SCI. MAR., 57(2-3): 153-159 SCIENTIA MARINA 1993

NORTHWESTERN MEDITERRANEAN FISHERIES. *J. LLEONART (ed.)*.

Population dynamics of the exploited cephalopod species of the Catalan Sea (NW Mediterranean)*

PILAR SÁNCHEZ and PALOMA MARTÍN

Institut de Ciències del Mar, CSIC, Passeig Nacional s/n, 08039 Barcelona, Spain.

SUMMARY: Cephalopods, 2572 tonnes landed during 1990, are an important fishing resource on the Catalan Coast (NW Mediterranean). The main exploited species are octopuses, *Eledone cirrhosa* and *Octopus vulgaris*, 70 % of the total cephalopod catch; cuttlefish *Sepia officinalis*, 10 % of the total; squid *Loligo vulgaris*, 7 %; and shortfin squid *Illex coindetii*, 3 %. Monthly catches (1981-1990) of these species show a marked seasonality, linked to their reproductive behaviour and short life span. Most commercial cephalopods are fished at depths down to 200 m. Hourly yields are related to the characteristic bathymetric distribution of each species. The *O. vulgaris* and *E. cirrhosa* size distributions are shown to be significantly associated with depth. The progression of the *I. coindetii* and *E. cirrhosa* size distributions during the year was analysed. In both species, recruitment lasts for several months and larger individuals disappear gradually from the population.

Key words: Cephalopods, fishing, abundance, northwestern Mediterranean.

RESUMEN: DINÁMICA DE POBLACIONES DE CEFALÓPODOS EXPLOTADAS EN EL MAR CATALÁN (MEDITERRÁNEO NO) . — Los cefalópodos, 2572 toneladas desembarcadas durante 1990, son un importante recurso pesquero en la costa catalana (NO Mediterráneo). Las principales especies explotadas son el pulpo, *Eledone cirrhosa* y *Octopus vulgaris*, que representó el 70 % de la captura total de cefalópodos; la sepia *Sepia officinalis*, 10 % del total; el calamar *Loligo vulgaris*, 7 % de la captura; y pota *Illex coindetii* con un 3 %. La evolución de las capturas mensuales (1981-1990) de todas ellas presenta una marcada estacionalidad, que se relaciona con el comportamiento reproductivo y el ciclo de vida corto. La mayor parte de los cefalópodos comerciales se capturan hasta 200 m. Los rendimientos horarios dependen de la distribución batimétrica característica de cada especie. Las distribuciones de talla de *O. vulgaris* y *E. cirrhosa* están significativamente asociadas con la profundidad. Se analizó la progresión de las tallas de *I. coindetii* y *E. cirrhosa* durante el año, observándose que, en ambas especies, el reclutamiento dura varios meses, y que los individuos más grandes desaparecen gradualmente de la población.

Palabras clave: Cefalópodos, pesca, abundancia, Mediterráneo noroccidental.

INTRODUCTION

Over the last decade, the total annual landings of all species off the Catalan coast have ranged between 50000 and 65000 tonnes. The fishing fleet has varied little over this period. The trawling fleet, responsible for most of the cephalopod catches, is made up of 438 vessels (mean gross tonnage 43.9 tonnes and mean horsepower 300 hp); the artisanal fleet consists of 1445 vessels (mean gross tonnage 5.0 tonnes and mean horsepower 40 hp), and the purse seining, 202 vessels (mean gross tonnage 26.4 tonnes and mean horse power 250 hp). Catches consist mostly of fish (about 90 % of total landings), crustacea amount to 2-3 % and molluscs represent from 6 % to 9 %. Cephalopods constitute most of the mollusc catches, bivalves and gastropod catches being rather low (MARTÍN, 1991).

* Received July 8, 1992. Accepted November 20, 1992.

