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Distribution and Biology of the Blackmouth Catshark *Galeus melastomus* in the Alboran Sea (Southwestern Mediterranean)

Javier Rey and L. Gil de Sola
I.E.O., Centro Oceanográfico de Málaga, Puerto Pesquero s/n, 29640 Fuengirola, Spain

Enric Massutí
I.E.O., Centre Oceanogràfic de les Balears, P. O. Box 291, 07080 Palma de Mallorca, Spain

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Abstract

The distribution, population size structure and reproductive biology of blackmouth catshark *Galeus melastomus* in the Alboran Sea were studied from 438 bottom trawls performed at depths of 40 to 796 m during twelve surveys carried out between 1994 and 2002. The species was only captured at the two deepest strata (below 200 m), reaching its maximum abundance and biomass between 501 and 800 m. Maximum indices, obtained in 1997 and 2002, indicate no specific trend in abundance, whereas the biomass showed a slightly decreasing trend from 1994. Similarly, seasonal variation of abundance and biomass during the last two years showed maximum values of biomass in autumn but with no trend in abundance. The size of the specimens ranged from 10 to 63 cm and all size groups were well represented in the length frequencies during all seasons. Juveniles and adults were restricted to depths below 500 m, while recruits were distributed throughout the whole bathymetric range in which the species was found. Both recruitment and spawning were continuous throughout the year and the total length at first maturity was calculated as 44.3 and 48.8 cm for males and females, respectively. Finally, the great abundance and biomass of the species as well as its wide population structure are compared and discussed with other Mediterranean areas.

Key words: abundance, Alboran Sea, distribution, *Galeus melastomus*, reproduction, size structure, Mediterranean.

Introduction

The Blackmouth catshark (*Galeus melastomus* Rafinesque, 1810) (Scyliorhinidae) is a small elasmobranch distributed in the eastern Atlantic Ocean, from Norway to Senegal, and in the whole Mediterranean Sea (Compagno, 1984). It shows a wide bathymetric range throughout the Mediterranean, in which it has been captured from depths of 55 to 1750 m (Stefanescu *et al.*, 1992; Relini *et al.*, 1999) and, in the western basin, it is between 400 and 1400 m (Moranta *et al.*, 1998). *Galeus melastomus* is an oviparous species, spawning all year round in the Mediterranean with a peak of activity in spring and summer (Wheeler, 1969).

In the Mediterranean, the distribution, behaviour and biology of *Galeus melastomus* have been studied, mainly in the central area; Tunisia (Capapé and Zaouali 1976, 1977), Italy (Relini Orsi and Wurtz 1975, 1977; Sartor and Ranieri 1995; Tursi et *al*. 1993; Ungaro *et al.* 1997 and Scacco *et al.* 2002). In the western basin, the only studies have been developed off the northeastern Iberian and focussed on distribution and feeding behaviour (Macpherson, 1980; Carrasón *et al*., 1992; Bozzano *et al.*, 2001).

In the Alboran Sea, *Galeus melastomus* shows the highest abundance and biomass densities of the whole northern Mediterranean (Bertrand *et al.*, 2000) and it is the most important by-catch species in the recently developed bottom trawl fishery targeting the deep-water shrimp *Aristeus antennatus* (Torres *et al.*, 2001). However, despite this, little is known about this species of shark. The only available information can be found in Gil de Sola (1994), where an insight into the distribution of demersal fishes down to a depth of 500 m is reported.

The distribution, population size structure and reproductive biology of *Galeus melastomus* from trawling grounds along the continental shelf and upper slope of the Alboran Sea (southwestern Mediterranean) are presented in this paper. This knowledge, together with that of other species, will allow the future assessment of these new deep-water fisheries and the understanding of their

possible effects on the poorly known bathyal ecosystems of the Alboran Sea.

Material and Methods

Data and samples were collected from 438 bottom trawls performed during twelve research surveys carried out in the Alboran Sea off the southeastern Iberian coast (Fig. 1). Nine of these surveys (MEDITS) were carried out during the spring, from 1994 to 2002, on board the R/V "*Cornide de Saavedra*", while three of them (MERSEL) were undertaken during summer 2001, autumn 2001 and winter 2002, on board the R/V "*Francisco de Paula Navarro*" (Table 1). These hauls were made on trawl fishing grounds along the continental shelf and upper slope from depths between 40 and 796 m. A GOC 73 gear (with average horizontal and vertical openings of 16.4 and 2.8 m, respectively) was used, having a codend mesh opening of 20 mm. In all these surveys, a random stratified sampling scheme was applied, following the protocols of most surveys undertaken recently in the Mediterranean Sea (MEDITS programme; Bertrand *et al*., 1998).

