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Demersal resource assemblages in the trawl fishing grounds off the Balearic Islands (western Mediterranean)*

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SUMMARY: The demersal resources distributed in the trawl fishing grounds off the Balearic Islands (western Mediterranean) were studied from two bottom trawl surveys carried out in spring and autumn along the continental shelf and upper slope off the islands of Mallorca and Menorca. A total of 88 hauls, between 41 and 745 m depth, were analysed by means of multivariate analysis and ecological parameter calculation in order to characterise the structure of commercial species assemblages. A different bathymetric distribution of abundance was observed by comparing the main taxonomic groups. Six main species assemblages were identified, primarily associated with depth but also with different macro-epibenthic communities. Seasonal or geographic differences were detected for three of these assemblages, which could be related to differences in habitats and macro-epibenthic communities, as well as to seasonal changes in the abundance of some species related to their life cycle.

Key words: demersal resources, bathymetric distribution, species assemblages, macro-epibenthos, bottom trawl, Balearic Islands, western Mediterranean.

RESUMEN: ASOCIACIONES DE RECURSOS DEMERSALES EN LOS FONDOS DE ARRASTRE DE LAS ISLAS BALEARES (MEDITERRÁNEO OCCIDENTAL). – Se estudian los recursos demersales distribuidos en los fondos de arrastre de las Islas Baleares (Mediterráneo occidental), a partir de dos campañas de arrastre de fondo realizadas en primavera y otoño a lo largo de la plataforma continental y talud superior de las islas de Mallorca y Menorca. El análisis multi-variante de un total de 88 pescas entre 41 y 745 m de profundidad y el cálculo de parámetros ecológicos ha permitido caracterizar la estructura de las asociaciones de especies comerciales. Se ha observado una distribución batimétrica diferente en la abundancia de los principales grupos taxonómicos y se han identificado seis grandes asociaciones de especies, relacionadas principalmente con la profundidad, aunque también con diferentes comunidades macro-bentónicas. Se han detectado diferencias estacionales y geográficas en tres de estas asociaciones, las cuales podrían estar relacionadas con diferencias en hábitats y comunidades macro-bentónicas, así como con cambios estacionales en la abundancia de algunas especies, debidos a sus ciclos vitales.

Palabras clave: recursos demersales, distribución batimétrica, asociaciones de especies, macro-epibentos, arrastre de fondo, Islas Baleares, Mediterráneo occidental.

INTRODUCTION

Demersal fish, crustacean and cephalopod assemblages in the Mediterranean Sea have been widely studied along the western (Demestre *et al.*, 2000; Abelló *et al.*, 2002; González and Sánchez, 2002; and references cited therein), central (Biagi *et al.*, 2002; Colloca *et al.*, 2003) and eastern (Labropoulou and Papaconstantinou, 2000; Kallianiotis *et al.*, 2000) coasts. As concerns the Balearic Islands, the available information is related to fish and crustacean assemblages on bathyal slope bot-

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toms off the southern islands (Moranta *et al*., 1998; Maynou and Cartes, 2000, respectively) and to fish and cephalopod assemblages from the trawl fishery, carried out on the continental shelf and upper slope off Mallorca (Massutí *et al*., 1996; Moranta *et al*., 2000; Quetglas *et al*., 2000).

Assessments of some of the main species exploited by trawl fishery of the Balearic Islands have been made from analytic methods based on population dynamics (Oliver, 1993; García-Rodríguez and Esteban, 1999), production models (Carbonell and Azevedo, 2003) and regression analysis (Alemany and Álvarez, 2003). These assessments consider the single species as the basic unit of the analysis, which has been considered as incomplete for multi-species fisheries such as the Mediterranean bottom trawl (Caddy, 1993; Lleonart and Maynou, 2003). According to these authors, this fishery should require a multi-species and ecosystem-based approach, which takes into account all living organisms and the environment, with special emphasis on habitats, communities and the effect of inter-specific relationships on the species abundance and distribution (Caddy and Sharp, 1986).

The aim of the present paper is to characterise, from a quantitative point of view, the demersal assemblages exploited in the trawl fishery off the Balearic Islands (western Mediterranean), their structure and species diversity, and the macro-epibenthic communities in which they are distributed.

MATERIAL AND METHODS

Study area

The Balearic Islands (Fig. 1) are separated from the Iberian Peninsula by large geographical barriers (depths of between 800 and 2000 m and a minimum distance of 93 nautical miles or 170 km). In addition, they can be considered as an isolated exploited demersal ecosystem, also according to the fishing fleet structure, in which 346 small-scale boats and 61 trawlers operate, providing annual landings estimated at about 4,000 tonnes (Massutí, 1991).