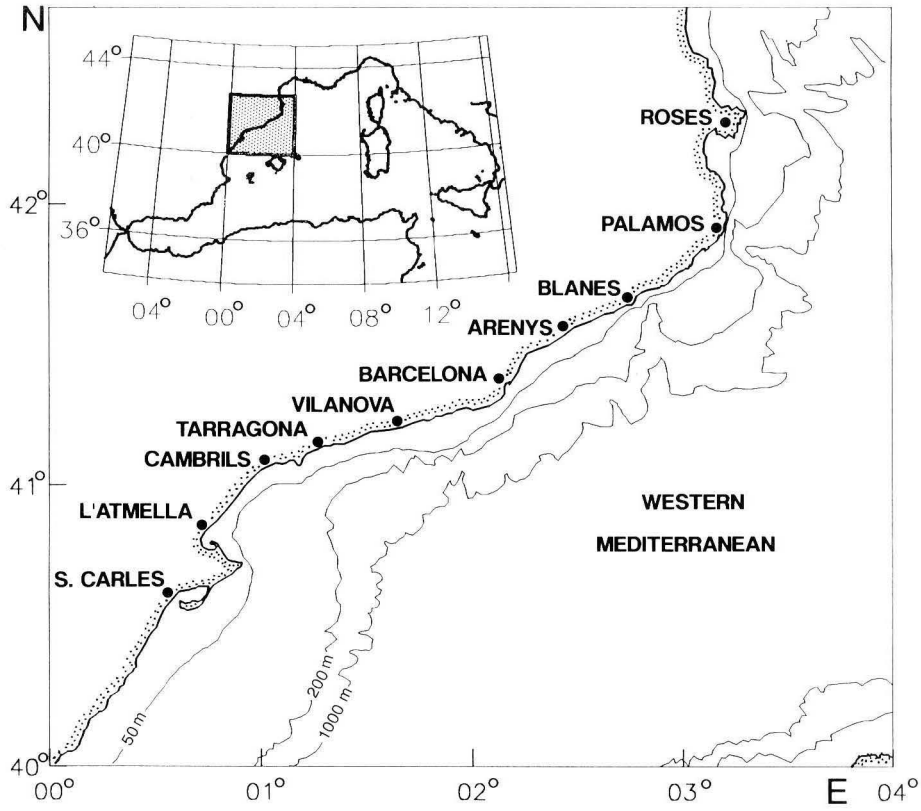

FIG. 1. — Study zone showing the main fishing ports of the Catalan coast which reported the monthly cephalopod catches of the commercial fleet.

MANGOLD and BOLETZKY (1988) mentioned fifty nine cephalopod species in the Mediterranean; forty six of them have been collected off the Catalan coast (SÁNCHEZ, in press). Cephalopod catches of the commercial fleet consist mainly of octopus, *Eledone cirrhosa* (Lamarck, 1798) and *Octopus vulgaris* Cuvier, 1797. Other abundant cephalopods along the Catalan coast are the cuttlefish *Sepia officinalis* Linnaeus, 1758, and, to a lesser extent, *Sepia orbignyana* Ferussac, 1826, *Sepia elegans* Blainville, 1827; the squid *Loligo vulgaris* Lamarck, 1798; and the shortfin squid *Illex coindetii* (Verany, 1839).

The biology and fishing of the main cephalopod species exploited in the western Mediterranean have been studied by various authors (MANGOLD-WIRZ, 1963; Boletzky, 1983; BOYLE, 1983; MANGOLD, 1983; MORIYASU, 1983, 1988; PALUMBO and WURTZ, 1983-84; WORMS, 1983; RELINI and ORSI-RELINI, 1984; SÁNCHEZ, 1984, 1986a, 1986b; BOYLE *et al.*, 1988; WURTZ, *et al.*, 1992).

Cephalopod catches along the Catalan coast and distribution of the resources, as well as the relationship between yield and biological characteristics of the main exploited species, are discussed.

MATERIAL AND METHODS

The study was carried out along the Catalan coast (NW Mediterranean; Fig. 1). Monthly catch statistics, by species, from ten fishing ports, from 1981 to 1990, have been used. The landings registered at these ten ports represent 85 % of the total production of the fishing fleet operating in the area.

