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Demersal Assemblages and Depth Distribution of Elasmobranchs from the Continental Shelf and Slope Trawling Grounds off the Balearic Islands (Western Mediterranean)

by

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Abstract

The analysis of 131 hauls performed during four bottom trawl fishing surveys carried out between depths of 46 and 1 713 m in two different areas off the Balearic Islands yielded a total of 23 elasmobranch species belonging to 8 families. Cluster analysis and multi-dimensional scaling (MDS) ordination were applied to detect zonation patterns and some ecological parameters (e.g. species richness, abundance and biomass, mean weight, diversity and evenness) were calculated for each assemblage. For each area, analysis of similitude (ANOSIM) and similarity percentage analysis (SIMPER) were also applied to detect differences between seasons and depths. For the most important species (*Galeus melastomus*, *Scyliorhinus canicula*, *Centroscymnus coelolepis*, *Etmopterus spinax*, *Squalus blainvillei*, *Raja naevus*, *Raja asterias*, *Raja clavata*, *Raja miraletus* and *Raja oxyrhinchus*), the bathymetric distribution of abundance and the length frequency were also analysed.

Keywords. Demersal elasmobranchs, community structure, bathymetric distribution, length frequency, trawl surveys, Balearic Islands, western Mediterranean.

Introduction

Demersal fish assemblages have been widely described in the Mediterranean Sea (e.g. Stefanescu *et al*., 1992; Gil de Sola, 1994; Papaconstantinou *et al*., 1994; Relini, 1995; Matarrese *et al*., 1996; Massutí *et al*., 1996; Moranta *et al*., 1998; among others). However, these studies include both selachians and teleosts. The only papers related exclusively to demersal elasmobranch assemblages are those by Capapé *et al*. (2000) in the Gulf of Lions, Relini *et al*. (2000) in Italian waters and Bertrand *et al*. (2000) in the whole northern Mediterranean, from the Strait of Gibraltar to the Aegean Sea, but without including the Balearic Islands. By contrast, other papers on Mediterranean elasmobranchs are more numerous, but they are focused on the distribution and biology of certain species. Among these there are studies related to the pleurotremate species *Galeus melastomus*, *Scyliorhinus canicula*, *Etmopterus spinax*, *Centroscymnus coelolepis* and *Squalus blainvillei* (e.g. Capapé and Zaouali, 1977; Macpherson, 1980; Capapé *et al*., 1991; Carrasón *et al*., 1992; Tursi *et al*., 1993; Cannizzaro *et al*., 1995; D'Onghia *et al*., 1995; Bozzano *et al*., 2001; Sion *et al*., 2002; Ungaro *et al*., 2002), the hipotremates *Raja miraletus* (Capapé and Quignard, 1974) and *Torpedo* spp. (Abdel-Aziz, 1994) and the rabbit fish *Chimaera monstrosa* (Ungaro and Marano, 2002).

The above mentioned papers on elasmobranch assemblages can reflect, in the Mediterranean, the increasing concern about this group of fishes in recent years at an international level. Certain factors form the basis of this interest, such as the likelihood that they are more affected by intense fishing activity than most teleosts, with increasing evidence that fishing exploitation affects their composition and biodiversity, and the increase in market value of some species (Stevens *et al*., 2000). These reasons can also be applied to the Mediterranean Sea, in which there is a high level of exploitation over the continental shelf and upper slope down to a depth of 800 m. In fact, evidence of changes in the number of elasmobranchs and a decrease in the abundance and biomass of some species (e.g. *Raja clavata*) throughout the last decade have been reported in a highly exploited area such as the Gulf of Lions (Aldebert, 1997; Bertrand *et al*., 1998a). Moreover, the elasmobranchs are widespread, although not too numerous in species, resulting in an interesting group for exemplification purposes related to biodiversity processes.

The present paper characterises the demersal elasmobranch assemblages on the bottom trawl fishing grounds along the continental shelf and upper slope, and in unexploited deeper areas of the middle and lower slope, off the Balearic Islands. For this purpose, experimental trawl surveys are analysed for the main species in terms of species composition, community structure and distribution and population structure. Our main aim was to provide information concerning the diversity and abundance of this group of fishes in this area, which could allow comparison with other Mediterranean areas and serve as a reference for the monitoring of any future trend in the same area.

Material and Methods

Data was collected from 131 hauls made during four bottom trawl surveys, carried out in two different seasons (spring and autumn) and two different areas of the Balearic Islands (Fig. 1): around Mallorca and Menorca (north area) and south of Eivissa and Formentera (south area).

The hauls carried out in the north area were sampled between depths of 40 and 800 m during the BALAR cruises, on board the R/V "*Francisco de Paula Navarro*" (length: 30 m: engine power: 1 100 hp) in April 2001 (41 hauls) and September-October 2001 (44 hauls). By contrast, the hauls in the south area were sampled between depths of 200 and 1 800 m during the QUIMERA cruises, on board the R/V "*García del Cid*" (length: 37 m; engine power: 1 500 hp) in October 1996 (32 hauls) and May 1998 (14 hauls). In each haul, the capture was sorted and abundance, biomass and length frequency (total length, in cm) of the species were determined.

In both areas, two different sampling gears were used. In the north area, a GOC73 towed by two warps at 2.8 knots was used, which has been used since 1994 by most surveys carried out in the Mediterranean Sea (Bertrand *et al*., 1998b). In the south area, an OTMS-27.5 was used, which consists of a benthic trawl towed by a single warp at 2.5 knots (Sardà *et al*., 1998). In both cases, the arrival and departure of the net at the bottom, as well as its horizontal and vertical openings (on average, 16.4-2.8 m for the GOC73 and 14.0-1.9 m for the OTMS-27.5), were measured using a SCANMAR system. The position at the start and the end of each trawl was recorded using GPS (Global Position System). Taking into account this information, catch data could be standardised to a common sampled area of 10 000 m^2 (or hectare, he).

It is generally agreed that selectivity among trawls is mainly dominated by mouth area, mesh size, towing speed, catching power of the vessel and whether the net is towed on one warp or two. In this sense, with the objective to avoid possible differences due to different selectivity of the gear, no comparisons were made between each area.

For each area, data on standardised abundance and biomass and mean fish weight were plotted over a depth axis to display trends with depth. The PRIMER package was used to analyse the abundance and biomass matrices of species by samples (Clarke and Gorley, 2001). To identify assemblages, cluster analysis and multidimensional scaling (MDS) were applied, after the square root transformation. The Bray-Curtis index was chosen as the similarity coefficient and the UPGMA was applied to link samples into clusters. Samples in which only one species appeared and species recorded in less than 5% of samples were omitted from the analysis, since it was statistically more significant than when all samples and species were included. Analysis of similitude (ANOSIM) and similarity percentage analysis (SIMPER) were also applied to detect differences between seasons and depths. The ecological parameters, species richness and mean species richness, total abundance and biomass, mean fish weight and the Shannon-Wiener diversity index and evenness were also calculated in each group resulting from the cluster analysis.

For the whole area, the bathymetric distribution of the main species was analysed by calculating mean abundance at ten established depth intervals. The overall length frequency distribution by sex was also calculated for these species, except for the most abundant, in which their length frequency distribution was calculated by each of the depth intervals considered.

Results

A total of 6 402 specimens and 789 kg of biomass belonging to 23 elasmobranch demersal species and 8 families were collected from 131 bottom trawls carried out between depths of 40 and 1 800 m in two different areas off the Balearic Islands (Table 1). By area, 22 (5 379 specimens and 630 kg) and 10 (1 023 specimens and 159 kg) species were caught in the 40-800 and 200-1 800 m depth-strata surveyed in the north and the south, respectively. In both areas, the most abundant species, with large differences from the rest, were *Galeus melastomus* and *Scyliorhinus canicula*. Other important species in the overall assemblage were the sharks *Etmopterus spinax*, *Squalus blainvillei* and *Centroscymnus coelolepis*. Rays were captured almost exclusively in the north area, with *Raja miraletus*, *Raja clavata, Raja asterias, Raja naevus* and *Raja oxyrhinchus* being the most important species. The rest of species were captured very occasionally in the whole area surveyed.

In both areas, the bathymetric distribution of standardised abundance and biomass of elasmobranchs as well as mean fish weight showed similar trends above a depth of 800 m (Fig. 2). Abundance reached its maximum between a depth of 300 and 400 m, whereas the biomass had minimum values around 500 m and mean fish weight reached its minimum between 400 and 500 m By contrast, in the south area, abundance and biomass values showed a decreasing trend below depths of 500 and 800 m, respectively, while mean fish weight remained constant below 800 m.

The similarity dendrograms for the trawls revealed the existence of four assemblages, which were confirmed by the MDS analysis (Fig. 3 and 4), with the bathymetric gradient being the factor of association, without seasonal differences. In the north area (Fig. 3), the first cluster separated samples taken above a depth of 235 m (SH) from the rest, which were grouped in two depth intervals: 326-632 m (SL1) and 624-745 m (SL2). In the south area (Fig. 4), the first cluster separated samples taken above a depth of 264 m (SH) from the rest, which were grouped in three depth intervals: 335-415 m (SL1), 502-1 322 m (SL2) and 1 416-1 713 m (SL3).