The continental shelf of Mallorca and Menorca is narrow and consists mainly of a rocky coast, with predominance of sea-grass meadows and sand and sandy-muddy bottoms. The only exceptions are the northern and southern areas off Mallorca, where the bays of Alcudia, Pollença and Palma and the channels between Mallorca and Menorca and between Mallorca and Cabrera (Fig. 1) increase the presence of muddy-sand bottoms and enlarge the continental shelf. The slope is also very steep, with an absence of submarine canyons, and its morphology is conditioned more by emergent geological structures than by the input of sediment from the shelf. The absence of river runoff reduces the presence of terrigenous muddy sediments. Consequently, in contrast with the bottoms of the Iberian Peninsula, the muddy bottoms in the Balearic Islands area are mainly of biogenic origin (e.g. Canals and Ballesteros, 1997).

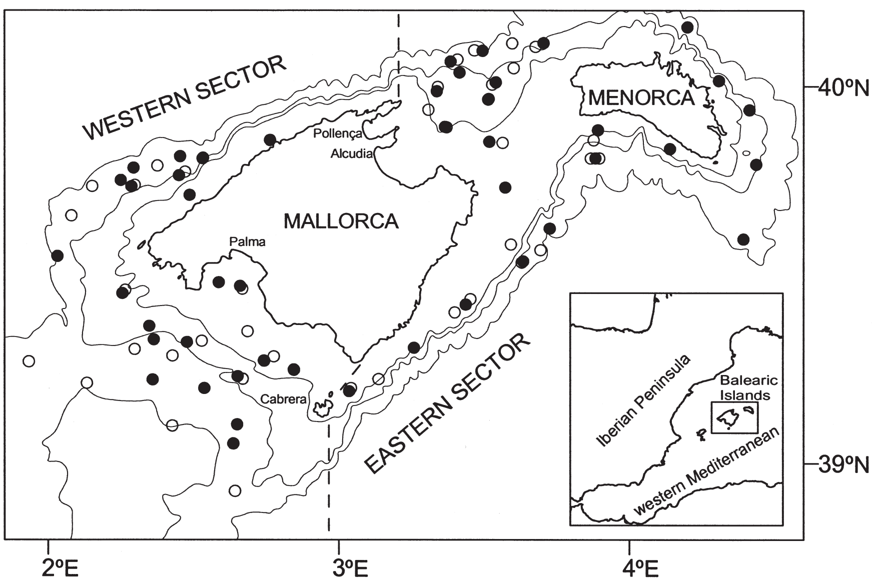

FIG. 1. – Maps of the studied area off Mallorca and Menorca Islands (Balearic Islands, western Mediterranean), showing the trawl samples made during the BALAR0401 (white circles) and BALAR0901 (black circles) cruises and the geographic sectors considered (western and eastern), which are separated by dashed lines. The 100, 200 and 800 m isobaths are shown.

Table 1. – Major benthic communities identified during BALAR surveys according to Pérès (1985) and main macro-epibenthic species found.

Benthic assemblage	Code	Macro-epibenthic taxa
Soft red and green algae facies of sandy and gravel detritic bottoms	1	*Vidalia volubilis*, *Phyllophora nervosa*, *Peyssonnelia*, *Codium bursa*, *Suberites domuncula*, *Spatangus purpureus*, *Astropecten*, *Turritella*, *Pecten*, Paguridae
Calcareous red algae facies of sandy and gravel detritic bottoms	2	*Lithothamnion*, *Lithophyllum*, *Laminaria rodriguezii*, *Suberites domuncula*, *Spatangus purpureus*, *Astropecten*, *Turritella*, *Pecten*, Paguridae
Muddy-detritic assemblages	3	*Alcyonium palmatum*, *Aphrodite aculeata*, *Ophiothrix*, *Phallusia mammillata*, *Diazona violacea*, *Microcosmus*
Shelf-edge detritic assemblages	4	*Alcyonium palmatum*, *Echinus*, *Astropecten*, *Ophiura*, *Aporrhais*
Bottoms with large braquiopoda	5	*Gryphus vitreus*
Bathyal muddy soft bottoms	6	*Pennatula*, *Veretillum*, *Cidaris cidaris*, *Brissopsis*, *Mesothuria*, *Aporrhais*, *Xenophora*, Sepiolidae, *Bathypolypus sponsalis*, *Polycheles typhlops*, *Munida*, *Macropipus tuberculatus*, *Thenea muricata*

The Balearic Islands are an area with high hydrographical variability, which is mainly conditioned by the water masses circulating through its channels (e.g. Pinot *et al.*, 1995, 2002). As in the western Mediterranean, the thermal and saline conditions of the study area are highly stable below 200 m depth, with a salinity of 38.3-38.5 and a temperature of 13.0-13.5ºC. Above this depth, the surface temperature shows seasonal variations, ranging between 13ºC during winter and 27ºC in summer. In this period, a clear strong temperature gradient is established between depths of 50 and 100 m (Fernández-Puelles *et al.*, 2004).