In addition, a total of 448 hauls were performed (185 between June 1981 and May 1983; and 263 in 1991) on board commercial trawlers with the nets usually employed by the fishermen of the area. The mesh size of the cod-end was 36-38 mm. Some tows (158 in the first period and 24 in the second) were made with the cod-end covered by a 8-9 mm mesh size covering bag in order to collect the smaller individuals. Location, depth and duration of each haul were recorded as well as the number of individuals and the total weight by species. Hourly yield (no.*h^{-1} and kg*h^{-1}) according to depth was estimated for the more important commercial species. Specimens of *Illex coindetii* and *Eledone cirrhosa* were weighed (total body weight in g) and measured (mantle length (ML) to the nearest 5 mm). The mean length per haul

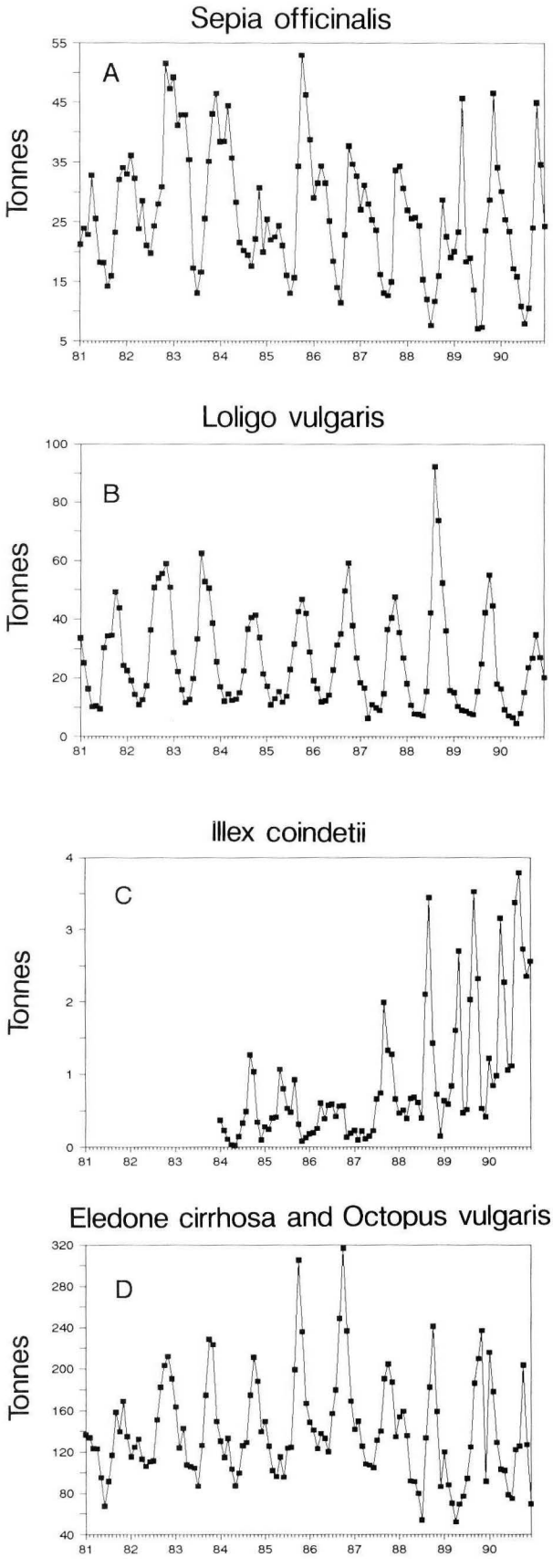

FIG. 2. — Monthly catches (1981-1990) of the main exploited cephalopods in Catalonia: A, *Sepia officinalis*; B, *Loligo vulgaris*; C, *Illex coindetii*; D, *Eledone cirrhosa* and *Octopus vulgaris*.

was calculated from the weight and number of specimens and from the mantle length (ML)-weight ratio (expressed as: ML = a*Weight^b). The ML-weight ratios proposed by SÁNCHEZ (1986b) were used for *Sepia officinalis* and *Loligo vulgaris*; that proposed by SÁNCHEZ (1981) was used for *I. coindetii*; that by SÁNCHEZ and OBARTI (1993) for *Octopus vulgaris*; and that for *E. cirrhosa* was estimated. Data from the 1981-1983 and 1991 samplings are presented jointly. The correlation coefficient of the linear regression haul mean mantle length vs depth was estimated to test the significance of depth on the length distribution pattern.

For the study of the seasonal length distribution, material collected during 1989 (445 specimen of *I. coindetii*) and 1991 (766 specimen of *E. cirrhosa*) was used. Mean mantle lengths were estimated; corresponding minimum and maximum sizes are also given.