The values of some ecological parameters in the different assemblages by area are given in Table 2. Large differences were obtained in species richness, with highest (17) and lowest (3) values in the SH and SL3 assemblages of the north and south area, respectively. By contrast, mean species richness was similar in all assemblages and ranged between 1.5 in the SL3 of the south area and 2.8 in the SH and SL1 of the north area. Mean abundance by assemblage was similar between areas, with maximum values (21-25 fish/he) for the SL1 assemblage. The highest (2.5 kg/he) and lowest (0.46 kg/he) mean biomass was obtained for SH and SL3 of the north and south area, respectively, while in the rest of the assemblages values were similar and ranged from 0.61 to 0.98 kg/he. In the north area, the highest diversity and evenness were obtained for SH, while in the rest of the assemblages these parameters showed similar values. In the south area, diversity was higher in the SH and SL2 assemblages, while maximum evenness was obtained for the SL2 and SL3 assemblages.

In both areas, the ANOSIM analysis showed no seasonal differences, in terms of abundance and biomass, but a high dissimilarity between assemblages obtained from cluster and MDS analyses (Table 3). Differences were obtained only between the SH and SL1 assemblages from the south area. The results of the SIMPER analysis showed the separate contributions, in terms of abundance, of the most important species to the average similarity within each assemblage and the average dissimilarity between them (Tables 4 and 5). These results indicated a high dissimilarity between assemblages and confirmed the existence of well-defined groups, with changes in the abundance of the main species. In the north area, the species which characterised the different assemblages were *Scyliorhinus canicula* and *Raja miraletus* for SH, *Galeus melastomus*, *S. canicula* and *Raja oxyrhinchus* for SL1 and *G. melastomus* and *Etmopterus spinax* for SL2. In the south area, the main species by assemblage were *S. canicula* for SH, *S. canicula* and *G. melastomus* for SL1, *G. melastomus* and *E. spinax* for SL2 and *Centroscymnus coelolepis* and *Centrophorus uyato* for SL3.

The bathymetric distribution of abundance, in the whole surveyed area and for the above mentioned main species, in the assemblages, showed clear differences (Fig. 5). Within the sharks, *Scyliorhinus canicula* reached its maximum abundance (12.9 fish/he) above a depth of 100 m but was captured down to 500 m. *Squalus blainvillei* was captured almost exclusively between depths of 101 and 300 m, with a mean abundance of 0.7 fish/he. *Galeus melastomus* appeared between depths of 301 and 1 800 m, with clear maximum abundance (16.1 fish/he) between 301 and 500 m. *Etmopterus spinax* was captured from 301 to 1 500 m, with similar values of abundance (0.4-0.5 fish/he) from 301 to 1 300 m. *Centroscymnus coelolepis* was only caught below a depth of 1 301 m and reached its maximum abundance (1.7 fish/he) at the deepest interval surveyed. By contrast, most of the analysed rays were abundant above a depth of 300 m, reaching their maximu m values at <100 m for *Raja miraletus* (0.9 fish/he) and between 101 and 300 m for *Raja asterias* (0.3 fish/he), *Raja clavata* (0.6 fish/he) and *Raja naevus* (0.4 fish/he). The only exception was *Raja oxyrhinchus*, which appeared from 101 to 500 m, reaching its maximum (0.13 fish/he) between depths of 301 and 500 m.

Length frequency distribution by depth for *Scyliorhinus canicula*, *Galeus melastomus* and *Etmopterus spinax* showed clear differences (Fig. 6). For *S. canicula*, the overall length frequency ranged from 5 to 50 cm, although specimens ≥25 cm were most frequent at depths of <100 m, while smaller fish were only distributed between depths of 101 and 500 m. By contrast, in *G. melastomus*, the length ranged between 10 and 70 cm, and specimens ≤30 cm appeared almost exclusively above a depth of 700 m, while females ≥40 cm predominated below this depth. Similar results were obtained for *E. Spinax*, since the length ranged between 5 and 45 cm, with specimens ≤20 cm distributed almost exclusively from 301 to 900 m, while fish ≥30 cm predominated below a depth of 701 m.

The overall length frequency distributions of rays are shown in Fig. 7. *Raja miraletus* (length range of 10-50 cm), *Raja asterias* (15-90 cm) and *Raja naevus* (10-55 cm) showed modes situated at 20, 20 and 35-40 cm, respectively. By contrast, no clear modes could be observed in *Raja clavata* and *Raja oxyrhinchus*, the two species with a major presence of large specimens (>40 cm), with length ranges situated at 10-90 and 15-115 cm, respectively. The sharks *Squalus blainvillei* and *Centroscymnus coelolepis* ranged between 20-70 and 20-90 cm, respectively, and showed a bimodal distribution (Fig. 7). In *S. blainvillei* there was a dominance of large fish (between 40 and 70 cm total length, with a mode at 50 cm), while small specimens ranged from 20 to 30 cm. By contrast, small specimens (mode at 20-30 cm) dominated in *C. coelolepis*, which also showed a second mode at 50-65 cm.

Discussion

The analysis of demersal elasmobranch species distributed in two different areas off the Balearic Islands, along the continental shelf and slope between depths of 41 and 1 713 m, has shown that some assemblages were related to depth. These results are similar to those obtained in Atlantic waters, when elasmobranch species were also analysed separately (Roel, 1987). The bathymetric boundaries obtained in this study are similar in both areas, and they are in accordance with those obtained in previous studies of fish communities (both selachians and teleosts) carried out in our study area (Massutí *et al*. 1996; Moranta *et al*., 1998) and in other areas of the western Mediterranean (Stefanescu *et al*., 1993; Demestre *et al*., 2000).

The assemblages found in this study can be attributed to the different fish zonations proposed by Haedrich and Merrett (1988) for Atlantic waters and corroborated in the Mediterranean by the above mentioned studies. Samples taken above a depth of 250 m correspond to the continental shelf (SH), over which the highest diversity of demersal elasmobranchs is reached. In this depth-strata, the most abundant species is *Scyliorhinus canicula*, although there are also other characteristic species such as the shark *Squalus blainvillei* and the rays *Raja miraletus*, *Raja asterias*, *Raja clavata* and *Raja naevus*. The low capture of ray species in the south area could be attributed to the low number of samples taken on the continental shelf and the absence of samples above a depth of 195 m. In the north area, where a large number of samples were taken on the shelf, a higher abundance of rays and other sharks (*Mustelus* spp.) were captured, as well as other rays (*Raja brachyura*, *Raja montagui*, *Raja polystigma* and *Raja undulata*) and other batoid species (*Torpedo* spp., *Dasyatis pastinaca* and *Myliobatis aquila*), which appeared at a very low frequency in bottom trawls (e.g. Massutí *et al*., 1996; Matarrese *et al*., 1996; Bertrand *et al*., 2000). This could be due not only to the scarcity of these species but also to the solitary habits of some and to the low efficiency of the gear used.

From slope bottoms, three different assemblages can be defined. In contrast to the shelf, these assemblages are characterised mainly by sharks, the only holocephalid species captured (*Chimaera monstrosa*), a very low presence of rays (*Raja oxyrhinchus* is the only ray with an abundance peak on the slope) and the absence of other batoid species (e.g. the genera *Torpedo*, *Dasyatis*, *Miliobatis*). The shallowest slope assemblage corresponds to the upper slope (SL1; 300-500 m depth) and it is mainly characterised by *Galeus melastomus*, *Scyliorhinus canicula* and *Raja oxyrhinchus*. The deepest slope assemblage, only surveyed in the south area, corresponds to the lower slope (SL3; >1 400 m depth) and it is mainly characterised by *Centroscymnus coelolepis*, a bathyal species restricted to this depth and which, in the western Mediterranean, can occur down to a depth of 2250 m (Carrasón *et al*., 1992). Between these two assemblages, a third group is found (SL2; 500-1 400 m depth), which extends from the deep upper to the middle slope. It is characterised by *Etmopterus spinax*, a species restricted to this assemblage, and *G. melastomus*. This last species is the most abundant captured on the slope, showing the widest bathymetric range of all elasmobranch species (SL1, SL2 and SL3 assemblages) and occurring in the deepest depth surveyed.

Some conclusions can be drawn concerning depth distribution patterns and the population structure of several abundance species regularly collected. In shark species, a clear segregation of sizes by depth has been observed. For *Scyliorhinus canicula*, a species mainly distributed over the continental shelf but also on the upper slope down to a depth of 500 m, the juveniles are found below 100 m and in shallower waters the population is composed exclusively of adults. Similar results have been obtained by D'Onghia *et al*. (1995) in the North Aegean Sea, who reported juveniles, together with adults, only at depths greater than 200 m and suggested that spawning takes place mainly on the slope. By contrast, a spawning in shallow waters with hard substrate off the Gulf of Lions has also been suggested (Capapé *et al*., 1991). In *Galeus melastomus* and *Etmopterus spinax*, two species mainly distributed on the upper and middle slope, the different bathymetric distribution of juveniles and adults is more evident but, on the contrary, these predominate in shallow and deep fishing grounds within the bathymetric range of the species, respectively. Similar results have been obtained by Tursi *et al*. (1993) in the Ionian Sea. In this area, *G. melastomus* found between 200 and 400 m were almost exclusively small (mainly concentrated at around 300 m), while between 400 and 650 m the population was found to be made up of all length classes, including a considerable number of recruits. Taking into account the available information concerning length at first maturity for *S. canicula* (Capapé *et al*., 1991; Ungaro *et al*., 2002) and *G. melastomus* (Capapé and Zaouali, 1977) in the Mediterranean, the immature specimens of these two species off the Balearic Islands are mainly distributed between depths of 100 and 700 m. These bottoms are widely exploited by the trawl fleet and, for this reason, *S. canicula* and *G. melastomus* represent an important fraction of discards from this fishery (Moranta *et al*., 2000).