Data source

During 2001, two bottom trawl cruises were conducted in April (BALAR0401) and September-October (BALAR0901), on board the R/V *Francisco de Paula Navarro*. They were undertaken in the trawl fishing grounds along the continental shelf and upper slope off Mallorca and Menorca (Balearic Islands, western Mediterranean; Fig. 1). The experimental hauls were performed according to a random stratified sampling strategy, taking into account depth and two geographic sectors (western and eastern; Fig. 1) established according to different trawl fleets working in the area (Carbonell *et al.*, 2003).

The sampling gear used was a GOC73 trawl net, which has been used since 1994 for different surveys undertaken throughout the western Mediterranean and its efficiency for catching demersal species has already been tested (Bertrand *et al.*, 2002). The average towing speed was 2.8 knots. The average horizontal and vertical openings were estimated as 16.4 and 2.8 m respectively using SCANMAR system. The geographical position of each haul was recorded using GPS (Global Positioning System).

A total of 88 experimental hauls were conducted between depths of 41 and 745 m: 41 hauls (44-745 m) during spring (BALAR0401) and 47 hauls (41-692 m) during autumn (BALAR0901) (Fig. 1). The tows, conducted during daylight hours, had a duration of 20 to 60 minutes. The catch of each sample was identified to species level (except for some invertebrates, which could only be identified to generic level), counted, weighed and standardised to 30 minutes. The analysis of the main macro-epibenthic species caught on each haul was used to assign the sampling stations to one of the benthic communities characteristic of the circalittoral soft bottoms of the western Mediterranean (Pérès, 1985). It should be noted that the bottom trawl collected only epi-benthic species (Ellis *et al.*, 2000). No infaunal data were used in the present study. The benthic communities found and their main macro-epibenthic species captured for each assemblage are shown in Table 1.

Statistical analysis

For the analysis of demersal resources, species that composed the bottom trawl fishery landings in the study area were considered (Carbonell, 1997). Species appearing fewer than three times on each

TABLE 2. – Total abundance (A, in number of individuals), bathymetric range (D, in metres) and frequency of occurrence (%, calculated as number of hauls in which the species appeared in relation to the total number of hauls analysed) of each commercial demersal species captured by the surveys BALAR0401 (Spring) and BALAR0901 (Autumn). Fishing time standardised to 30 minutes in each fishing operation.

Group/Family	Species	BALAR0401			BALAR0901		
		A	D	%	A	D	%
FISHES							
Scyliorhinidae	*Galeus melastomus*	214	101-745	37	1102	326-692	36
	Scyliorhinus canicula	925	44-400	59	1767	46-416	70
Squalidae	*Centrophorus uyato*				1	686	2
	Dalatias licha	1	698	2	1	624	2
	Squalus blainvillei	45	139-649	5	14	103-399	8
Triakinidae	*Mustelus asterias*				1	103	2
	Mustelus mustelus				1	68	2
Rajidae	*Raja asterias*	31	44-389	27	15	59-399	13
	Raja brachyura	2	70	2			
	Raja clavata	46	85-400	24	47	103-399	30
	Raja microocellata				27	41-58	8
	Raja montagui				3	77	2
	Raja miraletus	80	53-167	34	68	41-399	28
	Raja naevus	25	101-189	17	26	52-337	17
	Raja oxyrhinchus	6	371-400	7	10	235-444	13
	Raja polistigma				8	63-127	6
	Raja undulata	2	53	2			
Chlorophthalmidae	*Chlorophthalmus agassizi*	343	189-649	19	782	180-444	19
Congridae	*Conger conger*	7	139-737	19	6	63-692	15
Ophichthidae	*Echelus myrus*	1	96	2	1	92	2
Merluccidae	*Merluccius merluccius*	59	44-737	63	1203	52-686	72
Gadidae	*Micromesistius poutassou*	609	163-745	27	61	326-686	28
	Molva d. macrophthalma	12	334-538	15	16	337-494	11
	Phycis blennoides	295	139-745	54	563	92-692	55
	Phycis phycis	1	74	2	9	72-146	4
	Trisopterus m. capelanus	235	91-189	15	407	92-170	19
Moridae	*Mora moro*	13	388-745	17	6	444-692	15
Zeidae	*Zeus faber*	40	53-189	32	41	41-155	40
Serranidae	*Epinephelus marginatus*	2	53	2			
	Serranus cabrilla	483	44-163	46	1395	41-146	45
Cepolidae	*Cepola rubescens*	85	69-153	27	34	70-416	19
Mullidae	*Mullus barbatus*	1239	44-189	29	1959	41-117	15
	Mullus surmuletus	959	44-538	66	1474	41-337	57
Sparidae	*Diplodus annularis*	218	44	2	531	41-46	4
	Diplodus puntazzo	2	44	2			
	Diplodus vulgaris	90	44-74	5	123	41-63	4
	Dentex dentex	2	74	2			
	Pagellus acarne	19	44-101	7	485	41-103	17
	Pagellus bogaraveo	1	96	2	8	91–146	4
	Pagellus erythrinus	70	44-101	15	300	41-103	28
	Spondyliosoma cantharus				10	41	2
	Pagrus pagrus	14	44	2	46	41	2
Centracanthidae	*Spicara smaris*	2923	53-139	34	15538	41-144	32
Labridae	*Coris julis*	6	70	2	195	52-77	8
Trachinidae	*Trachinus draco*	365	44-167	49	387	41-144	40
	Trachinus radiatus	216	44	2	19	41-59	8
Uranoscopidae	*Uranoscopus scaber*	32	44-153	24	36	41-144	23
Blenniidae	*Blennius ocellaris*	57	44-139	32	107	41-176	42
Ophidiidae	*Ophidion barbatum*	1	919	2	1	41	2
Centrolophidae	*Centrolophus niger*	8	353-538	10			
Scorpaenidae	*Helicolenus dactylopterus*	187	153-538	27	465	117-686	45
	Scorpaena elongata	1	189	2	3	180	2
	Scorpaena notata	535	44-139	27	581	41-160	38
	Scorpaena porcus	56	53-160	15	22	41-74	11
	Scorpaena scrofa	56	44-139	32	117	41-337	45
Triglidae	*Aspitrigla obscura*				3	155-176	6
	Chelidonichthys cuculus	380	76-189	29	2209	70-235	36
	Lepidotrigla cavillone	1067	44-167	49	1785	41-146	30
	Trigla lucerna	1	74	2	1	70	2
	Trigla lyra	19	139-389	17	47	103-416	30
	Chelidonichthys lastoviza	374	44-101	24	1103	41-91	28
Peristeiidae	*Peristedion cataphractum*	10	69-706	19	41	52-686	34
Dactylopteidae	*Dactylopterus volitans*	4	44-53	5	4	63	2
Citharidae	*Citharus linguatula*	165	74-153	22	183	92-103	
Scophthalmidae	*Lepidorhombus boscii*	80	97-436	41	223	137-626	45
	Lepidorhombus whiffiagonis	3	189-371	7	19	160-444	17
Soleidae	*Bathysolea profundicola*	1	436	2			
	Microchirus ocellatus	2	58	2	1	52	2