RESULTS

Catches

In 1990, 2572 tonnes of cephalopods were landed in Catalonia (GENERALITAT DE CATALUNYA, 1991). Octopuses (*Eledone cirrhosa* and *Octopus vulgaris*) made up more than 70 % of the total cephalopod catch, and cuttlefish (mainly *Sepia officinalis*) around 10 %. Two other species with significant amounts were the squid *Loligo vulgaris* (7 %) and the shortfin squid *Illex coindetii* (3 %). The fishing port of Sant Carles, located in the southern zone of the study area, obtained the highest catches of cephalopods (450 tonnes annually), followed by the fishing ports of Cambrils and Roses (around 260 tonnes annually) (Fig. 1).

Cephalopod catches showed marked seasonality. The monthly catches of cuttlefish *S. officinalis* ranged between 10-50 tonnes, and catches were lowest between June and August (Fig. 2a).

The squid *L. vulgaris* was more abundant in summer and autumn than in winter and spring. Highest monthly catches were about 60 tonnes (exceptionally 90 tonnes, in July 1988), and the lowest 10 tonnes (Fig. 2b).

Since 1987 an increase in the catches of the shortfin squid *I. coindetii* has been observed (Fig. 2c). The highest monthly catches (3.5 tonnes) were attained in September-October and April-May, with two minima, one in late autumn-early winter and the other in summer.

Highest monthly octopus catches (*E. cirrhosa* plus

TABLE 1.— Abundance by depth stratum (n = number of hauls where the species appeared; occ. = percentage of the species occurrence in the total hauls performed at each depth stratum; no.*h^{-1} = number of individuals per hour; kg*h^{-1} = kg per hour; avg = average; std = standard deviation.)

depth (m)	n	occ.	no.*h^{-1} avg	std	kg*h^{-1} avg	std
Sepia officinalis						
0-25	12	27.3	7.3	8.8	1.3	1.6
25-50	23	22.1	8.0	8.6	1.5	2.2
50-100	12	7.1	3.7	2.4	0.8	0.7
100-200	3	2.0	5.4	3.2	0.06	0.06
Loligo vulgaris						
0-25	13	29.5	36.5	54.7	0.6	0.7
25-50	35	33.7	62.1	100.9	1.3	2.2
50-100	44	26.2	109.7	251.9	0.7	0.9
100-200	25	16.7	15.0	25.2	0.2	0.2
200-400	1	1.0	1.3		0.01	
Illex coindetii						
50-100	24	14.3	3.8	5.4	0.2	0.4
100-200	54	36.0	14.3	26.8	0.5	0.7
200-400	8	7.4	4.6	4.1	0.3	0.4
Octopus vulgaris						
0-25	13	29.5	6.5	8.4	3.5	4.7
25-50	28	26.9	17.2	33.2	9.0	15.0
50-100	31	18.5	5.3	9.0	2.1	4.0
100-200	11	7.3	1.9	3.0	0.5	0.9
Eledone cirrhosa						
25-50	26	25.0	21.4	41.0	0.9	1.1
50-100	26	15.5	36.5	38.6	3.2	5.0
100-200	99	66.0	27.1	29.2	2.5	4.6
200-400	39	41.5	5.8	7.1	1.2	1.5
>400	10	13.9	4.6	8.6	0.8	1.3

O. vulgaris), close to 220 tonnes, were obtained in autumn (from September to November). The smallest catches corresponded to late spring (May and June). In autumn 1985 and 1986 exceptional catches, higher than 300 tonnes, were landed.

Abundance by depth stratum

Most of commercial cephalopods are fished at depths down to 200 m, although a few species can be found below 400 m (Table 1).

The cuttlefish *Sepia officinalis* showed the most restricted distribution among the commercially exploited cephalopods along the Catalan Coast. It was found preferentially in shallow waters down to 50 m (occasionally at 130 m). Highest yields, both in number and weight, were obtained in the depth strata 0-25 m and 25-50 m.

The squid *Loligo vulgaris* has a wider bathymetric distribution than that of the cuttlefish, occasionally reaching 220 m. Maximum abundance (no.*h^{-1}) was obtained at 50-100 m depth, while maximum hourly yield (kg*h^{-1}) was obtained at 25-50 m depth.