In each trawl, fresh weight in grams and the number of *Galeus melastomus* were recorded and the total length of specimens by sex was measured to the nearest lowest centimetre. Data was standardised taking into account the arrival and departure of the net at the bottom, which was measured using a SCANMAR system. Following the standard procedures of the MEDITS program, the indices of abundance and biomass were calculated as a stratified mean and variance, for the whole surveyed area and for the five bathymetric intervals considered: i) 10–50 m; ii) 51–100 m; iii) 101–200 m; iv) 201–500 m; v) 501–800 m. Temporal and bathymetric variations in the population size structure were analysed with the same procedure (Table 1).

To obtain an expression describing the depth-size trends of this species, a logistic regression analysis was calculated for the two variables size and depth. Consequently, only hauls in which more than 20 specimens were captured have been considered. The coefficient of determination (r^2) was also calculated to determine what proportion of the total variation in size was explained by a change in depth.

To analyse reproductive aspects of the species, the biological sampling of the total catch, or of random subsamples, was also carried out during the five cruises undertaken in 2001 and 2002 (Table 1). Maturity stages were determined by macroscopic examination of the gonads, following a four point scale for both sexes, based on Holden and Raitt, 1974. Females maturity stages are described as: *Immature*; narrow uterus or not appreciable, white ovary with no apparent follicles and formless capsule gland. *Maturing*; developed follicles in ovary and clear capsule gland. *Spawning*; capsules in uterus or in the glands. *Post-spawning*; irrigated glands, ovary reducing and expanded uterus. For males different maturity stages

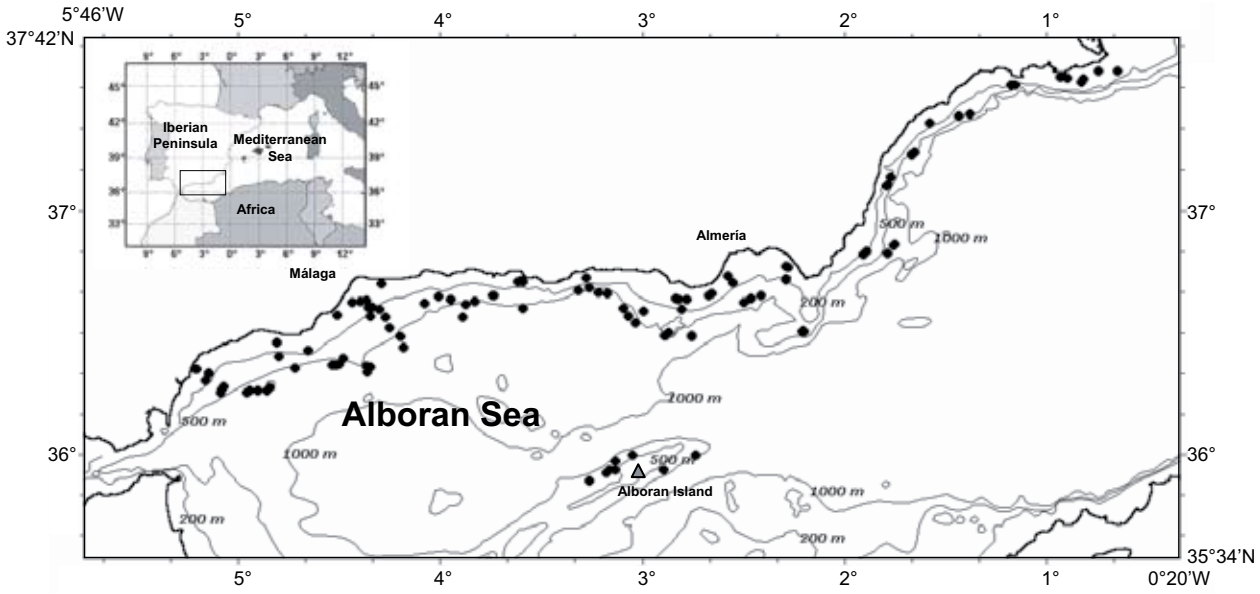

Fig. 1. Location of the studied area (Alboran Sea, north-western Mediterranean), showing the trawl stations surveyed and the 200, 500 and 1 000 m isobaths.