TABLE 2 (Cont.). – Total abundance (A, in number of individuals), bathymetric range (D, in metres) and frequency of occurrence (%, calculated as number of hauls in which the species appeared in relation to the total number of hauls analysed) of each commercial demersal species captured by the surveys BALAR0401 (Spring) and BALAR0901 (Autumn). Fishing time standardised to 30 minutes in each fishing operation.

Group/Family	Species	BALAR0401			BALAR0901		
		A	D	%	A	D	%
	Microchirus variegatus	10	69-94	10	15	70-137	8
	Monochirus hispidus	56	44-53	5	6	41-52	6
	Solea impar				10	58	2
	Solea kleinii	5	53	2	18	52	2
Lophiiae	*Lophius budegassa*	28	94-400	24	69	96-494	45
	Lophius piscatorius	23	53-745	34	42	59-669	49
CRUSTACEANS							
Solenoceridae	*Solenocera membranacea*	25	353-538	12	8	494-686	8
Aristeidae	*Aristeus antennatus*	716	649-745	19	1301	510-692	19
	Aristaeomorpha foliacea	1	737	2	9	626-692	8
Penaeidae	*Parapenaeus longirostris*	602	334-538	19	856	139-624	32
Pandalidae	*Plesionika acanthonotus*	58	472-702	12	100	510-686	15
	Plesionika antigai	299	334-436	15	460	326-444	17
	Plesionika edwardsii	30	388-436	5	1499	326-686	11
	Plesionika gigliolii	347	334-737	27	487	326-686	21
	Plesionika heterocarpus	247	153-745	22	3180	155-686	25
	Plesionika martia	951	436-745	27	1868	399-692	28
Nephropidae	*Nephrops norvegicus*	32	371-694	15	101	375-686	21
Palinuridae	*Palinurus elephas*	5	96-133	5	4	96-146	6
Calappidae	*Calappa granulata*	2	53	2	14	52-137	13
Homolidae	*Paromola cuvieri*	8	538-706	15	18	160-692	19
Portunidae	*Liocarcinus depurator*	23	91-353	12	23	92-337	11
	Macropipus tuberculatus	40	70-698	34	277	52-686	53
Geryonidae	*Geryon longipes*	12	649-745	17	29	63-686	19
MOLLUSCS							
Sepiidae	*Sepia elegans*	38	58-334	27	46	52-160	28
	Sepia officinalis	20	44-69	5	28	46-70	13
	Sepia orbignyana	11	139-189	5	43	41-353	19
Loliginidae	*Alloteuthis media*	319	69-189	44	9668	46-176	17
	Loligo vulgaris	371	44-108	22	70	41-494	51
Ommastrephidae	*Illex coindetti*	48	69-353	32	110	91-416	40
	Todarodes sagittatus	17	139-668	19	10	337-692	17
Octopodidae	*Octopus vulgaris*	226	44-163	39	789	41-326	43
	Scaeurgus unicirrhus	46	74-167	29	47	74-326	30
	Eledone cirrhosa	317	53-400	46	56	92-375	34
	Eledone moschata	20	44-101	12	52	41-103	19
ECHINODERMS							
Stichopodidae	*Stichopus regalis*	509	53-436	58	300	58-686	60

cruise, as well as species considered as pelagic or mesopelagic in previous studies in the area (Massutí *et al.*, 1996; Moranta *et al.*, 1998), were omitted from this analysis.