The shortfin squid *Illex coindetii* appeared at depths ranging from 49 to 252 m. This species is most abundant, both in number and in weight, at 100-200 m.

The octopus, *Octopus vulgaris* was found preferentially between 0 and 50 m. Greatest yield is reached, both in number and weight, at 25-50 m depth. The species occurs between 11 and 176 m.

The octopus, *Eledone cirrhosa*, showed the widest bathymetric distribution among the species considered in this study. It was caught at depths ranging from 28 to 549 m, being most abundant, in number, between 25 and 200 m, and in weight, at depths between 50 and 200 m.

Length distribution by depth

The *Octopus vulgaris* and *Eledone cirrhosa* size distributions are significantly associated with depth (*O. vulgaris*: $r = 0.312$, $p < 0.01$, 81 degrees of freedom; *E. cirrhosa*: $r = 0.360$, $p < 0.01$, 274 degrees of freedom), unlike those corresponding to *Sepia officinalis*, *Loligo vulgaris* and *Illex coindetii* (*S. officinalis*: $r = 0.229$, $p < 0.05$, 48 degrees of freedom; *L. vulgaris:* $r = 0.062$, $p < 0.5$, 116 degrees of freedom; *I. coindetii:* $r = 0.065$, $p < 0.05$, 83 degrees of freedom).

The larger specimens of *O. vulgaris* (haul mean mantle length > 180 mm) occurred mainly down to 50 m, while medium and small sized reached depths of 176 m. Small and medium sized individuals of *E. cirrhosa* were found down to 300 m depth, while large specimens covered the complete distribution range, from shallow waters to depths of 549 m (Fig. 3).

Seasonal length distribution

A similar progression of the seasonal mean sizes was observed in both sexes of *Illex coindetii*. Small individuals (ML < 40-50 mm) appeared from spring to autumn. Seasonal mean mantle length fluctuated between 102 mm ML in summer and 147 mm ML in autumn in females, while in males, the seasonal mean size was very similar throughout the year (around 100 mm ML). Larger females appeared in spring (250 mm ML); while larger males were observed in winter and spring (170 mm ML). Apparently the disappearance of the largest individuals from the population begins in summer (Fig. 4).

Smaller individuals of *Eledone cirrhosa*, both females and males, appeared during winter and spring (ML < 20 mm). Mean mantle length during the year

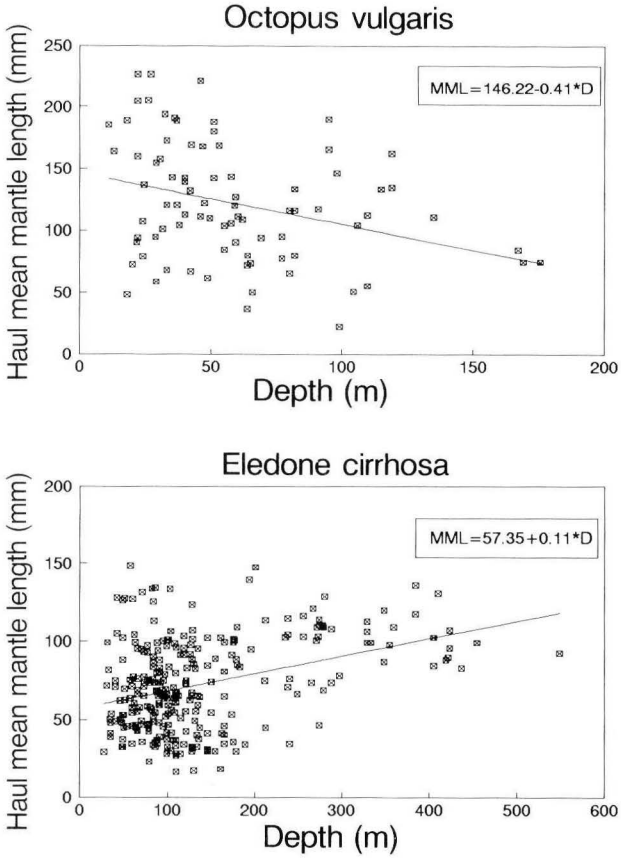

FIG. 3. — *Octopus vulgaris* and *Eledone cirrhosa*. Relationship between haul mean mantle length (mm) and depth (m), estimated from catches of commercial trawlers obtained during 1981-1983 and 1991 (MML= mean mantle length; D= depth).

