994. Males dominated the size range from DML 17.5

cm to 23.5 cm and females were consistently more numerous in the 24 cm to 34 cm DML range (figure 1). Squids larger than 34 cm were males (except 1 female).

Overall weight-length relationships for males and females for the period May 1993 to April 1994 are given below:

$$\begin{array}{llll} \text{BW} = 0.12794 \times \text{DML}^{2.458} & r=0.99 & n=618 & \text{for males} \\ \text{BW} = 0.10715 \times \text{DML}^{2.554} & r=0.99 & n=659 & \text{for females} \end{array}$$

The relative weight/length constant (the exponent, *b*) is lower in males than in females. The proportion of mature specimens (males and females) in monthly samples is shown in figure 2. Mature males are predominant in November-January and mature females in January-April. Average reproductive indices for each period are presented in figure 3 and figure 4 (males and females respectively). In both males and females, there was a gradual increase in the values of the reproductive indices from September to January. Thereafter, in females, there was a pronounced peak of these values in January. Some mature animals were present throughout the year.

Two male size modes at maturity were observed: about 17 cm DML and about approximately 26 cm DML (figure 5). However this phenomenon was not found in females in which 50% mature was reached about approximately 23 cm DML (figure 6).

The size of squid in commercial categories CA00, CA0 and CA1 was higher than the previously established size at maturity for both males and females and these categories also consisted of more than 75% mature individuals (table II). Figure 7 shows the monthly percentages of the 'spawners' (CA00, CA0 and CA1) in the landings from 1983 to 1993. This figure suggests the presence of one main spawning season in winter-early spring (November-March) since 1985, and that period includes the two periods with maximum percentages of mature males and females previously obtained.

Figure 8 also shows the monthly percentages of 'recruits' (CA5) in the landings for the same period. There was one main peak during summer (June-September) and a second one during winter (December-February) in most of the years considered. Some recruitment apparently occurred throughout the year. There was a marked difference in the pattern of recruitment between two periods (1983-1987 and 1988-1993). In the second period, 1988-1993, the summer peak of recruitment was much more prominent. In order to confirm the main recruitment period during summer, figure 9 presents recruitment indices in summer and winter from 1983 to 1993. This figure shows a recruitment index higher during summer than during winter since about 1988. This index during summer also increases from this year until 1993.

## DISCUSSION

The sex ratio corresponds to an overall ratio of 1:1. However males tended to be more abundant in samples containing small animals (6.5-8.5 cm DML) and specimens from 17.5 cm to 23.5 cm DML (figure 1), corresponding to the two male groups of size at maturity. Females are more abundant from around 24 cm DML, with around 26 cm being the size of maturity estimated in females.

The results on the spawning season (mainly in January-April) of *Loligo vulgaris* obtained in the present study in the Saharan Bank (21°N-26°N) are broadly consistent with the winter (December-March) peak of hatching reported by Arkhipkin (1995), although Arkhipkin also found a summer peak of hatching. Cort and Pérez-Gándaras (1973) observed evidence of two spawning peaks (March-April and December-January) in the Saharan Bank. Baddy (1988) recorded spawning throughout the year on the Moroccan coast (30°N). Mangold-Wirz (1963) found this species spawned throughout the year, but more intensively from January to October (with two peaks in March-April and June-July) in the western Mediterranean. In Galician waters the main spawning season of this species extends from December to April (Rocha, 1994). A spawning peak was found during autumn-winter by Moreno *et al.* (1994) in Central and Northern Portuguese coast and during November-March in South Portugal (Coelho *et al.*, 1994). There is evidence of annual migrations in the Loliginidae (Boyle *et al.*, 1995) and it is possible that migratory movements of mature animals between different fishing areas explain the different 'spawning seasons' in different areas.

A main recruitment season in summer was also found in *Loligo vulgaris* from Spain and Portugal (Guerra and Rocha, 1994; Coelho *et al.*, *op. cit.*; Moreno *et al.*, *op. cit.*) and in *Loligo forbesi* in Scottish waters (Pierce *et al.*, 1994) and Irish waters (Collins *et al.*, 1994).