The bathymetric distribution of each species caught was analysed quantitatively by estimating the centre of gravity (COG; Daget, 1976) and habitat width (HW; Pielou, 1969). Both techniques have previously been applied to describe the bathymetric distribution of demersal fish species (e.g. Moranta *et al.*, 1998). Before the analysis, the bathymetric range sampled was divided into eight strata of 100 m. COG and HW were calculated as follows: COG= $(x_1+2x_2+3x_3+\ldots+nx_n)/\sum x_i$ and HW= $e^{H'}$, where x_i represents the calculated mean abundance values of the species *x* present in the stratum *i*, e is the natural log and H' the Shannon-Wiener function ($H' = -\sum p_i * \log p_i$, where p_i is the proportion of individuals of the species in the depth stratum).

In order to identify species assemblages, cluster analysis and non-metric multidimensional scaling (MDS) were applied after the double square root transformation had been performed. The percentage haul similarity was calculated by means of the Bray-Curtis index (Clifford and Stephenson, 1975) and the Unweighted Pair-Group Mean Analysis (UPGMA) was applied to link similar samples into clusters. All the analyses were carried out using the PRIMER package (Clarke and Warwick, 1994). Similarity percentage analysis (SIMPER) and analysis of similitude (ANOSIM) routines were also applied to identify the species that contributed most to each group and to detect seasonal and spatial differences within each of these assemblages respectively. Two levels of the two factors considered were (i) season (spring and autumn); and (ii) geographic sectors (western and eastern; Fig. 1). For each assemblage, mean abundance and total and mean species richness were calculated.

To estimate the importance of the commercial species within the community and to provide an overview of their accompanying macro-epibenthos, the percentage of non-commercial and commercial species and the mean standardised capture, in terms of biomass, were calculated for each assemblage. The main taxonomic groups, algae, echinoderms, molluscs, crustaceans and fishes, were considered, while the less abundant taxa (sponges, cnidarians, annelids, brachiopods and ascidians) were grouped.

RESULTS

A total of 130,777 individuals belonging to 103 commercial demersal species (74 fishes, 17 decapod crustaceans, 11 cephalopod molluscs and 1 holoturoid echinoderm) were captured (Table 2).

Bathymetric distribution of species

On both cruises, abundance by depth showed a rather similar trend for each of the main taxonomic groups analysed (Fig. 2). However, large differences were observed by comparing bathymetric trends between groups. Fish abundance generally decreased throughout the whole bathymetric range surveyed. An increasing trend with depth was observed in decapod crustacean abundance, while an opposite trend was detected for cephalopod mollusc abundance. For the only echinoderm analysed (*Stichopus regalis*), the maximum abundance by