TABLE 1. Sampling cruises (date, depth range and number of hauls) developed in the Alboran Sea (south-western Mediterranean) and sampling collections (catch data, specimens measured and biological sampling) of Galeus melastomus analyzed in this study.

Surveys	Date	Depth (m)	Hauls	Catch data No.	Weight (g)	Length sampling
MEDITS0694	28/05–14/06/94	41–786	25	882	177 232	522
MEDITS0595	22/04–21/05/95	47–771	27	2 281	430 759	520
MEDITS0596	02/05–26/05/96	44–776	33	4 047	609 791	689
MEDITS0597	10/05–03/06/97	46–728	33	4 467	680 460	1656
MEDITS0598	04/05–14/05/98	47–707	32	2 818	405 115	610
MEDITS0599	04/05/–13/05/99	46–790	39	1 918	372 328	592
MEDITS0600	22/05–01/06/99	45–776	38	2 082	410 377	641
MEDITS0501	12–22/05/01	44–796	38	1 792	467 309	897
MERSEL0801	01–17/08/01	40–790	44	2 417	156 712	733
MERSEL1001	14/10–03/11/01	44–704	45	946	231 021	426
MERSEL0302	05–20/03/02	46–724	40	1 014	169 542	450
MEDITS0502	11–22/05/02	43–760	44	1 319	369 029	1117
Total		40–796	438	25 983	4 479 675	8853

are described as: *Immature*; narrow testes, unformed seminal vesicle and soft claspers, smaller than pelvic fins. *Maturing*; developing soft claspers passing pelvic fins and no sperm in vesicle, wide testes. *Spawning*; calcified claspers and abundant sperm in vesicle. *Post-spawning*; expanded empty vesicle, wide testes. Since spawning and post-spawning stages in males did not show any observable morphological change they were combined for analysis.

Maturity data from these five seasonal surveys were used to calculate the size at first maturity (length at which 50% of fish become mature) in both sexes. For this purpose, the percentages of mature (maturing, spawning and post-spawning) males and females for each size class were fitted to a least squares curve.

The chi-squared test was applied to assess differences in the sex ratio for the whole population and by length interval, as well as in the percentage of different maturity stages by season.

Results

Distribution and population structure

A total of 25 983 specimens of *Galeus melastomus*, weighing 4 480 kg, were caught in 40% of the trawls analysed. In all spring surveys studied (Fig. 2), the species was captured only at the two deepest strata surveyed, reaching its maximum abundance and biomass between 501 and 800 m. The species appeared almost exclusively below 300 m, except for three individuals captured during a trawl carried out at a depth of 283 m.

During the nine year period considered 1994–2002 (Fig. 2), maximum abundance were obtained in 1997 and 2002, for both strata considered (201–500 and 501–800 m). In 1997 values of 74 fish/hr (201–500 m) and 373 fish/hr (501–800 m) were obtained and in 2002 values of 94 fish/h (201–500 m) and 276 fish/hr (501–800 m). For biomass indices, maxima were also obtained in 1997 and 2002 at the 501–800 m depth-stratum (55–66 kg/hr), but not at the 201–500 m depth-stratum, in which the historical data series seemed to show a decreasing trend from 1994, with maximum values of 3 kg/hr.

Seasonal variations in abundance and biomass indices for the whole surveyed area were analysed from surveys carried out in 2001 and 2002 (Fig. 3). A clear maximum biomass was obtained in autumn 2001 (38 kg/hr), while winter, spring and summer values were similar and ranged between 15 and 23 kg/hr. By contrast, the abundance did not show any specific trend, with maximum values in autumn 2001 (151 fish/hr) and winter and spring 2002 (132 and 141 fish/hr, respectively). The high values of biomass and abundance found in autumn could be explained by the presence of larger individuals and a greater proportion of hauls in the 200–800 m depth range performed during this survey.