The size at maturity in males in Saharan Bank shows similar evidence of two components in the population to that found on the Portuguese coast and in Galician waters. The same first peak in size at maturity (17-18 cm DML) was also found in these waters and a second peak about 30 cm (with 100% matures) and 33 cm respectively was found in Portuguese waters and the NW Spanish coast (Moreno *et al.*, *op. cit.*; Coelho *et al.*, *op. cit.*; Guerra and Rocha, *op. cit.*). A very similar pattern was described in *Loligo forbesi* off the West coast of Scotland by Boyle *et al.*, *op. cit.*). They suggested that this phenomenon derives either from two different growth cohorts at breeding, the mixing of two populations or stocks from different sources and with different size characteristics, perhaps migratory and non-migratory, and with different growth characteristics.

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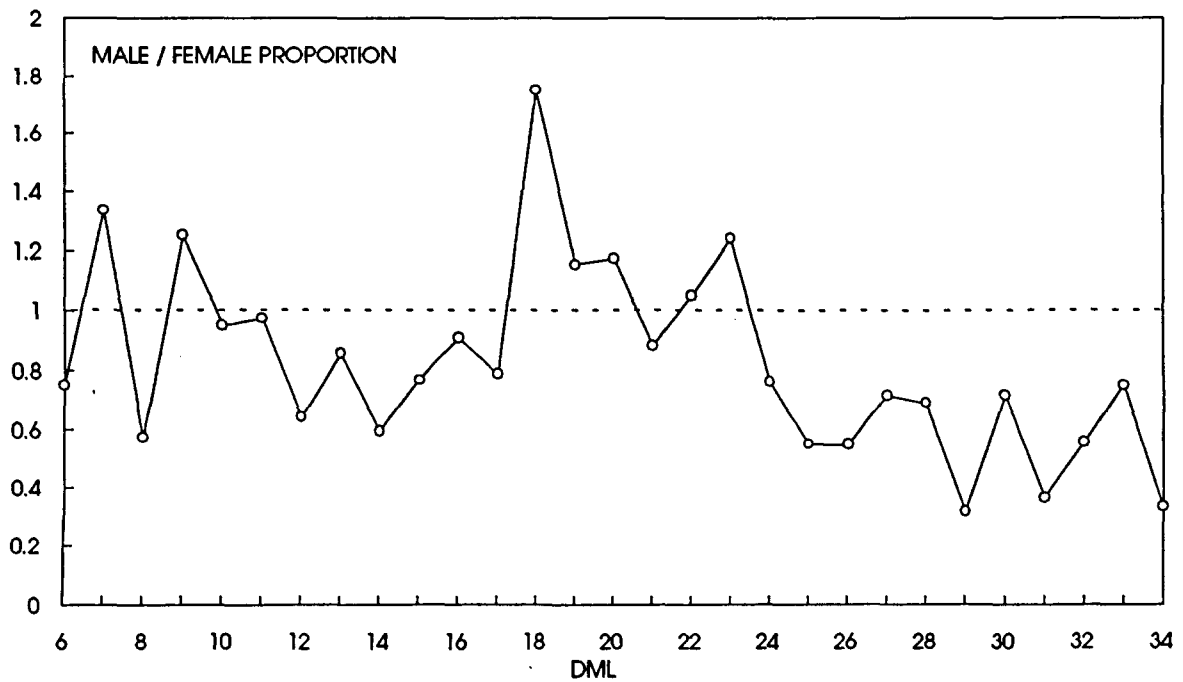


Figure 1. Sex ratio (number of males/number of females) in each 1 cm DML class.