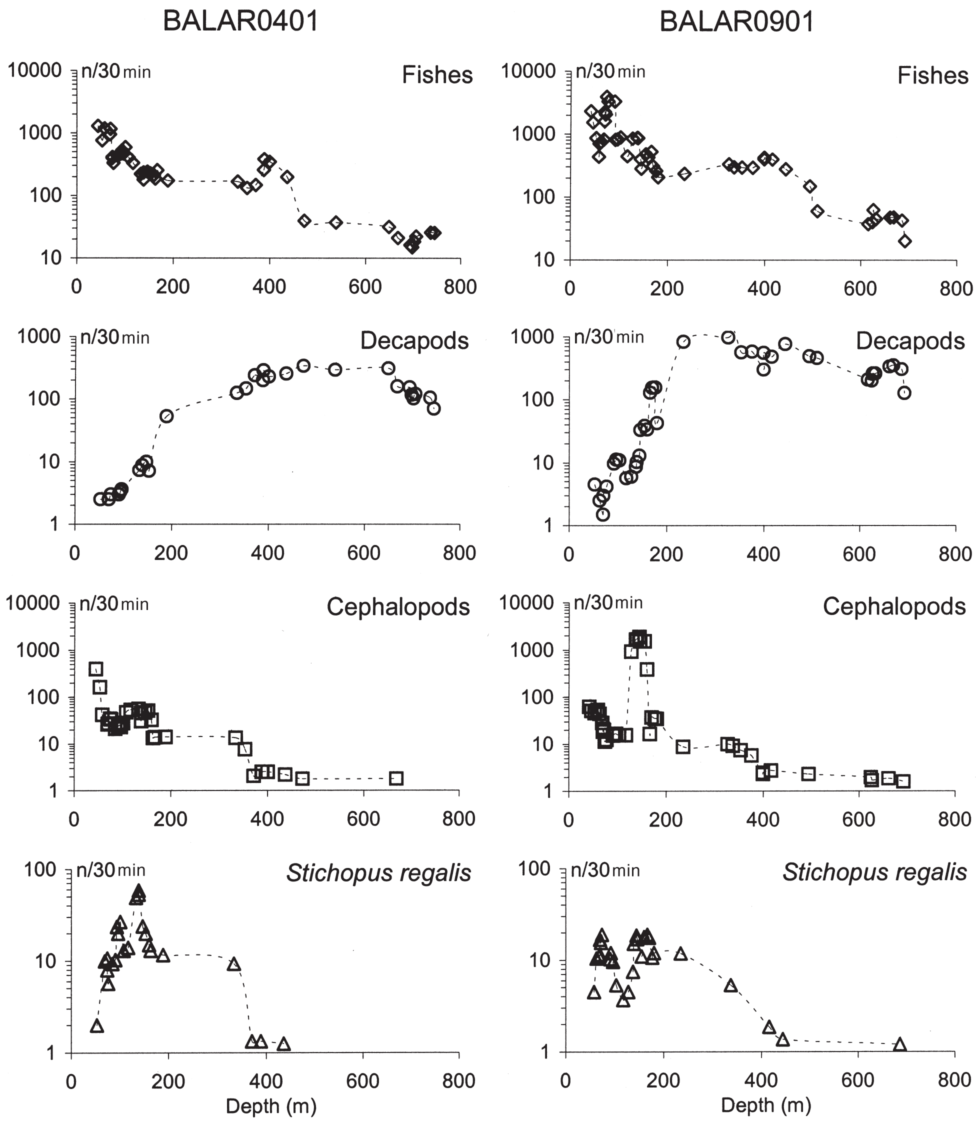

FIG. 2. – Distribution by depth and survey (BALAR0401 and BALAR0901) of the abundance (individuals/30 min) of the main groups considered (fishes, decapod crustaceans and cephalopod molluscs) and the only commercial holothuroid echinoderm (*Stichopus regalis*).

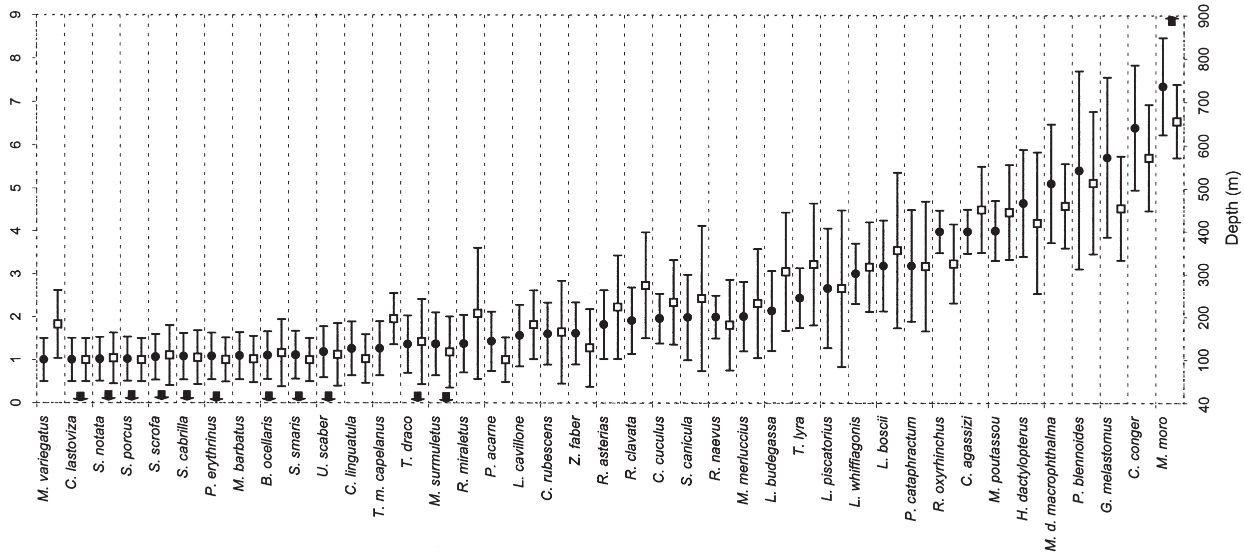

FIG. 3. – Bathymetric distribution of fish species in terms of centre of gravity and habitat from the BALAR0401 (black circles) and BALAR0901 (white squares) surveys. Black arrows indicate a displacement in real terms of the centre of gravity beyond the depth range sampled, according to other studies conducted in the same and adjacent areas (Reñones *et al.*, 1995; Massutí *et al.*, 1996; Moranta *et al.*, 1998). Numbers 1-8 correspond to the eight depth intervals into which the sampled bathymetric range was divided (see Material and Methods). Full species names are given in Table 2.