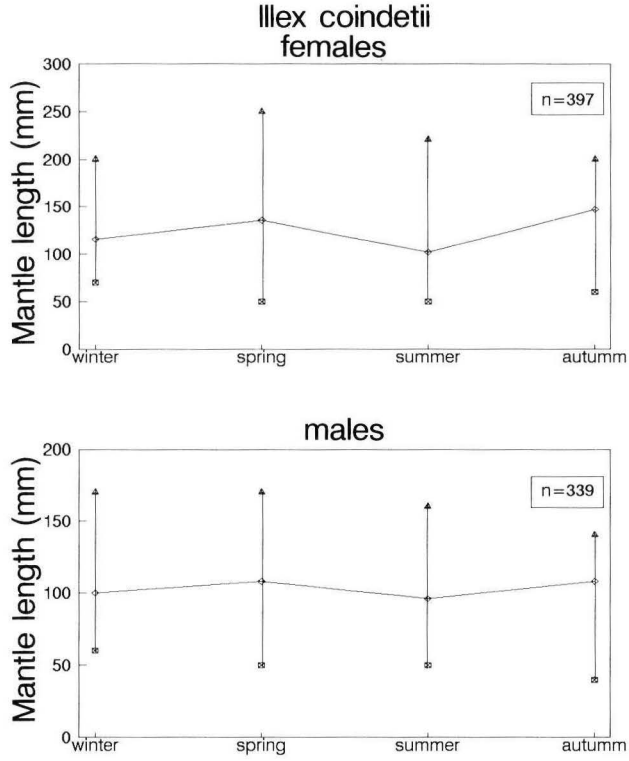

FIG. 4. — *Illex coindetii*. Progression of seasonal mean mantle length, with maximum and minimum mantle length, in mm.

was similar in both sexes, maximum differences in mean sizes were observed in spring (47 mm ML in females and 46 mm ML in males) and autumn (73 mm ML and 76 mm ML respectively). Both sexes showed a similar seasonal size distribution pattern. The mean size increased gradually, from spring to autumn. A slight decrease in mean size was observed from winter to spring. Maximum sizes in both sexes appeared in winter (150 mm ML), thereafter decreasing gradually until autumn in females (100 mm ML), while larger males were observed in this season (120 mm ML) (Fig. 5).

DISCUSSION

Data used to estimate species abundance came from daytime catches of commercial bottom trawlers. In some cases, depending on the characteristics of the species, the estimates of abundance may be underestimated. Thus, *Illex coindetii* associated with the bot-

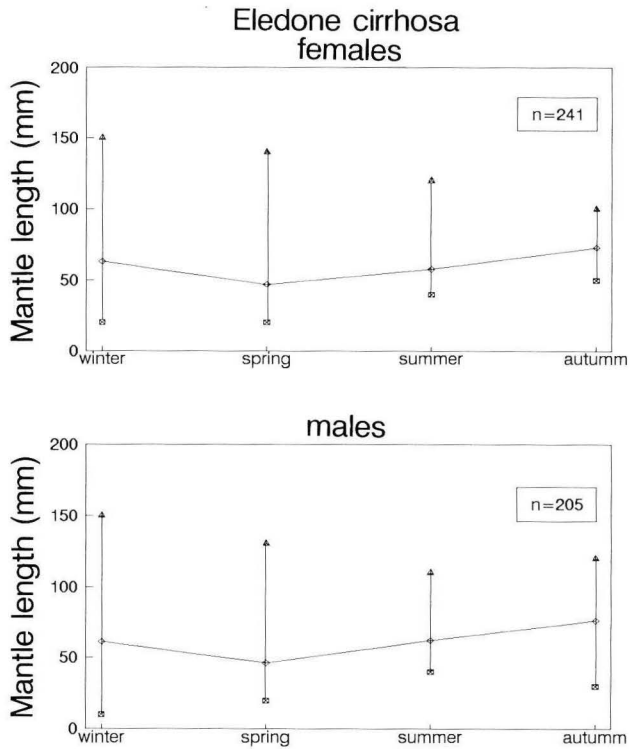

FIG. 5. — *Eledone cirrhosa*. Progression of seasonal mean mantle length, with maximum and minimum mantle length, in mm.

tom during the day, would be sampled adequately, as *Eledone cirrhosa*, a benthic species inhabiting a depth range sampled by the trawlers. On the other hand, *Sepia officinalis*, another benthic species, lives in shallow waters (less than 25 m depth), where the trawling fleet seldom operates, as does *Octopus vulgaris*, which lives on rocky bottoms inaccessible to trawlers. The estimate of *Loligo vulgaris* abundance would be also underestimated because this species is pelagic.