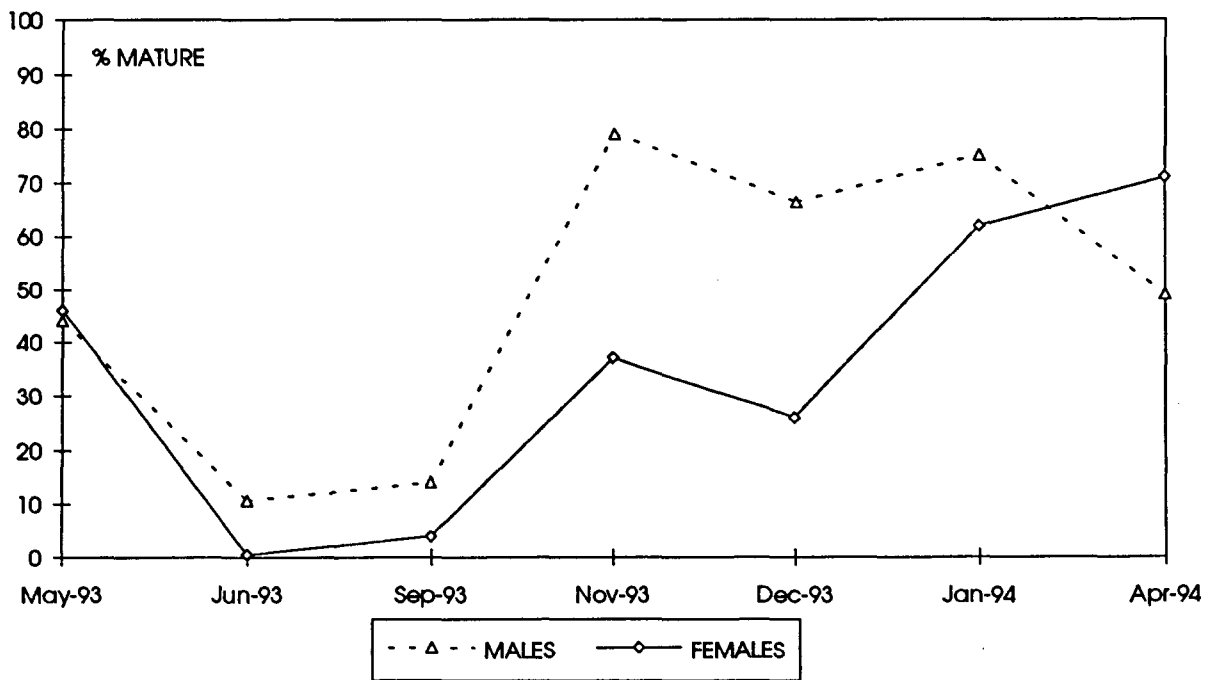
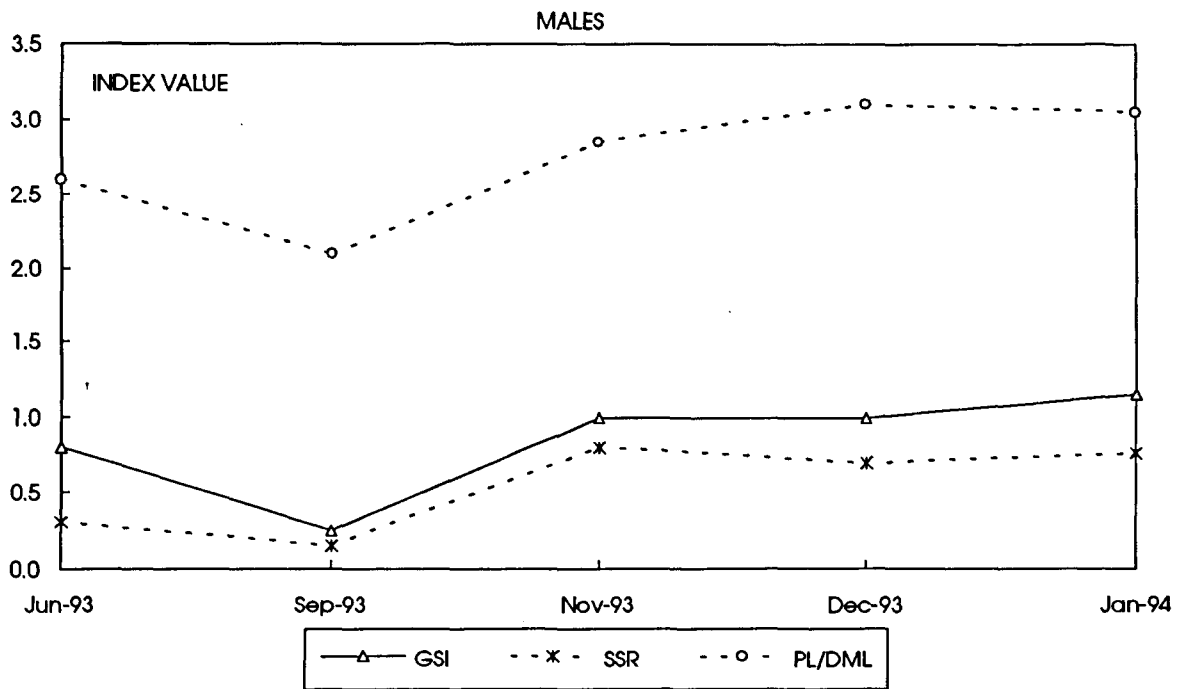