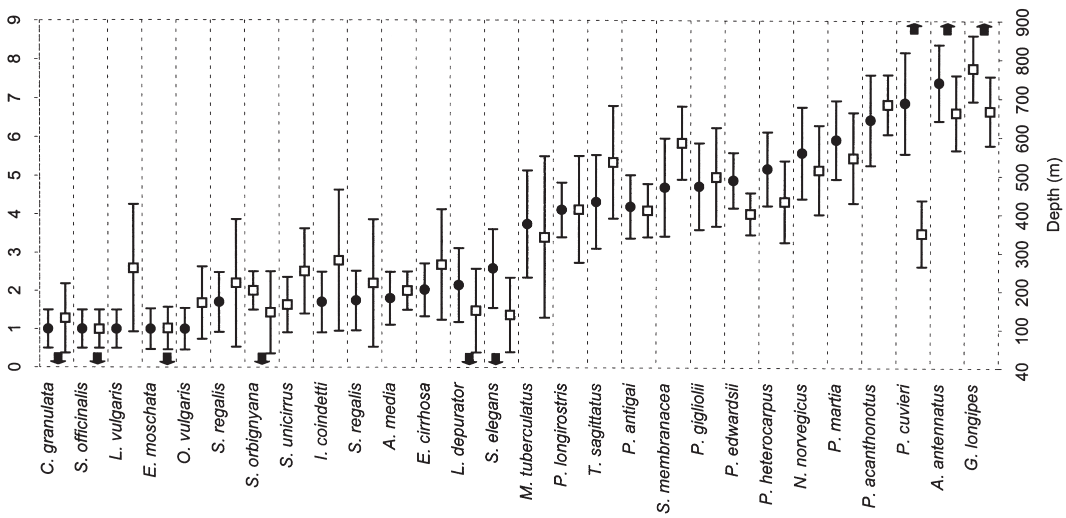

FIG. 4. – Bathymetric distribution of invertebrate species (decapod crustaceans, cephalopod molluscs and the holothurian echinoderm) in terms of centre of gravity and habitat from the BALAR0401 (black circles) and BALAR0901 (white squares) surveys. Black arrows indicate a displacement in real terms of the centre of gravity beyond the depth range sampled, according to other studies conducted in the same and adjacent areas (Maynou and Cartes, 2000; Quetglas *et al.,* 2000). Numbers 1-8 correspond to the eight depth intervals into which the bathymetric range sampled was divided (see Material and Methods). Full species names are given in Table 1.

depth was between 100 and 200 m during the two surveys.

The bathymetric distribution of the species is shown in Figures 3 and 4. Within the fishes, some species (e.g. *Chelidonichthys lastoviza*, *Scorpaena* spp., *Serranus cabrilla*, *Pagellus* spp., *Mullus* spp., *Spicara smaris*, *Uranoscopus scaber* and *Trachinus draco*) were restricted to depths shallower than 200 m, whereas others (e.g. *Chlorophthalmus agassizi*, *Micromesistius poutassou*, *Helicolenus dactylopterus*, *Phycis blennoides* and *Galeus melastomus*) were found only below this depth. Within the invertebrate species, clear differences were observed between crustaceans and molluscs. While decapods, except for *Calappa granulata*, *Liocarcinus depurator* and *Macropipus tuberculatus*, were distributed below a depth of 300 m, all cephalopods, with the only exception of *Todarodes sagittatus*, were restricted to a depth above 400 m. From the 103 species analysed, 29 fishes and 18 invertebrates were restricted to the bathymetric range surveyed. Differences in the centre of gravity and habitat of some species width were observed by comparing the two surveys.