The bathymetric distribution of *Raja miraletus* in the study area is similar to that found in the central Mediterranean, where it is mainly concentrated between depths of 50 and 150 m (Relini *et al*., 1999) and off Tunisia, where it is distributed down to a depth of 200 m (Capapé and Quignard, 1974). Taking into account length at first maturity and the growth parameters reported by these last authors and by Abdel-Aziz (1994, the population found in the trawl fishing grounds off the Balearic Islands is mainly composed of immature specimens of 1, 2 and 3 years of age. In fact, this species forms part of the by-catch of the bottom trawl fishery, with a high proportion of individuals discarded. By contrast, the population structure of *Raja clavata* shows a large proportion of mature specimens (>50 cm; Relini *et al*., 1999). Similar results are obtained for *Squalus blainvillei*, where a second mode of mature fish older than 3 years of age (Cannizaro *et al*., 1995) at around 50 cm in length can be observed.

The analysis of available long-term data series has shown the impact of fishing activity on elasmobranchs, which is reflected in the reduction of species numbers and their declining abundance. Some biological factors may contribute to the vulnerability of this type of fish since they are long-lived and slow growing, mature at a late age and have a low fecundity. In the Atlantic Ocean, *Raja naevus* and *Raja oxyrhinchus* have been shown to be close to extinction in the north-west area (Casey and Myers, 1998) and in the Irish Sea (Dulvy *et al*., 2000), respectively, while *Raja clavata* has decreased both in abundance and in average length in the North Sea (Walker and Heessen, 1996). In the Mediterranean Sea, elasmobranch fishing landings and number of species have regularly decreased during recent decades in the Gulf of Lions, related to the development of the trawl fishery (Aldebert, 1997). In this area, the decline of abundance indices for *Raja clavata* and the reduction of its distribution area have also been reported (Bertrand *et al*., 1998a).

The comparison of our results with those obtained throughout the whole northern Mediterranean by Bertrand *et al*. (2000), where the same gear and sampling scheme as our study was used, suggests that diversity of demersal elasmobranch species in the Balearic Islands, even considering the low number of samples analysed, is similar to those insular Mediterranean areas in which the highest values have been reported (e.g. Sardinia, Corsica and Sicily islands) and higher than in adjacent areas off the Iberian Peninsula (Table 6). Although biogeographic factors could form the basis of these differences, if we take into account that chondrichthyans may be indicators of fishing pressure (e.g. Stevens *et al*., 2000), these results could also suggest the existence of some differences in fishing exploitation between areas, with lower intensity on the insular continental shelf and upper slope than along the peninsular bottoms. In addition, the presence of *Raja oxyrhinchus* on the slope bottoms of our surveyed area must also be pointed out. According to Bertrand *et al*. (2000), this species, which shows high vulnerability to fishing pressure, only occurs around Corsica Island, where trawling activity may be lower than in other areas, and around Sardinia.

The clear differences in abundance indices for some of the most important species could also encourage this hypothesis. In general, their values off the Balearic Islands (Table 6) are higher than those reported from the Iberian Peninsula and similar to the maximum abundance reported from other western Mediterranean areas off Corsica and Sicily for *Raja miraletus*, off Corsica and Sardinia for *Raja clavata* and off Corsica for *Scyliorhinus canicula*. The only exceptions were *Galeus melastomus* and *Etmopterus spinax*, which had maximum abundance off Alboran, with values much higher than those obtained from the other Mediterranean areas. The low levels of fishing effort below a depth of 500 m in this area could be on the basis of the highest abundance indices of these two species, which are restricted to the slope. In fact, this factor has also been used to explain differences in abundance and population structure obtained in a teleost species between this and other northern areas of the Iberian coast (Massutí *et al*., 2001).

The present results must be considered as an insight into the knowledge, and also as a reference point, of the present status of demersal elasmobranchs in the Balearic Islands. This area, together with other insular areas, shows the most diverse and abundant elasmobranch assemblages in the western Mediterranean. For this reason, the necessity for harvest strategies linked to the conservation of these species is becoming more evident in these areas, as well as the need to assemble data for their monitoring over as long a time scale as possible.

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References

ABDEL-AZIZ, S.H. 1994. Observations on the biology of the common torpedo (*Torpedo torpedo*, Linnaeus, 1758) and marbled electric ray (*Torpedo marmorata*, Risso, 1810) from Egyptian Mediterranean waters. *Aust. J. Mar. Freshwater Res.*, **45**: 693-704.

ALDEBERT, Y. 1997. Demersal resources of the Gulf of Lions (Mediterranean). Impact on fish diversity. *Vie et Milieu*, **47**: 275-284.

BERTRAND, J.A., Y. ALDEBERT, and A. SOUPLET. 1998a. Temporal variability of demersal species in the Gulf of Lions from trawl surveys (1983-1997). *IFREMER Actes de Colloques*, **26**: 153-164.

BERTRAND, J.A., L. GIL DE SOLA, C. PAPACONSTANTINOU, G. RELINI, and A. SOUPLET. 1998b. An international bottom trawl survey in the Mediterranean: the MEDITS programme. *IFREMER Actes de Colloques*, **26**: 76-93.

BERTRAND, J.A., L. GIL DE SOLA, C. PAPACONSTANTINOU, G. RELINI, and A SOUPLET. 2000. Contribution on the distribution of elasmobranchs in the Mediterranean (from the MEDITS surveys). *Biol. Mar. Medit.*, **7**: 1-15.

BOZZANO, A., R. MURGIA, S. VALLERGA, J. HIRANO, and S. ARCHER. 2001. The photoreceptor system in the retinae of two dogfishes, *Scyliorhinus canicula* and *Galeus melastomus*: possible relationship with depth distribution and predatory lifestyle. *J. Fish Biol.*, **59**: 1258-1278.

CANNIZARO, L., P. RIZZO, D. LEVI, and S. GANCITANO. 1995. Age determination and growth of *Squalus blainvillei* (Risso, 1826). *Fish. Res.*, 23: 113-125.

CAPAPÉ, C., and J.P. QUIGNARD. 1974. Contribution à la biologie des Rajidae des côtes tunisiennes. I. *Raja miraletus* Linné, 1758: répartition géographique et bathymétrique, sexualité, reproduction, fécondité. *Archs. Inst. Pasteur Tunis*, **51**: 39-60.

CAPAPÉ, C., and J. ZAOUALI. 1977. Contribution à la biologie des Scyliorhinidae des côtes tunisiennes. VI: *Galeus melastomus* Rafinesque, 1810. Répartition géographique et bathymétrique, sexualité, reproduction, fécondité. *Cah. Biol.. Mar.*, **18**: 449-463.

CAPAPÉ, C., J.A. TOMASINI, and J.L. BOUCHEREAU. 1991. Observations sur la biologie de reproduction de la petite roussette, *Scyliorhinus canicula* (Linnaeus, 1758) (Pisces, Scyliorhinidae) du golfe du Lion (France méridionale). *Ichtyophysiol. Acta*, **13**: 87-109.

CAPAPÉ, C., J.A. TOMASINI, and J.P. QUIGNARD. 2000. Les elasmobranches pleurotrêmes de la côte du Languedoc (France, Méridionale): observations biologiques et démographiques. *Vie et Milieu*, **50**: 123-133.

CARRASÓN, M., C. STEFANESCU, and J.E. CARTES. 1992. Diets and bathymetric distributions of two bathyal sharks of the Catalan deep sea (western Mediterranean). *Mar. Ecol. Prog. Ser.*, **82**: 21-30.

CASEY, J.M., and R.A. MYERS. 1998. Near extinction of a large, widely distributed fish. *Science*, **281**: 690-691.

CLARKE, K.R., and R.N. GORLEY. 2001. *PRIMER v5: User Manual/Tutorial*. PRIMER-E: Plymouth, 91 pp.

DEMESTRE, M., P. SÁNCHEZ, and P. ABELLÓ. 2000. Demersal fish assemblages and habitat characteristics on the continental shelf and upper slope of the north-western Mediterranean. *J. Mar. Biol. Ass. U.K.*, **80**: 981-988.

D'ONGHIA, G., A. MATARRESE, A. TURSI, and L. SION. 1995. Observations on the depth distribution pattern of the small-spotted catshark in the North Aegean Sea. *J. Fish Biol.*, **47**: 421-426.

DULVY, N.K., J.D. METCALFE, J. GLANVILLE, M.G. PAWSON, and J.D. REYNOLDS. 2000. Fishery stability, local extinctions and shifts in community structure in skates. *Conserv. Biol.*, **14**: 283-293.