A total of 8 853 specimens of *Galeus melastomus* were measured. The overall length frequency distributions

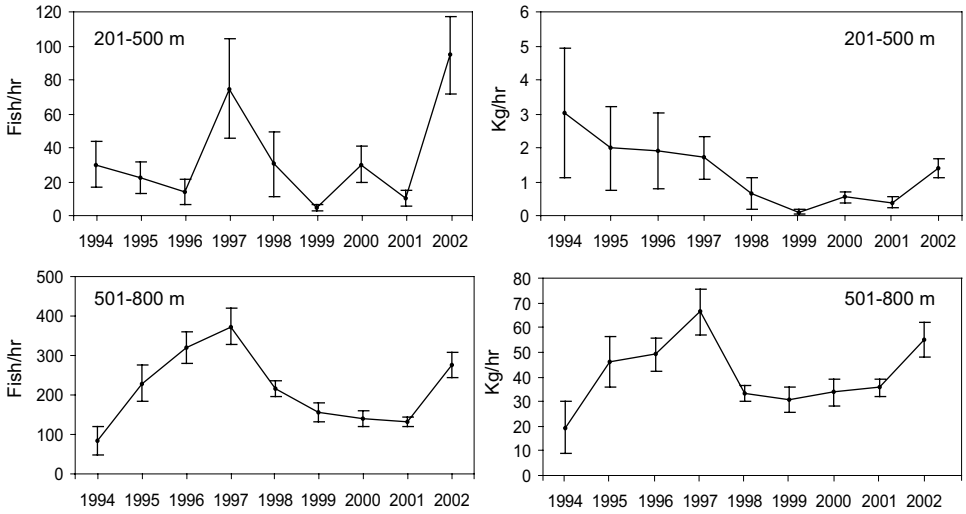

Fig. 2. Historical data series of standardized mean abundance (fish/hr) and biomass (kg/hr), obtained by depth-strata in which *Galeus melastomus* was captured from spring MEDITS surveys in the Alboran Sea. The confidence intervals at 95% are shown.

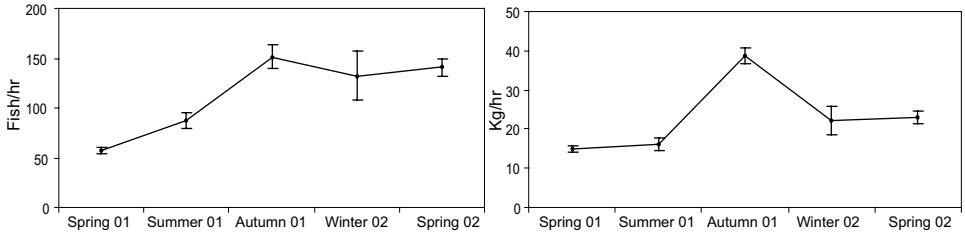

Fig. 3. Seasonal standardised mean abundance (fish/hr) and biomass (kg/hr) of *Galeus melastomus*, calculated from MEDITS (spring 2001 and 2002) and MERSEL (summer and autumn 2001 and winter 2002) surveys for the whole surveyed area in the Alboran Sea. The confidence intervals at 95% are shown.

by sex during spring were polymodal (Fig. 4), with sizes ranging between 10 and 62 cm for females and between 10 and 63 cm for males. However, if this last isolated value is omitted, the maximum size for males was 58 cm, which showed that females usually had the largest sizes. In general, all size groups were well represented, with a constant presence of lengths between 20 and 55 cm throughout the whole period analysed. Nevertheless, some differences were observed between years, with specimens smaller than 20 cm being well represented in 1995, 1997 and 2002, although there was also a clear mode at 14 cm in 2002.

Seasonal length frequency distributions by depth-strata (Fig. 5) showed that specimens between depths of 201 and 500 m were almost all smaller than 20 cm, although they were also distributed in the 501–800 m depth-strata. Specimens larger than 20 cm were almost restricted to the 501–800 m range. Specimens smaller than 30 cm were present in every season, with a very clear mode between 13 and 18 cm obtained in spring 2002 between 201 and 500 m. In each season, fish larger than 30 cm were also well represented, with clear modes at 50–52 cm. On the other hand, medium sized specimens only showed clear modes at around 35 cm in winter and spring 2002, although they were well represented in every season.