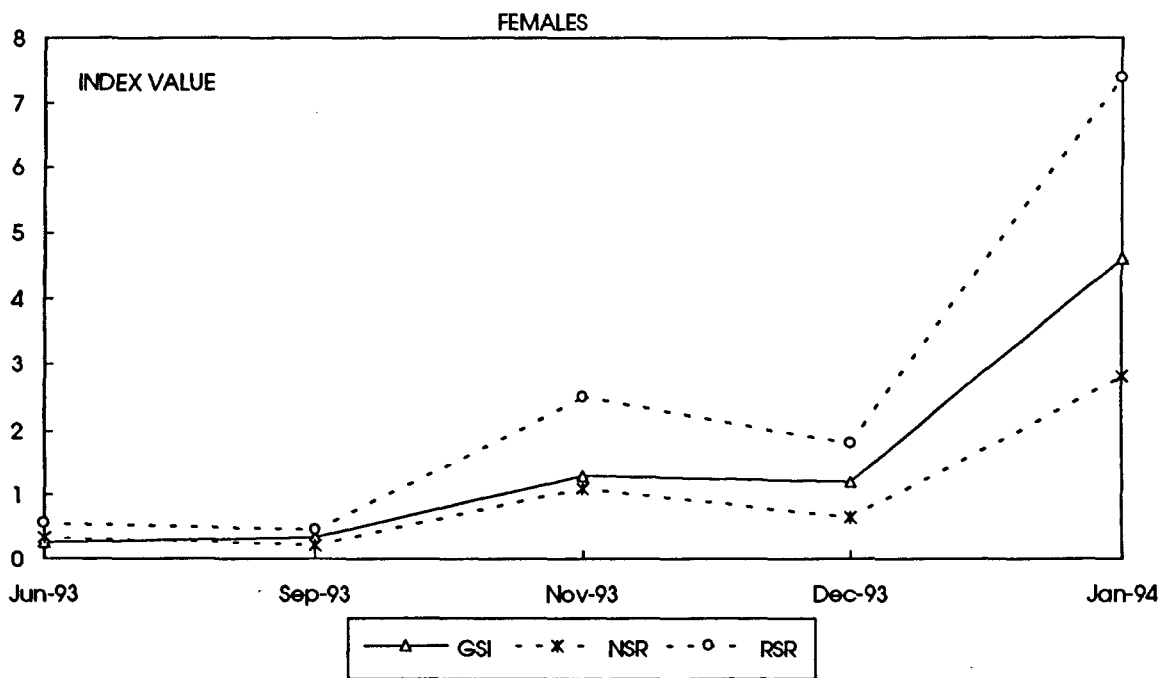