GIL DE SOLA, L. 1994. Ictiofauna demersal de la plataforma continental del mar de Alborán (Mediterráneo suroccidental ibérico). *Bol. Inst. Esp. Oceanogr.*, **10**: 63-79.

HAEDRICH, R.L., and N.R. MERRET. .1988. Summary atlas of deep-living demersal fishes in the North Atlantic Basin. *J. Nat. Hist.*, **22**: 1325-1362.

MACPHERSON, E. 1980. Regimen alimentaire de *Galeus melastomus* Rafinesque, 1810, *Etmopterus spinax* (L., 1758) et *Scymnorhinus licha* (Bonnaterre, 1788) en Méditerranée occidentale. *Vie et Milieu*, **30**: 139-148.

MASSUTÍ, E., O. REÑONES, A. CARBONELL, and P. OLIVER. 1996. Demersal fish communities exploited on the continental shelf and slope off Majorca (Balearic Islands, NW Mediterranean). *Vie et Milieu*, **46**: 45-55.

MASSUTÍ, E., J. MORANTA, L. GIL DE SOLA, B. MORALES-NIN, and L. PRATS. 2001. Distribution and population structure of the rockfish *Helicolenus dactylopterus* (Pisces: Scorpaenidae) in the western Mediterranean. *J. Mar. Biol. Ass. U.K.*, **81**: 129-141.

MATARRESE, A., G. D'ONGHIA, A. TURSI, and M. BASANISI. 1996. New information on the ichthyofauna of the south-eastern Italian coast (Ionian Sea). *Cybium*, **20**: 197-211.

MORANTA, J., C. STEFANESCU, E. MASSUTÍ, B. MORALES-NIN, and D. LLORIS. 1998. Fish community structure and depth-related trends on the continental slope of the Balearic Islands (Algerian basin, western Mediterranean). *Mar. Ecol. Prog. Ser.*, **171**: 247-259.

MORANTA, J., E. MASSUTÍ, and B. MORALES-NIN. 2000. Fish catch composition of the deep-sea decapod crustacean fisheries in the Balearic Islands (western Mediterranean). *Fish. Res.*, **45**: 253-264.

PAPACONSTANTINOU, C., V. VASSILOPOULOU, G. PETRAKIS, E. CARAGITSOU. C. MYTILINAEOU, A. FOURTOUNI, and C.-Y. POLITOU. 1994. The demersal fish fauna of the North and West Aegean Sea. *Bios*, **2**: 35-45.

RELINI, G. 1995. La fauna ittica batiale del Mediterraneo con particolare riferimento ai campionamenti dello strascico. *Biol. Mar. Medit.*, **2**: 177-183.

RELINI, G., J.A. BERTRAND, and A. ZAMBONI. Eds. 1999. Synthesis of the knowledge on bottom fishery resources in Central Mediterranean (Italy and Corsica). *Biol. Mar. Medit.*, 6 (suppl. 1): 94-98.

RELINI, G., F. BIAGI, F. SERENA, A. BELLUSCIO, M.T. SPEDICATO, P. RINELLI, M.C. FOLLESA, C. PICCINETTI, N. UNGARO, L. SION, and D. LEVI. 2000. I Selaci pescati con lo strascico nei mari italiani. *Biol.. Mar. Medit.*, **7**: 347-384.

SARDÀ, F., J.E. CARTES, J.B. COMPANY, and A. ALBIOL. 1998. A modified commercial trawl used to sample deep-sea megabenthos. *Fish. Sci.*, 64: 492-493.

SION, L., G. D'ONGHIA, and R. CARLUCCI. 2002. A simple technique for ageing the velvet belly shark, *Etmopterus spinax* (Squalidae). *Proc. 4th Europ. Elasm. Assoc. Meet., Livorno (Italy), 2000, Vacchi, M., La Mesa, G., Serena, F & B. Séret, eds ICRAM, ARPAT & SFI*, 2002: 135-139.

STEFANESCU, C., D. LLORIS, and J. RUCABADO. 1992. Deep-living demersal fishes in the Catalan Sea (western Mediterranean) below a depth of 1000 m. *J. Nat. Hist.*, **26**: 197-213.

STEFANESCU, C., D. LLORIS, and J. RUCABADO. 1993. Deep-sea fish assemblages in the Catalan Sea (western Mediterranean) below a depth of 1000 m. Deep-Sea Res., **40**: 695-707.

STEVENS, J.D., R. BONFIL, N.K. DULVY, and P.A. WALKER. 2000. The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. *ICES J. Mar. Sci.*, **57**: 476-494.

TURSI, A., G. D'ONGHIA, A. MATARRESE, and G. PISCITELLI. 1993. Observations on population biology of the blackmouth catshark *Galeus melastomus* (Chondrichthyes, Scyliorhinidae) in the Ionian Sea. *Cybium*, **17**: 187-196.

UNGARO, N., and C.A. MARANO. 2002. Notes about the rabbit fish population, *Chimaera monstrosa*, in the southern Adriatic Sea. *Proc. 4th Europ. Elasm. Assoc. Meet., Livorno (Italy), 2000, Vacchi, M., La Mesa, G., Serena, F & B. Séret, eds ICRAM, ARPAT & SFI*, 2002: 161-169.

UNGARO, N., G. MARANO, and M.C. MARZANO. 2002. Size at sexual maturity of the smallspotted catshark, *Scyliorhinus canicula*, in the southern Adriatic Sea. *Proc. 4th Europ. Elasm. Assoc. Meet., Livorno (Italy), 2000, Vacchi, M., La Mesa, G., Serena, F & B. Séret, eds ICRAM, ARPAT & SFI*, 2002: 171-175.

WALKER, P.A., and H.J.L. HEESSEN. 1996. Long-term changes in ray populations in the North Sea. *ICES J. Mar. Sci.*, **53**: 1085-1093.

Table 1. Elasmobranch species caught between depths of 40 and 1800 m during BALAR and QUIMERA trawl surveys carried out in two different areas off the Balearic Islands. Total abundance (A; in number of specimens) and biomass (B; in kg), frequency of occurrence (F), depth range (D; in m) and size range (S; total length in cm) are shown by species for each surveyed area.

		North Area				South Area			
Family	Species	A	B	F	Depth range	A	B	F	Depth range
Scyliorhinidae	*Galeus melastomus* Rafinesque, 1810	2471	135.43	38	101-745	563	88.49	73	239-1713
	Scyliorhinus canicula (Linnaeus, 1758)	2440	261.75	67	44-416	305	14.56	18	195-402
Triakidae	*Mustelus asterias* Cloquet, 1821	1	0.17	1	103	-	-	-	-
	Mustelus mustelus (Linnaeus, 1758)	1	0.76	1	68	-	-	-	-
Squalidae	*Centrophorus uyato* (Rafinesque, 1810)	1	3.96	1	686	1	4	2	802
	Centroscymnus coelolepis Bocage & Capello, 1864	-	-	-	-	39	23.22	29	1012-1713
	Dalatias licha (Bonnaterre, 1788)	2	3.73	2	624-698	5	9.01	9	595-892
	Etmopterus spinax (Linnaeus, 1758)	65	5.90	19	616-745	76	13.31	53	311-1416
	Squalus blanvillei (Risso, 1826)	53	39.95	7	103-649	24	2.4	2	241
Torpedinidae	*Torpedo nodiliana* Bonaparte, 1835	1	0.22	1	371	-	-	-	-
	Torpedo marmorata Risso, 1810	5	0.87	6	108-180	-	-	-	-
Rajidae	*Raja oxyrinchus* Linnaeus, 1758	23	21.43	11	235-444	-	-	-	-
	Raja naevus Müller & Henle, 1841	44	15.52	18	52-337	4	1.602	4	908
	Raja asterias Delaroche, 1809	42	20.63	20	44-399	5	2.19	4	195-264
	Raja brachyura Lafont, 1873	1	0.67	1	70	-	-	-	-
	Raja clavata Linnaeus, 1758	92	83.26	28	85-400	-	-	-	-
	Raja miraletus Linnaeus, 1758	112	20.56	32	69-399	-	-	-	-
	Raja montagui Fowler, 1910	2	1.12	1	77	-	-	-	-
	Raja polystigma Regan, 1923	7	2.14	4	63-127	1	0.22	2	398
	Raja undulata Lacepède, 1802	1	1.40	1	53	-	-	-	-
Dasyatidae	*Dasyatis pastinaca* (Linnaeus, 1758)	3	3.92	4	41-53	-	-	-	-
Myliobatidae	*Myliobatis aquila* ((Linnaeus, 1758)	10	10.69	4	41-46	-	-	-	-
Chimaeridae	*Chimaera monstrosa* Linnaeus, 1758	2	0.15	2	494-538	-	-	-	-

Table 2. Number of hauls analysed and mean ecological parameters (standard error) for each group resulting from cluster and MDS analyses (see Fig. 3 and 4) of elasmobranch samples obtained during bottom trawl surveys carried out in two different areas off the Balearic Islands.