Bathymetric distribution by size was best described ($r^2 = 0.78621$) by a logistic regression analysis between depth and size, with an increase of the mean size with depth (Fig. 6), according to the following expression:

$$Length = \frac{MaxLength}{1+e^{A-\frac{K*Depth}{100}}}$$

Although the logistic regression has a more realistic prediction of size on bigger depths than a linear regression, data fits to the linear part of the logistic equation.

Parameter	Estimate	Std. Error
K	0.5011	0.0463
A	3.2928	0.0858
Maximum length	83.6841	11.5452

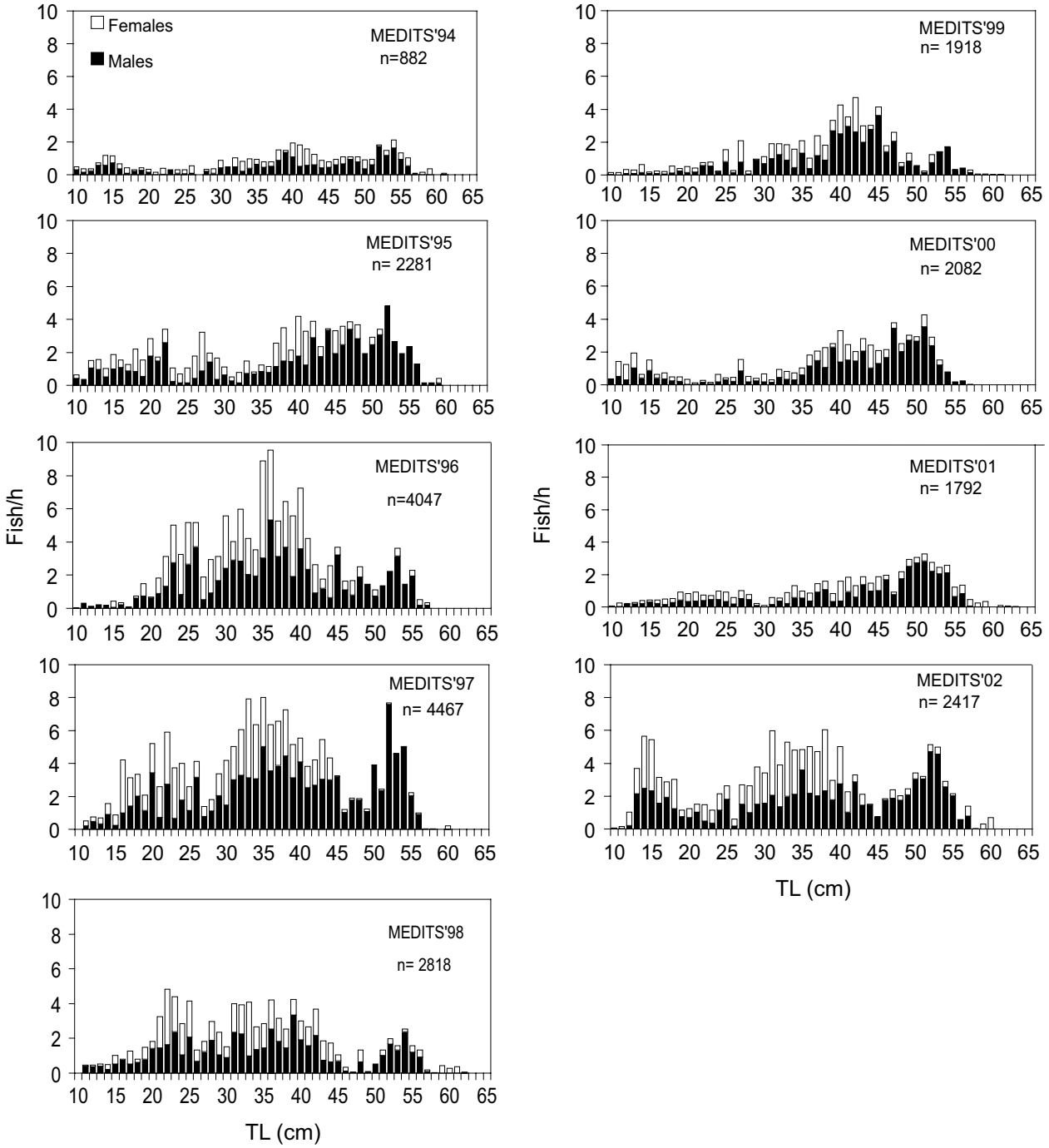

Fig. 4. Length frequency distribution (TL: total length; n: number of specimens measured) by sex (white bars for females and black bars for males) of *Galeus melastomus*, obtained for the whole surveyed area in the Alboran Sea during spring MEDITS surveys from 1994 to 2002.