Figure 2. Monthly percentage of mature male and female (stages IV and V) *Loligo vulgaris*.

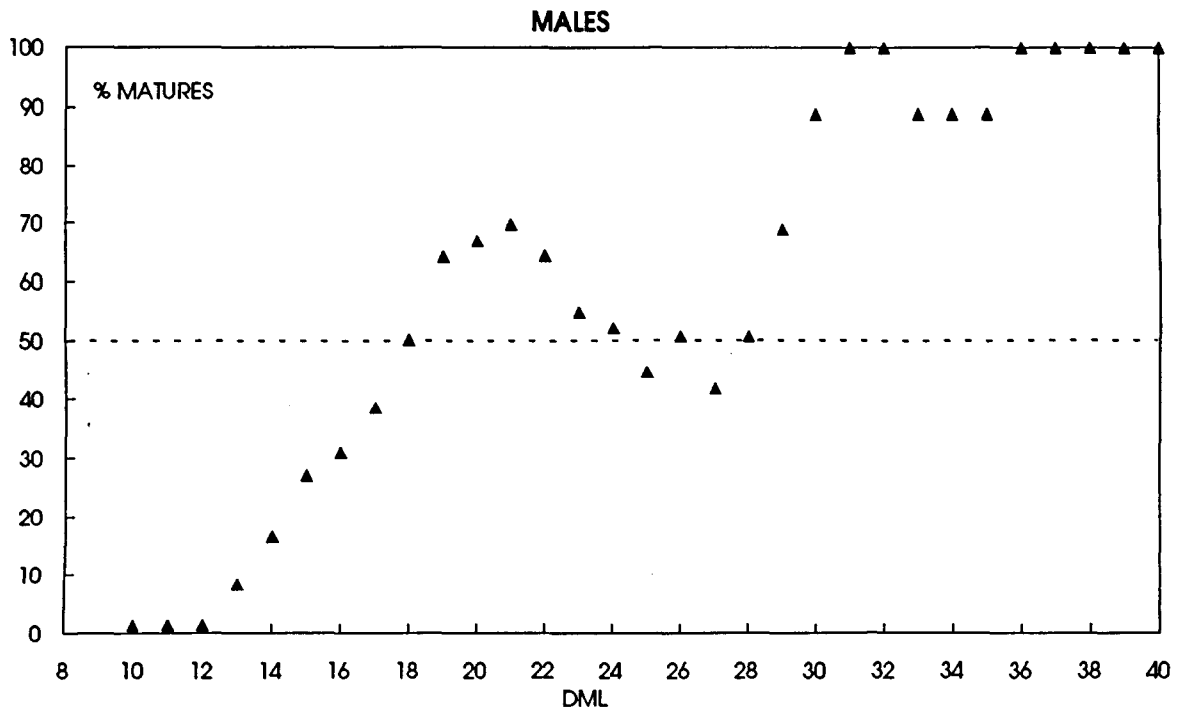


**Figure 3.** Seasonal reproductive indices variation in male *Loligo vulgaris*.

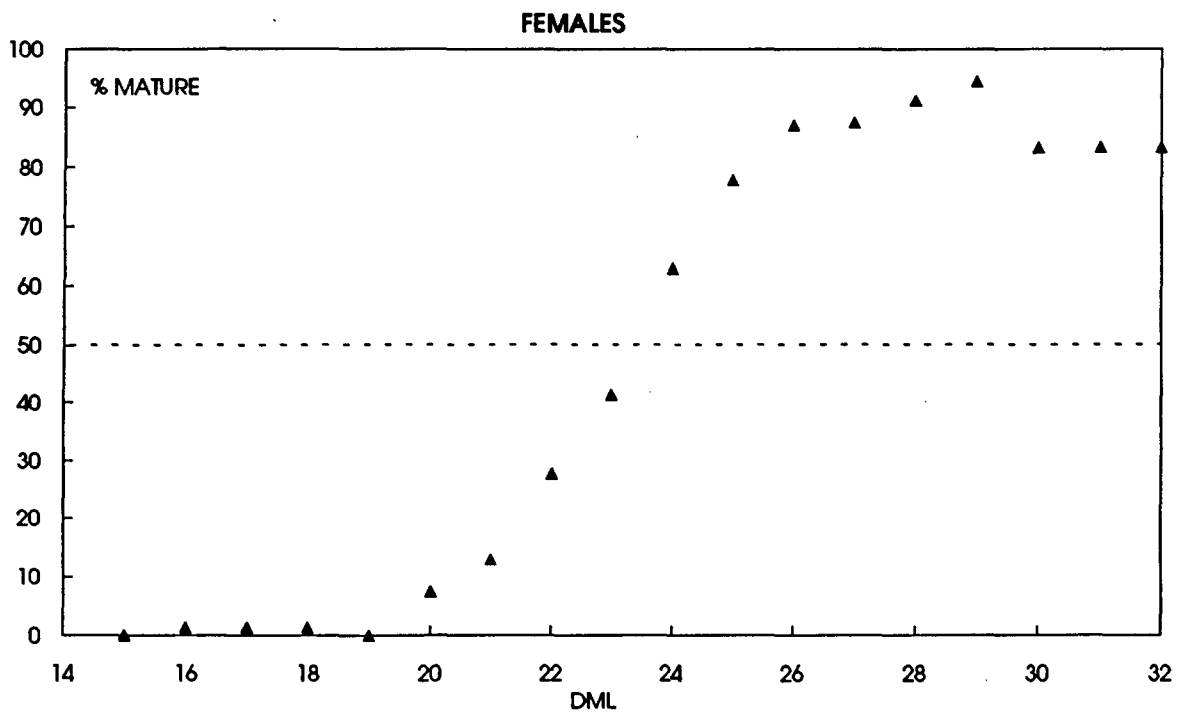


**Figure 4.** Seasonal reproductive indices variation in females *Loligo vulgaris*.





**Figure 5.