	North Area			South Area			
	SH	SL1	SL2	SH	SL1	SL2	SL3
Hauls	52	15	18	3	6	26	10
Species richness	17	10	6	4	4	6	3
Mean species richness	2.8 (0.2)	2.8 (0.4)	2.1 (0.1)	2.3 (0.3)	2.1 (0.2)	2.1 (0.1)	1.5 (0.2)
Fish/He	13.1 (1.8)	21.0 (5.6)	3.8 (1.0)	12.4 (1.3)	25.1 (7.2)	2.7 (0.2)	1.0 (0.2)
g/He	2564.3 (365.2)	876.1 (217.1)	612.4 (141.6)	945.5 (205.9)	900.2 (242.9)	982.5 (157.4)	461.3 (132.6)
Mean fish weight (g)	246.3 (25.7)	45.6 (5.5)	184.0 (38.3)	76.8 (18.4)	36.1 (7.4)	431.9 (92.6)	480.9 (139.1)
Diversity (H')	0.52 (0.06)	0.36 (0.09)	0.36 (0.05)	0.42 (0.23)	0.25 (0.08)	0.46 (0.16)	0.25 (0.10)
Evenness (J')	0.55 (0.04)	0.42 (0.09)	0.51 (0.05)	0.46 (0.18)	0.36 (0.12)	0.70 (0.09)	0.79 (0.02)

Table 3. Results of the ANOSIM routine to analyse differences between seasons and depths, considering the groups resulting from cluster and MDS analyses (Fig. 3 and 4) for elasmobranch samples obtained during bottom trawl surveys carried out in two different areas off the Balearic Islands.

Comparison	R Global			
	North Area		South Area	
	Abundance	Biomass	Abundance	Biomass
Between seasons				
Autumn *vs* Spring	-0.001	-0.001	-0.066	-0.007
Between depth ranges	0.62*	0.72*	0.72*	0.53*
SH *vs* SL1	0.52*	0.63*	0.23	0.13
SH *vs* SL2	0.81*	0.92*	0.86*	0.82*
SH *vs* SL3			1.00*	1.00
SL1 *vs* SL2	0.52*	0.52*	0.64*	0.38*
SL1 *vs* SL3			0.92*	0.81*
SL2 *vs* SL3			0.69*	0.47*

(*) denotes a statistically significant difference at the 95% confidence interval

Table 4. Results of the SIMPER routine to analyse dissimilarity between groups resulting from cluster and MDS analyses (Figure 3) for elasmobranch samples obtained during BALAR bottom trawl surveys, carried out between depths of 40 and 800 m in the north area off the Balearic Islands and percentage contribution, in terms of abundance, of the main species to each group. $\overline{A}$: abundance; $\overline{S_i}$: average similarity; $\overline{d_i}$: average dissimilarity, *SD*: standard deviation. See Table 1 for abbreviation of species.

Depth range	Species	$\overline{A}$	$\overline{S_i}$	$\overline{S_i}/SD$	$\overline{S_i}$ %	$\sum S_i$ %
SH $\overline{S_i}$ = 30.44						
	S. canicula	10.72	27.16	1.02	89.22	89.22
	R. miraletus	0.64	1.42	0.34	4.66	93.88
SL1 $\overline{S_i}$ = 30.56						
	G. melastomus	16.73	27.24	1.03	89.11	89.11
	S. canicula	3.93	3.07	0.45	10.04	99.15
	R. oxyrhinchus	0.19	0.24	0.44	0.79	99.94
SL2 $\overline{S_i}$ = 56.32						
	G. melastomus	3.59	50.57	2.36	89.79	89.79
	E. spinax	0.45	5.74	1.1	10.19	99.98
Pair-waise comparisons			$\overline{d_i}$	$\overline{d_i}/SD$	$\overline{d_i}$ %	$\sum d_i$ %
SH vs SL1 $\overline{d_i}$ = 89.36						
	G. melastomus		43.16	1.43	48.3	48.3
	S. canicula		34.55	1.19	38.67	86.96
	R. miraletus		3.06	0.43	3.42	90.39
SH vs SL2 $\overline{d_i}$ = 98.40						
	S. canicula		48.66	1.54	49.45	49.45
	G. melastomus		29.76	1.26	30.25	79.69
	R. miraletus		4.65	0.56	4.72	84.42
	E. spinax		4.09	0.86	4.16	88.58
SL1 vs SL2 $\overline{d_i}$ = 74.66						
	G. melastomus		54.89	2.13	73.51	73.51
	S. canicula		13.44	0.68	18	91.52
	E. spinax		3.77	0.72	5.05	96.57
	R. oxyrhinchus		1.2	0.44	1.6	98.17

Table 5. Results of the SIMPER routine to analysis dissimilarity between groups resulting from cluster and MDS analyses (Figure 4) of elasmobranch samples obtained during QUIMERA bottom trawl surveys, carried out between depths of 200 and 1800 m in the south area off the Balearic Islands and percentage contribution, in terms of abundance, of the main species to each group. $\overline{A}$: abundance; $\overline{S_i}$: average similarity; $\overline{d_i}$: average dissimilarity, *SD*: standard deviation. See Table 1 for abbreviation of species.

Depth range	Species	$\overline{A}$	$\overline{S_i}$	$\overline{S_i}/SD$	$\overline{S_i}$ %	$\sum S_i$ %
SH $\overline{S_i}$ = 50.24						
	S. canicula	9.55	49.55	1.73	98.63	98.63
	S. blainvillei	2.12	0.74	0.43	1.01	99.64
	R. asterias	0.5	0.69	0.58	0.36	100
SL1 $\overline{S_i}$ = 20.4						
	S. canicula	9.29	10.97	0.5	53.79	53.79
	G. melastomus	14.5	8.97	0.56	43.96	97.75
SL2 $\overline{S_i}$ = 54.98						
	G. melastomus	1.98	45.17	1.65	82.16	82.16
	E. spinax	0.51	9.42	0.98	17.13	99.29
SL3 $\overline{S_i}$ = 51.20						
	C. coelolepis	0.87	47.51	2.08	92.80	92.80
	C. uyato	0.20	3.69	0.41	8.20	100
Pairwise comparisons			$\overline{d_i}$	$\overline{d_i}/SD$	$\overline{d_i}$ %	$\sum d_i$ %
SH vs SL1 $\overline{d_i}$ = 72.88						
	S. canicula		28.78	1.6	39.49	39.49
	G. melastomus		28.5	0.86	39.11	78.6
SH vs SL2 $\overline{d_i}$ = 99.96						
	S. canicula		62.51	2.56	62.53	62.52
	S. blainvillei		15.55	0.7	15.56	78.10
	G. melastomus		12.86	1.81	12.86	90.96
SH vs SL3 $\overline{d_i}$ = 100						
	S. canicula		69.26	2.58	69.26	69.26
	S. blainvillei		17.42	0.69	17.42	86.68
	C. coelolepis		6.35	1.51	6.35	93.03
SL1 vs SL2 $\overline{d_i}$ = 86.97						
	S. canicula		37.64	0.99	43.27	43.27
	G. melastomus		36.20	0.99	41.63	84.90
	E. spinax		12.41	0.52	14.27	99.17
SL1 vs SL3 $\overline{d_i}$ = 98.29						
	S. canicula		40.54	0.99	41.25	41.25
	G. melastomus		38.31	0.93	38.97	80.22
	E. spinax		14.47	0.47	14.72	94.94
SL2 vs SL3 $\overline{d_i}$ = 82.62						
	G. melastomus		47.27	2.01	54.84	54.84
	C. coelolepis		23.64	1.47	27.42	82.62
	E. spinax		13.68	1.16	15.86	98.12

Table 6. Number of hauls analysed, elasmobranch species captured and standardised abundance (specimens/km^2) for the most abundant species reported from different areas of the western Mediterranean (Bertrand *et al.*, 2000) and those obtained off the Balearic Islands from the BALAR surveys analysed in the present study, in which the same gear and sampling scheme were used. Abundance values from areas throughout the whole northern Mediterranean were obtained from an average of the 1994-1998 data series reported by Bertrand *et al.* (2000) at the different depth-strata in which the species were mainly distributed: (i) 10-200 m for *Raja clavata* and *Raja miraletus*; (ii) 200-800 m for *Galeus melastomus* and *Etmopterus spinax*; (iii) 10-800 m for *Scyliorhinus canicula*. Abundance values from the Balearic Islands were obtained from an average of spring and autumn data, in which no differences were detected (see Table 3).