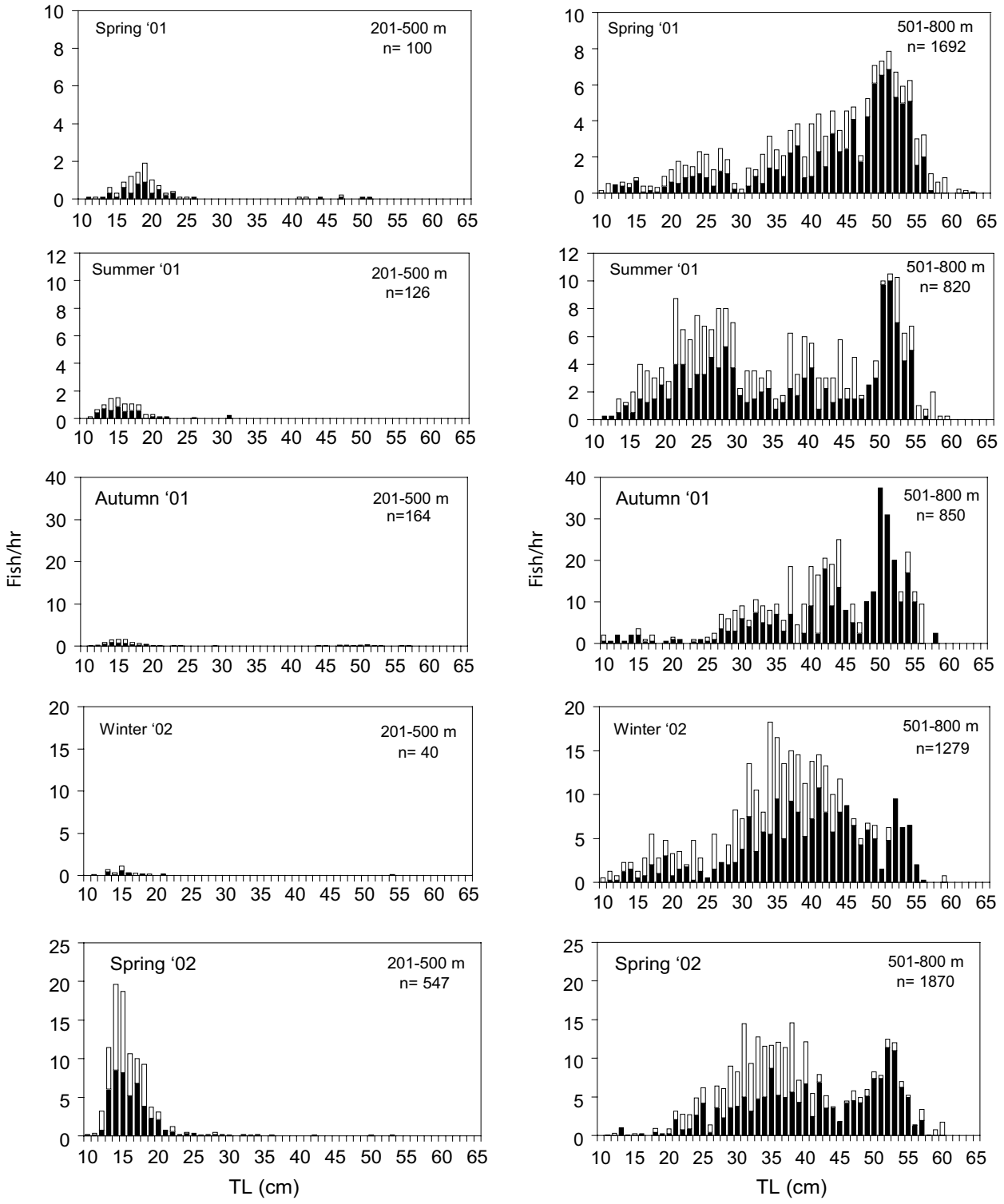

Fig. 5. Seasonal length distribution (TL: total length; n = number of specimens measured) by sex (white bars for females and black bars for males) and depth-strata of *Galeus melastomus*, obtained in the Alboran Sea during MEDITS (spring 2001 and 2002) and MERSEL (summer and autumn 2001 and winter 2002) surveys.