** Moving averages of the percentages of mature male *Loligo vulgaris* in each 1 cm DML class.



**Figure 6.** Moving averages of the percentages of mature female *Loligo vulgaris* in each 1 cm DML class.

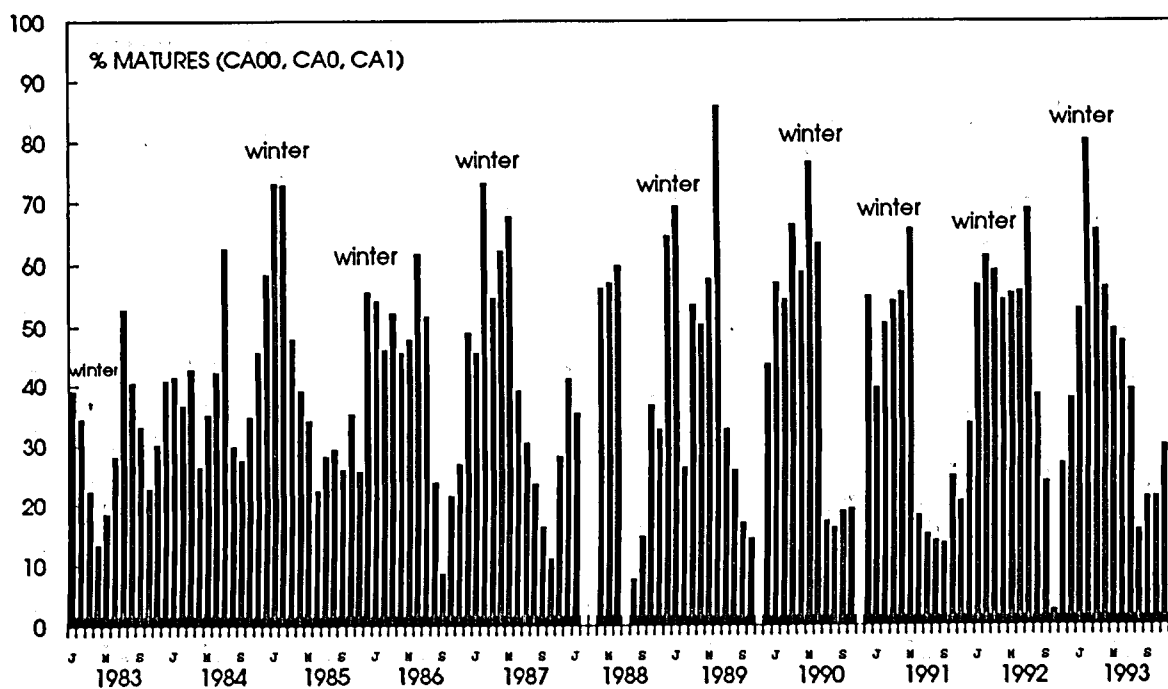


Figure 7. Monthly percentages of 'spawners' (commercial categories CA00, CA0, CA1) in the Spanish landings of *Loligo vulgaris* in Saharan Bank from 1983 to 1993.