Area	Total	Species	Abundance: specimens/Km^2				
	hauls	number	*R. clavata*	*R. miraletus*	*S. canicula*	*G. melastomus*	*E. spinax*
Alboran Sea	170	16	0.0	0.4	50.2	1876.8	281.0
Central Iberian Peninsula	150	13	3.0	3.2	96.4	176.8	46.2
Northern Iberian Peninsula	215	10	2.0	0.0	231.4	107.4	8.4
Gulf of Lions	325	23	7.4	0.0	92.3	932.2	42.6
Corsica Island	120	26	40.2	101.2	590.4	641.4	54.2
Ligurian and Northern and Central Thyrrhenian	765	24	2.6	7.4	17.9	288.4	52.2
Sardinia Island	625	24	46.4	32.8	255.4	868.0	67.6
Sicily Island and South Thyrrhenian	705	29	7.6	115.6	34.0	253.6	67.8
Balearic Islands	85	22	54.0	88.0	804.0	1131.0	27.0

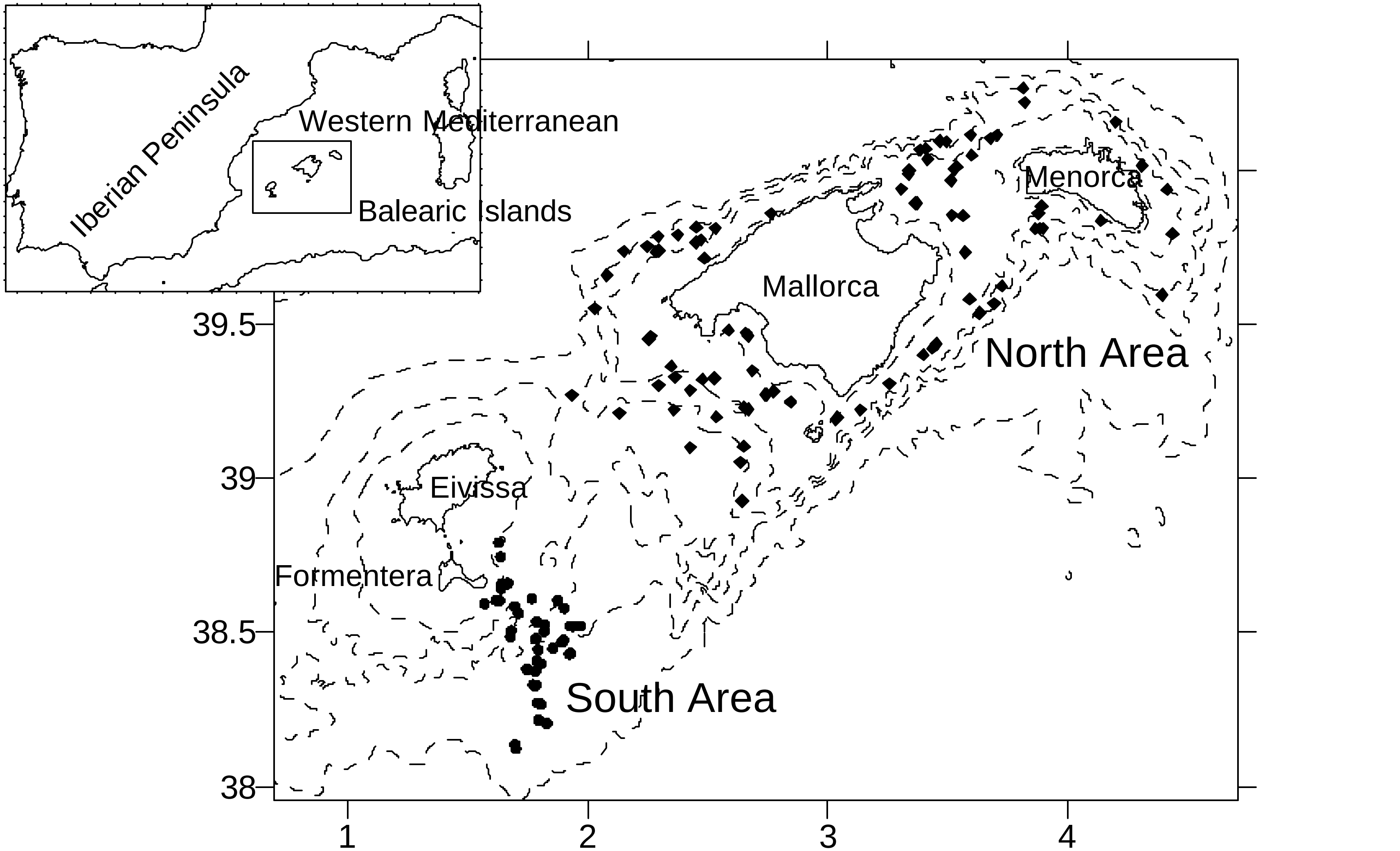

Fig. 1. Location of the two areas studied off the Balearic Islands (south and north) and the trawl stations surveyed during the different surveys: BALARs (♦) and QUIMERAs (•).

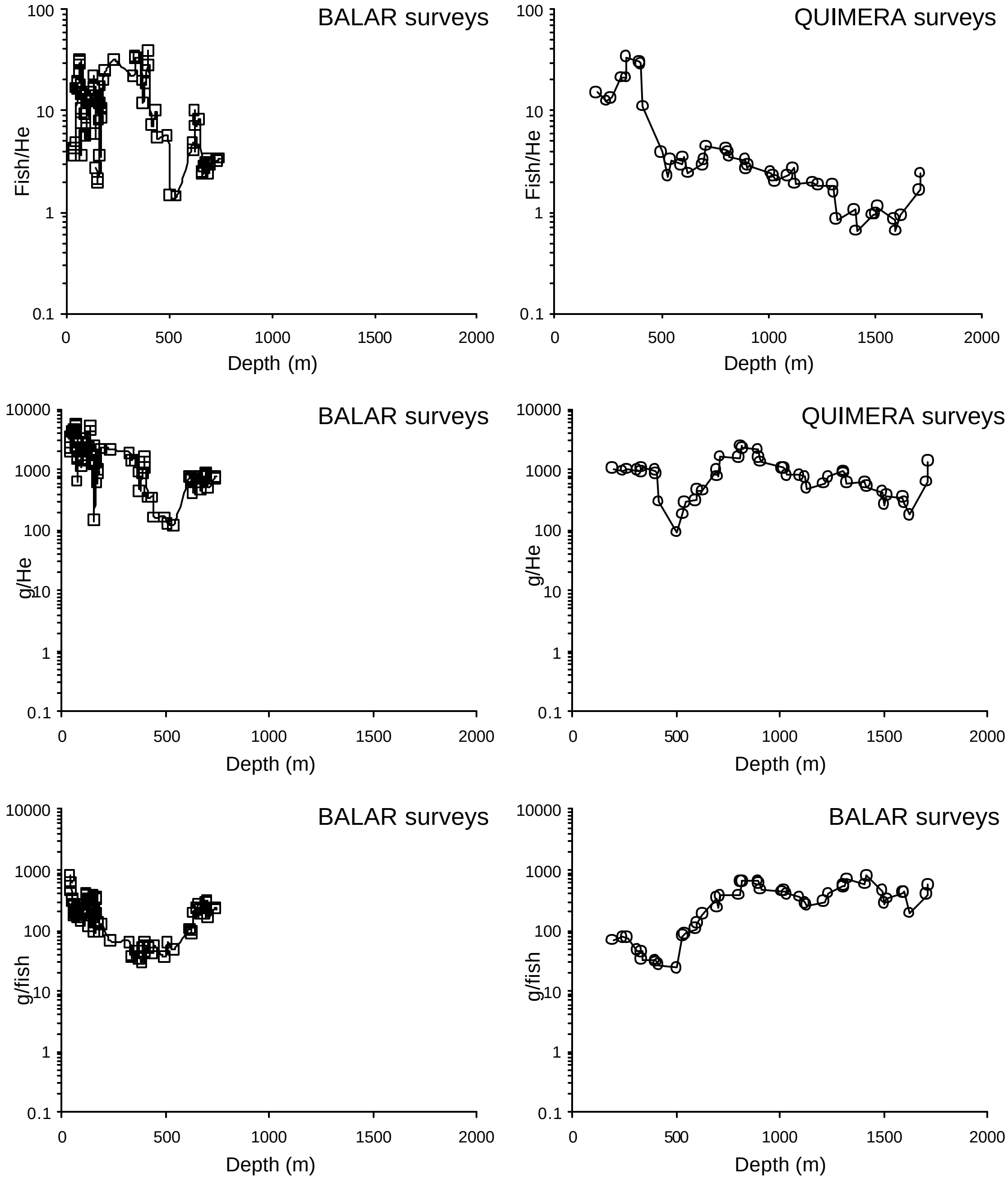

Fig. 2. Distribution by depth of the standardised abundance and biomass (specimens and kg by 10 000 m^2) and the mean weight of elasmobranchs captured during bottom trawl surveys carried out in two different areas off the Balearic Islands.