Reproductive aspects

Based on data from 1 629 specimens, males were significantly more abundant than females (1.7:1; $p<0.05$, Chi-square test) in the whole population of *Galeus melastomus* distributed along the upper slope of the Alboran Sea. Differences in the percentage of sexes by length class were also obtained (Fig. 7), with both sexes being equally represented from 10 to 44 cm ($p>0.05$, Chi-square test). In larger sizes, males were more abundant between 45 and 54 cm ($p<0.05$, Chi-square test), while females proportion increases gradually from 55 cm to the maximum lengths observed ($p<0.05$, Chi-square test).

The number of egg capsules found in spawning females fluctuated from one to four per uterus. Spawning and post-spawning specimens were found in each season, for both males and females (Fig. 8), but with no significant differences in the proportion of spawning and post-spawning for either sex ($p>0.05$, Chi-square test).

The smallest mature males and females were 42 cm and 45 cm, respectively, and size at first maturity was calculated as 48.8 cm for females ($r = 0.87$) and 44.3 cm for males ($r = 0.97$). Although reproductive adults represented almost 25% of the whole population in each season, most of the population was made up of pre-reproductive individuals, due to the wide size range and the late maturation.

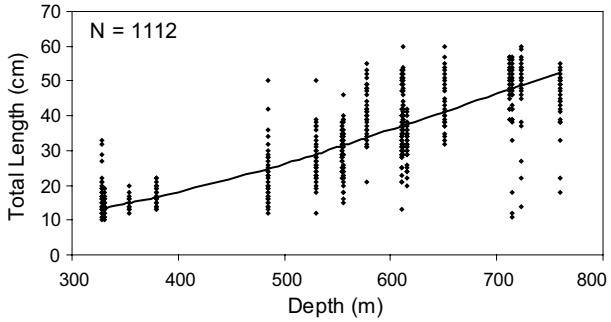

Fig 6. Relationship between length distribution of *Galeus melastomus* captured in a sample and sampling depth along the upper slope of the Alboran Sea. The logistic regresion explaining changes of size by depth is represented by a straight line ($r^2 = 0.78621$).

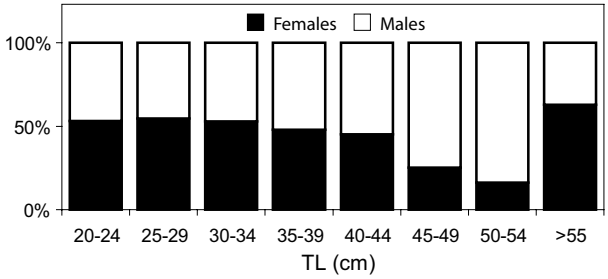

Fig. 7. Proportion of females (black bars) and males (white bars) by 5 cm length-classes of *Galeus melastomus* on the upper slope of the Alboran Sea, based on data from 1 629 specimens.

Discussion

Our results revealed that *Galeus melastomus* in the Alboran Sea is found exclusively on slope bottoms below a depth of 200 m, with a regular presence below 300 m and the highest abundance and biomass indices between 501 and 800 m. Thus, although the present data allow the accurate definition of its upper distribution limit in the area, because the species reached its maximum in the deepest strata surveyed and was present at the maximum depths explored (796 m) its lower bathymetric limit could not be determined. However, Carrasón *et al.* (1992) indicated that northwards along the Iberian coast, the species is abundant from 1 000 to 1 400 m, but declines very sharply and becomes rare below this depth.

The maximum abundance and biomass obtained in the present study can be considered as representative for the species in the area, since it has been shown that the highest frequencies of occurrence for the species in a nearby area of the southern Balearic Islands were reached between 400 and 800 m and decreased below this depth (Moranta *et al.*, 1998). Taking into account the comparison of densities throughout the whole northern Mediterranean, made by Bertrand *et al.* (2000) using the same gear and sampling scheme, the abundance and biomass indices of *Galeus melastomus* in the Alboran Sea can be considered as the highest obtained for the species in the Mediterranean.