Cephalopod catches obtained by the trawling and artisanal fleets throughout the year, show a marked seasonality, like other resources, with different characteristics, in the Mediterranean fishery (MARTÍN, 1991; MARTÍN and SABATÉS, 1991). In cephalopods, the seasonality is related to their short life span, rapid population turnover and reproductive behaviour.

Cuttlefish *S. officinalis* are fished with trammel nets, traps, and by trawling. The artisanal fleet follows the spawning migration towards the shallower water. Spawning in this species lasts from January to September (MANGOLD-WIRZ, 1963). During summer, minimum catches coincide with the disappearance from shallow water of larger specimens that have already spawned. Moreover, females enter rocky or coralline areas to lay their eggs and so are inaccessible to trawlers.

The squid *L. vulgaris* is a pelagic migratory species, although in the Mediterranean, the migrations are less pronounced than in the Atlantic (TINBERGEN and VERWEY, 1945). Lowest catches are taken in winter and spring, coinciding with the spawning period. Egg strings are attached to fixed supports (isolated rocks, etc.) at depths of 20 to 80 m, making it difficult for trawlers to catch mature specimens (MANGOLD-WIRZ, 1963). In autumn, medium sized squid are caught at 25-100 m as they migrate towards the coast.

I. coindetii, a mesopelagic species, has a long spawning season (from April to November), which is more intense from May to June, and from September to November (SÁNCHEZ, 1984), giving rise to the long recruitment period observed during the year. The spawning location is unknown, though it does not occur inshore since the larger individuals, after a short stay in coastal waters, migrate offshore (200 to 400 m depth). The largest annual catches coincide with the beginning of sexual maturity, and are previous to the spawning migration to deeper waters.

Catches of *O. vulgaris* and *E. cirrhosa* are recorded in the fishing statistics as "octopus". The spawning seasons of both species coincide and last from February to July (MORIYASU, 1988; SÁNCHEZ and OBARTI, 1993). Although they live at different depths, their spawning behaviour is similar, as they both look for sheltered sites to lay and brood their eggs, making them less vulnerable to trawling. Highest octopus catches are obtained in summer and autumn, when gonadal maturity is not observed.

The seasonal mean sizes of *I. coindetii* and *E. cirrhosa*, despite the population growth, show slight variations during the year, being affected by the incorporation of the small individuals and the disappareance of the larger ones by death after spawning. These two factors represent a quick turnover of the population.

There is an incorporation of small sized *I. coindetii* from spring to autumn, that is more intense in summer, as evidenced by the observed decrease in the mean length, both in females and males, although large individuals are present. Because embryonic development is relatively short and hatching occurs within 10 to 14 days after spawning at 15°C (BOLETZKY *et al.*, 1973), these small individuals recruited in summer must come from the spring spawning.

In *E. cirrhosa*, the small recruited individuals during winter and spring, come from a long spawning period that lasts for 5 to 6 months, beginning in March and ending in August (MORIYASU, 1988). Considering that females may proceed with spawning for 10 to 15 days, exceptionally for 3 to 4 weeks, and that the brooding period is very long (100 days at 16 °C in the laboratory; MANGOLD *et al.*, 1971), assuming 120 days between spawning and hatching at sea, as these authors do, the first newly hatched individuals would appear in July-August. These individuals would be 5-6 months old when they recruit into the fishery in winter.

ACKNOWLEDGEMENTS

The study was partially financed by the Generalitat de Catalunya, Research Project Contract Ref. PCC 300 12/90, carried out by the Mediterranean Population Dynamics Group of the I.C.M. We acknowledge the anonymous reviewers for their helpful comments.

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