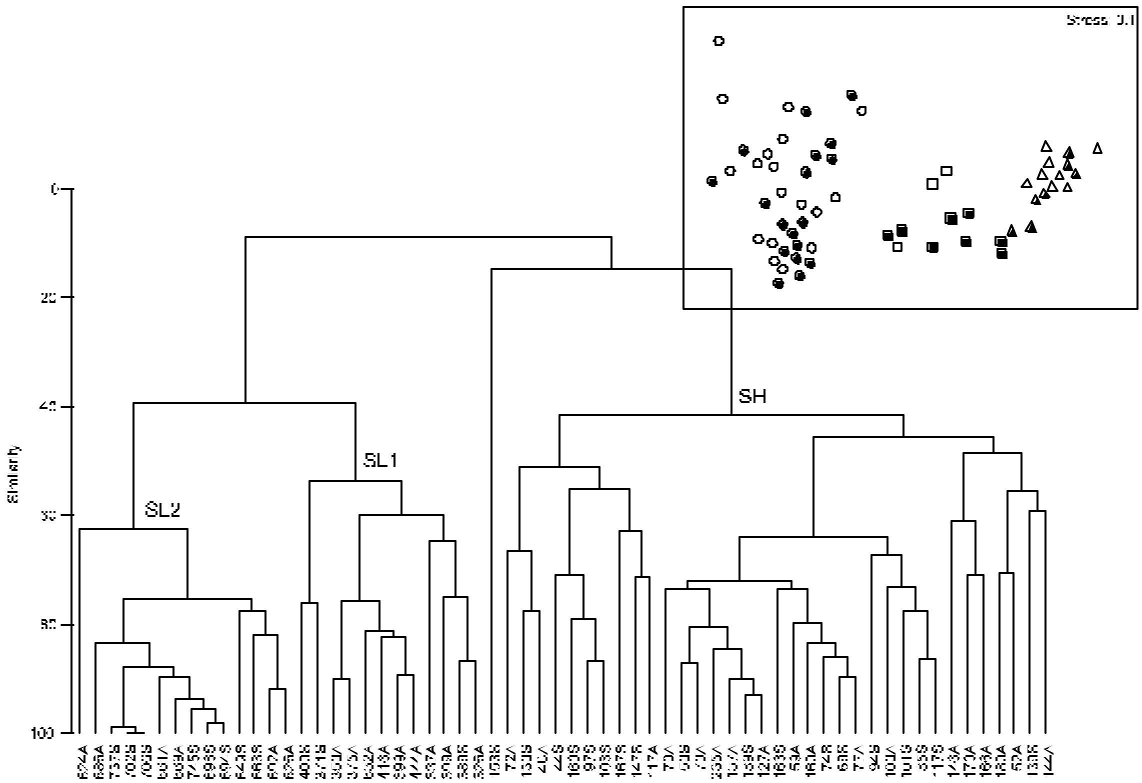

Fig.3. Dendrogram (A) and multidimensional scaling ordination (B; indicating the groupings obtained from cluster analysis) of elasmobranch samples obtained during BALAR bottom trawl surveys, carried out between depths of 40 and 800 m in the north area off the Balearic Islands. The dendrogram shows the mean depth (in metres) and season (S: spring; A: autumn) for the samples. The groupings obtained from cluster analysis are indicated in MDS by different white (spring) and black (autumn) symbols.

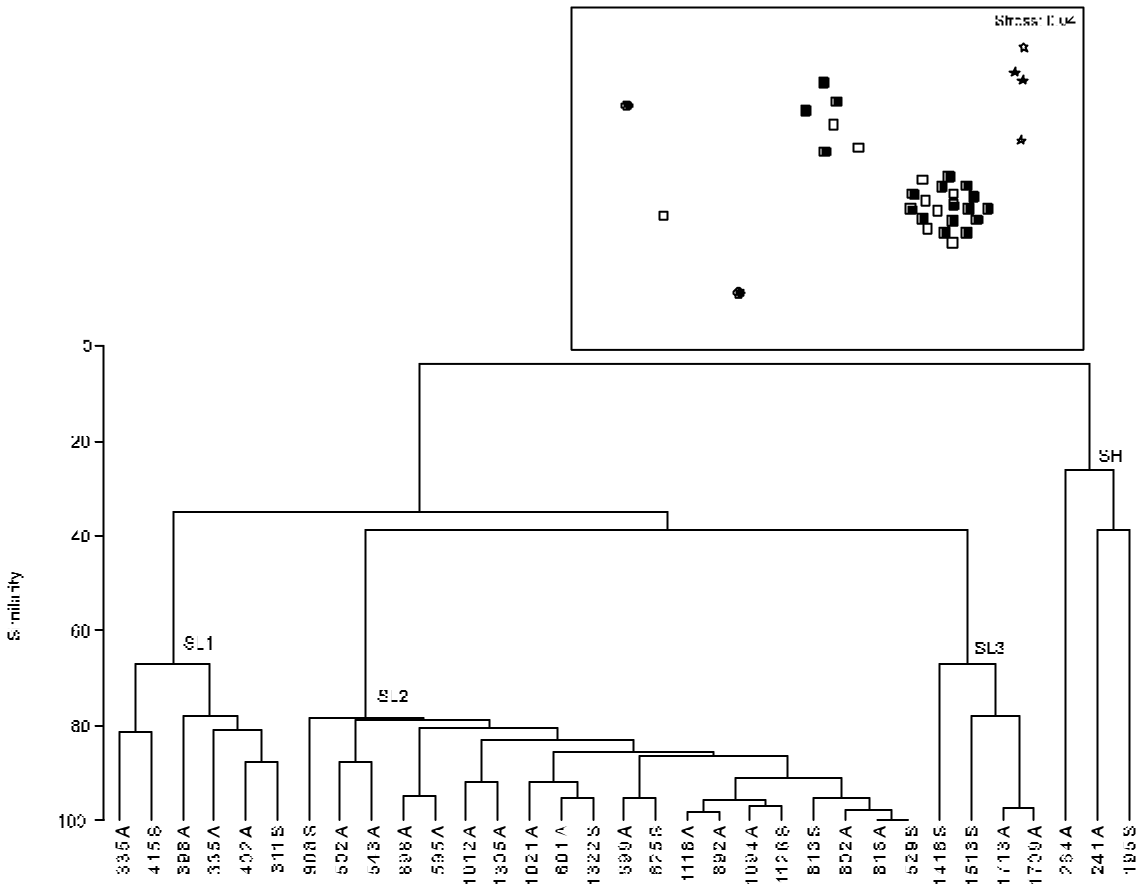

Fig. 4. Dendrogram (A) and multidimensional scaling ordination (B; indicating the groupings obtained from cluster analysis) of elasmobranch samples obtained during QUIMERA bottom trawl surveys, carried out between depths of 200 and 1800 m in the south area off the Balearic Islands. The dendrogram shows the mean depth (in metres) and season (S: spring; A: autumn) for the samples. The groupings obtained from cluster analysis are indicated in MDS by different white (spring) and black (autumn) symbols.

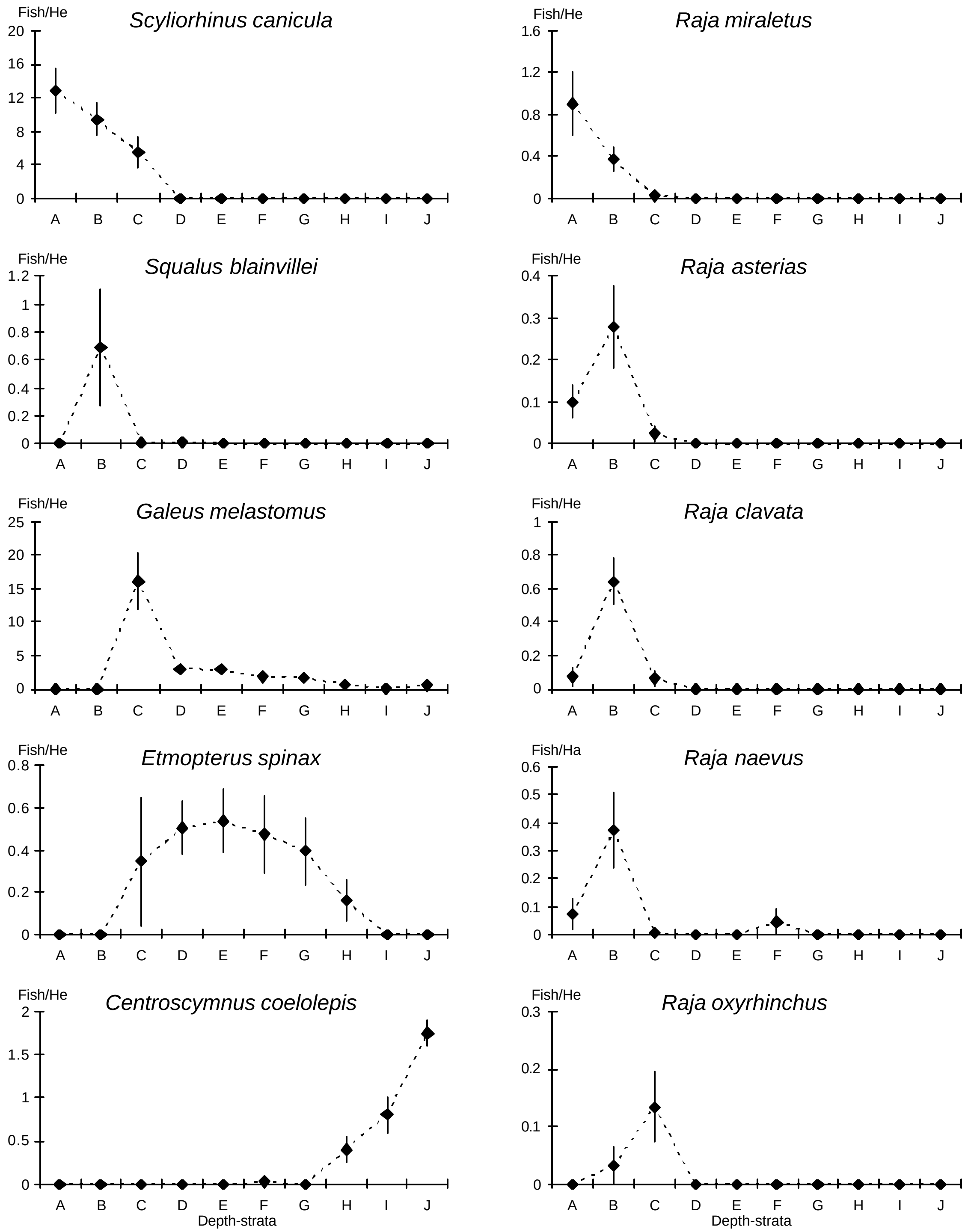

Fig. 5. Mean and standard error of standardised abundance (specimens/10,000 m^2), calculated in the whole area surveyed and by depth interval (A: <100 m; B: 101-300 m; C: 301-500 m; D: 501-700 m; E: 701-900 m; F: 901-1100 m, G: 1101-1300 m; H: 1301-1500 m; I: 1501-1700 m; J: >1700 m), for the main species of elasmobranchs captured during bottom trawl surveys carried out off the Balearic Islands.