Length frequency distributions showed a very wide size range, with all size groups well represented in the population and a constant presence during the whole study period. In addition, recruits, as well as juveniles and adults, occurred in every season. Nevertheless, a greater abundance of large rather than medium sized fish was observed within the population, which could be in accordance with the hypothesized ontogenic variations in the behaviour of this species (Scacco *et al.*, 2002). According to these authors, medium sized specimens have higher mobility, which could enable them to avoid capture by the trawl net.

The bathymetric distribution of young and adult *Galeus melastomus* in the Alboran Sea followed the general pattern of other Mediterranean (Relini Orsi

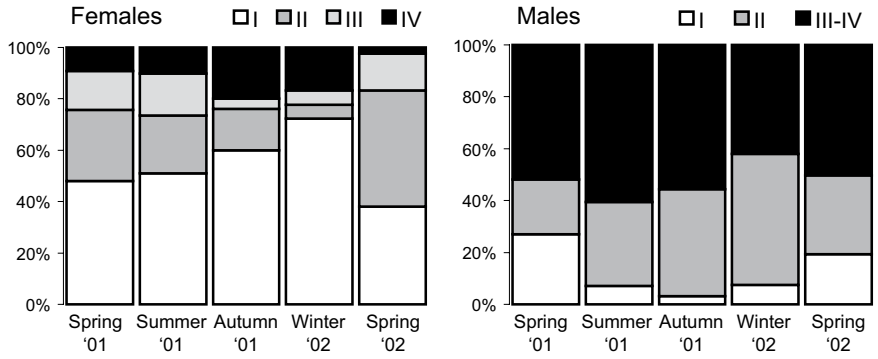

Fig. 8. Seasonal percentage of maturity stages (see Material and Methods for more details) by sex from specimens of *Galeus melastomus* >40 cm in length, obtained along the upper slope of the Alboran Sea during MEDITS (spring 2001 and 2002) and MERSEL (summer and autumn 2001 and winter 2002) surveys.

and Wurtz, 1977; Tursi *et al.*, 1993) and Atlantic areas (Figueiredo *et al.*, 1995), with the youngest specimens mostly concentrated in shallower depths (300–500 m), whereas adult specimens were only distributed below 500 m. Although these results, in conjunction with the increase of mean size with depth obtained in the study, could suggest a bathymetric segregation of sizes by ontogenic migration, the limited depth range surveyed did not allow any conclusion to be reached. In fact, results obtained in the north-western Mediterranean have shown the presence of immature and adult specimens from 10 to 61 cm at a depth of 1 400 m (Carrasón *et al.*, 1992).

The continuous recruitment was in agreement with the presence of spawning fish all year round and the lack of any seasonal trend in abundance indices. These results agree with the idea of a continuous reproductive cycle (spawning and recruitment) in the study area, as has been reported in other Mediterranean areas (Capapé and Zaouali, 1977; Tursi *et al*., 1993). The sizes at first maturity obtained were also similar to those given by Ungaro *et al.* (1997) and Tursi *et al.* (1993) in Italian waters, but larger than that reported by Capapé and Zaouali (1977) off Tunisia.

The population size structure of the species in the studied area, with a high percentage of adult fish, showed clear differences compared to the results obtained by Tursi *et al.* (1993) in the Ionian Sea from a study which consisted mostly of young individuals. According to these authors, this could be attributed to the overfishing carried out at the bathyal depths in their study area. In fact, elasmobranchs are intensively affected by fishing pressure. For these reasons, the great abundance of *Galeus melastomus* in the Alboran Sea with respect to other Mediterranean areas, as well as its wider population structure, as has also been shown for a teleost species (Massutí *et al.*, 2001), could be the result of a low fishing exploitation level applied at the deepest strata surveyed (below 500 m). In fact, deep-water fisheries along the wide slope of the Alboran Sea (almost 9 000 km^2 between depths of 200 and 800 m) are restricted to Alboran Island, the Gulf of Vera and some submarine canyons around Cape of Gata, whereas the open slopes of the western Alboran Sea have remained almost unexploited below a depth of 500 m (Gil de Sola, 1993; Torres *et al.*, 2001).

Acknowledgements

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