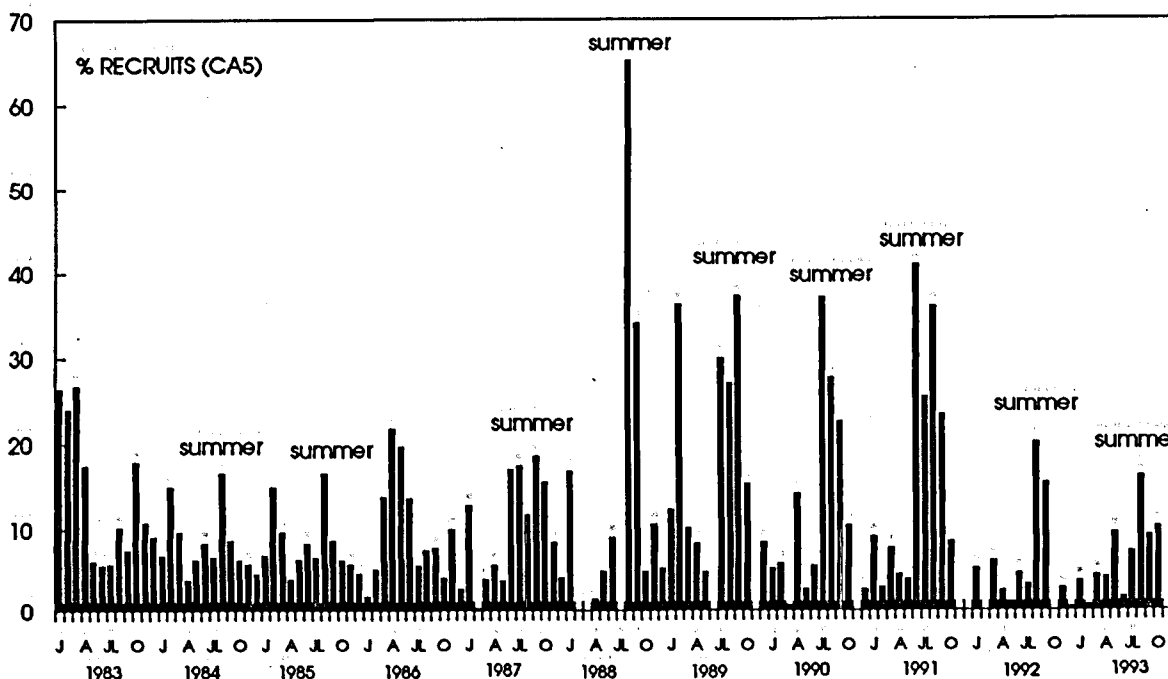
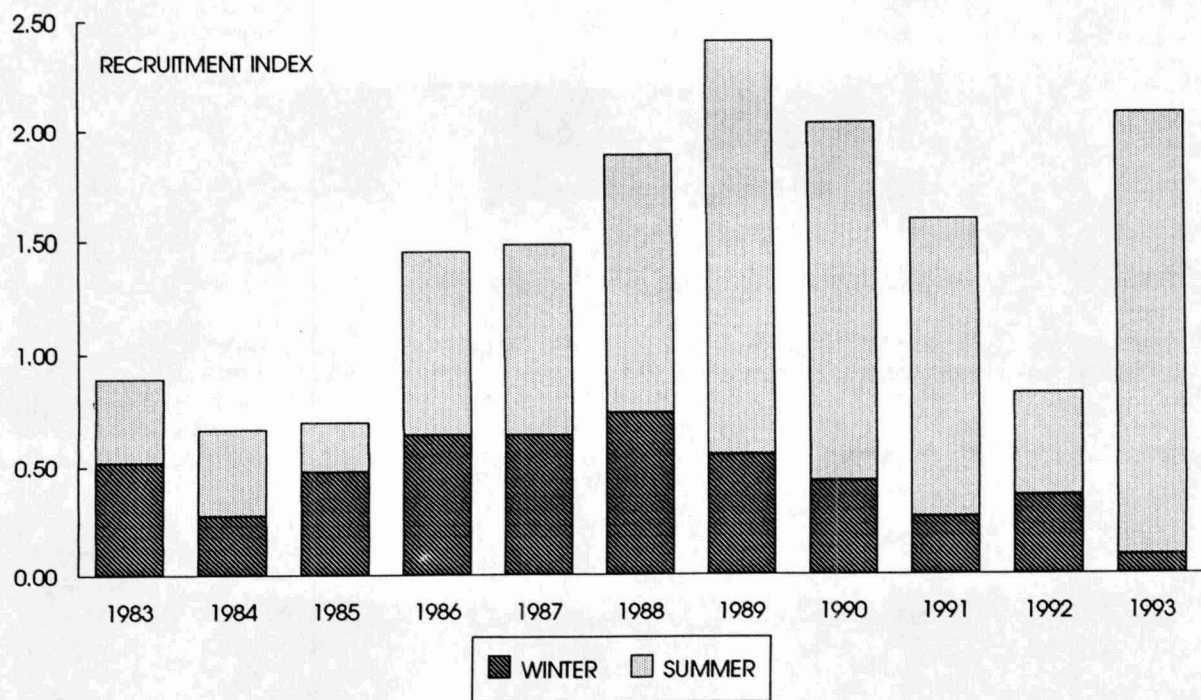


Figure 8. Monthly percentages of 'recruits' (commercial category CA5) in the Spanish landings of *Loligo vulgaris* in Saharan Bank from 1983 to 1993.



**Figure 9.** Mean recruitment indices CPUE (tons x 100/fishing days) in winter and summer of individuals with less than 11 cm DML (commercial category CA5) during 1983-1993.