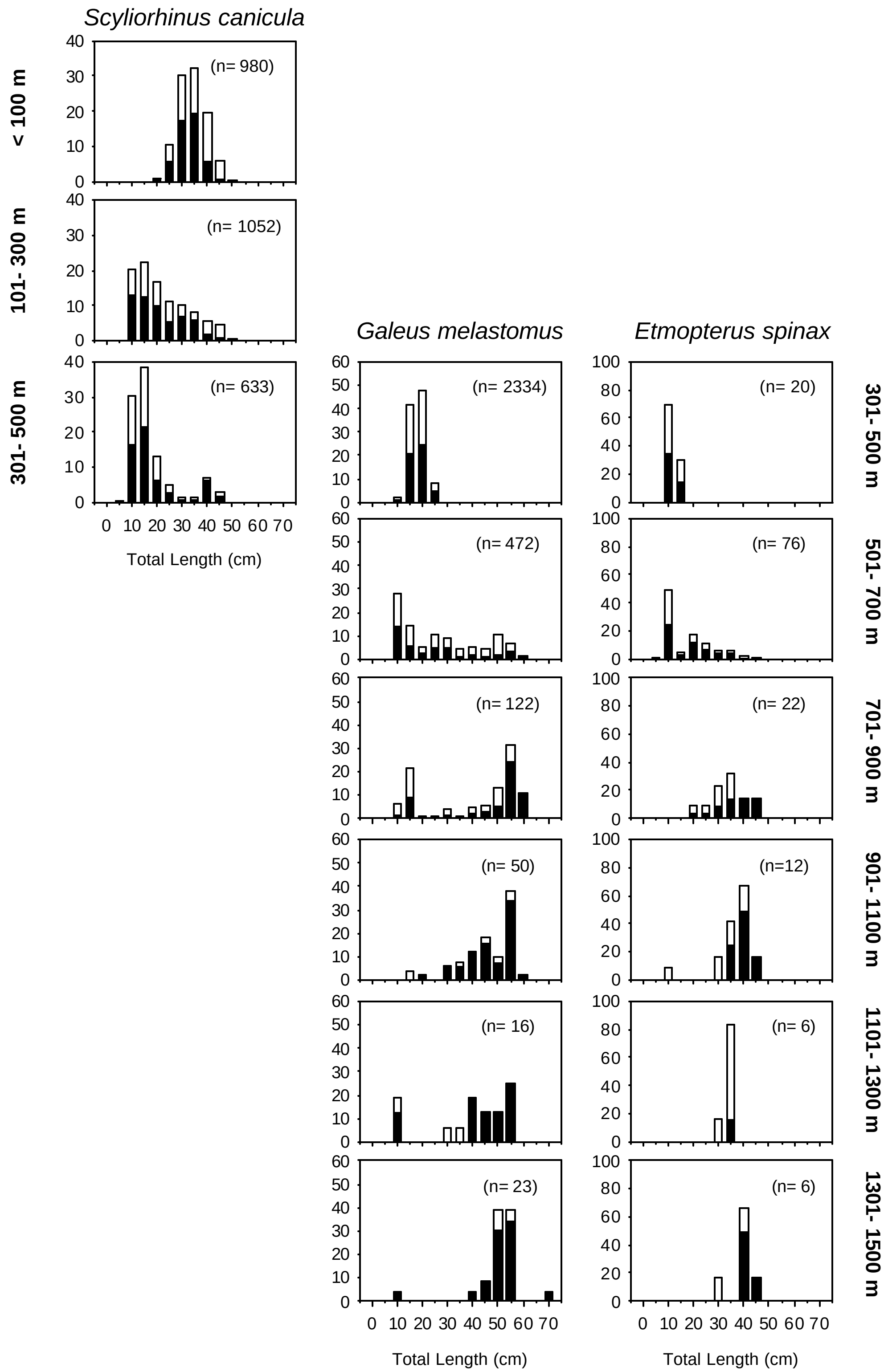

Fig. 6. Length frequency distribution (in percentage and by 5 cm size classes) by sex (black bars for females and white bars for males) and depth interval of *Scyliorhinus canicula*, *Galeus melastomus* and *Etmopterus spinax* captured during bottom trawl surveys carried out off the Balearic Islands.

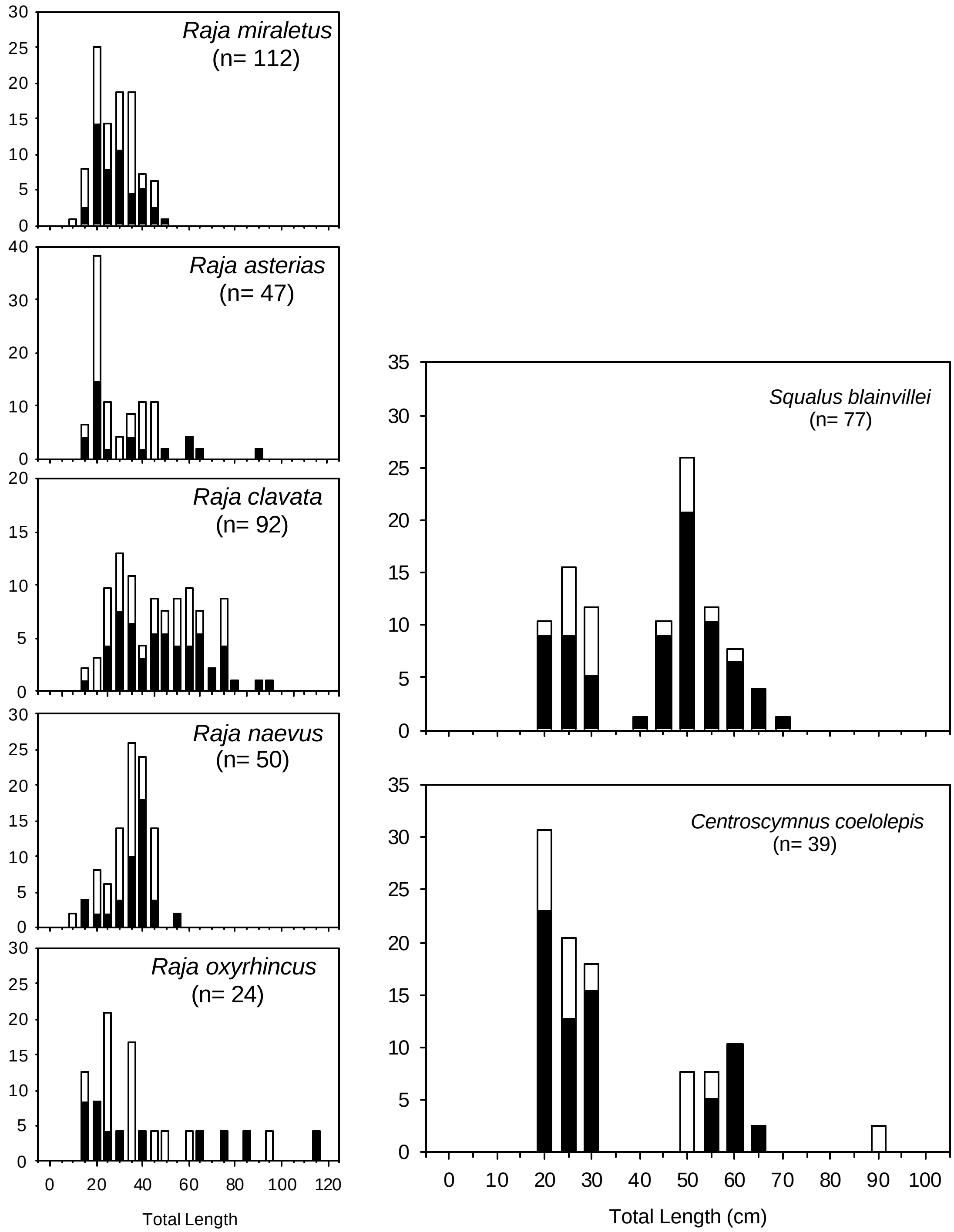

Fig. 7. Overall length frequency distribution (in percentage and by 5 cm size classes) by sex (black bars for females and white bars for males) of the rays *Raja miraletus*, *Raja asterias*, *Raja clavata*, *Raja naevus*, *Raja oxyrhinchus* and the sharks *Squalus blainvillei* and *Centroscymnus coelolepis* captured during bottom trawl surveys carried out off the Balearic Islands.