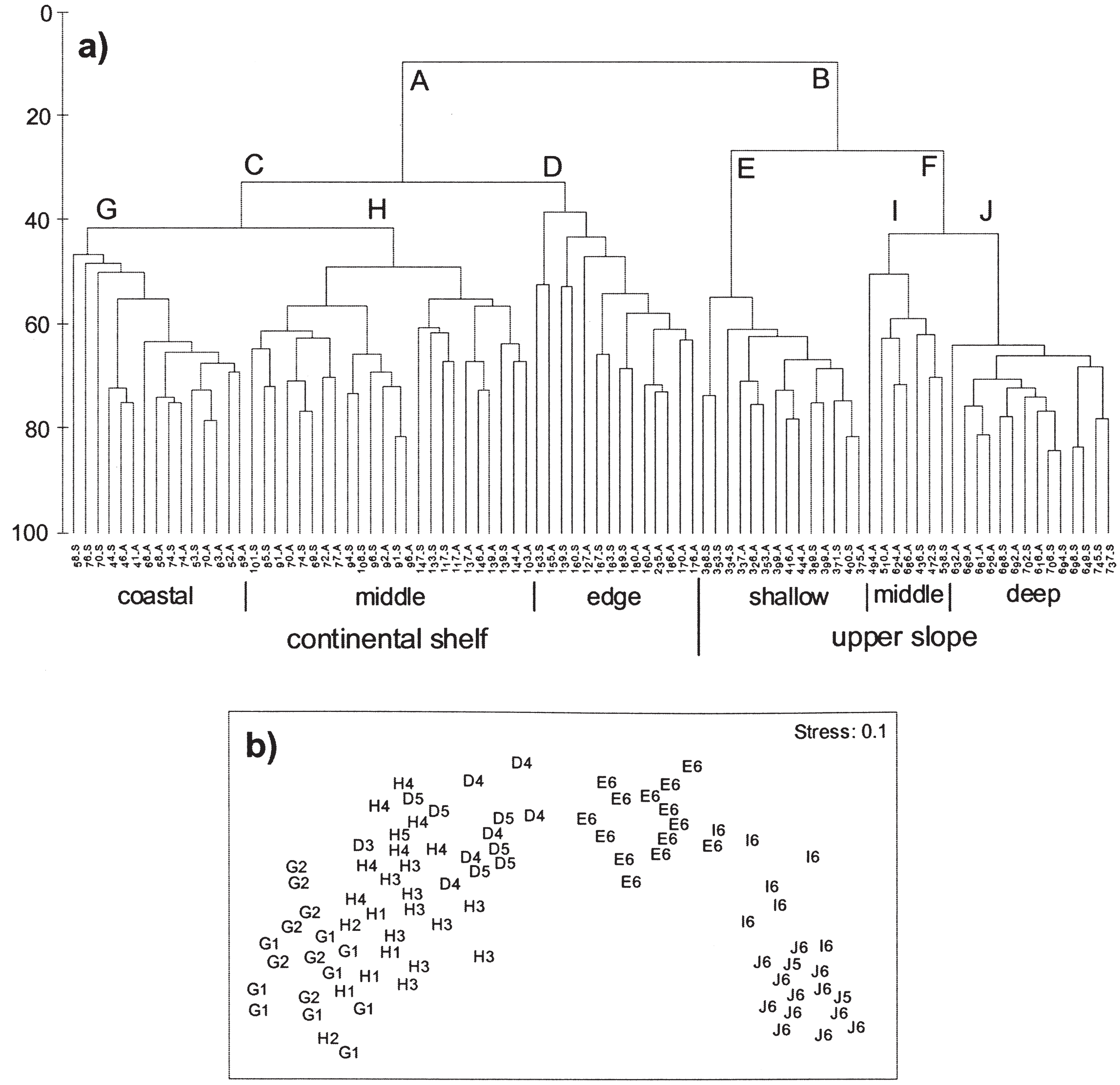

FIG. 5. – Dendrogram (a) and MDS diagram (b) of trawl samples obtained during the BALAR0401 and BALAR0901 surveys. In the dendrogram, mean depth (in metres) and season (S: spring; A: autumn) are shown for each station. In the MDS, the group obtained in the cluster analysis (letters) and the benthic community found (numbers; see Table 1 for details) are shown for each station. The stress of MDS ordination is indicated.

Demersal resource associations

Cluster analysis revealed the existence of six main groups of samples (Fig. 5a). The level of similarity of about 15% separated samples at depths between 41 and 235 m from those at depths between 326 and 745 m (noted as A and B in the figure). The level of similarity of about 30-35% separated samples at depths between 41 and 147 m from those at depths between 127 and 235 m (C and D in the figure) and samples at depths between 326 and 444 m from those at depths between 436 and 745 m (E and F in the figure). Finally, a third dichotomy was considered, which separated samples at depths between 41 and 76 m from those at depths between 69 and 147 m (G and H in the figure) and samples at depths between 436 and 686 m from those at depths between 616 and 745 m (I and J in the figure). The MDS analysis (Fig. 5b) confirmed the presence of six groups of samples (G, H, D, E, I and J), which could be related to depth: on average, 60, 106, 167, 377, 537 and 678 respectively. These groups of samples were distributed on different macro-epibenthic communities, from coastal sandy and gravel detritic bottoms (group G) to bathyal muddy soft bottoms (groups E, I and J).

The average dissimilarity between the six groups (Table 3) ranged from 78% (between I and J) to 99% (between G and I and J and between H and I and J). These differences were due to the distinct contribu-

TABLE 3. – SIMPER results: Average dissimilarity (%) between the six groups of samples identified from the cluster and MDS analyses.

	G	H	D	E	I
H	86.33				
D	92.38	84.67			
E	98.48	97.39	92.05		
I	99.89	99.67	97.95	86.51	
J	99.94	99.80	98.48	94.01	77.73

tion of species in each group (Table 4), with 10, 13, 11, 9, 3 and 3 species representing more than 90% of the groups G, H, D, E, I and J respectively. The following species could be considered as the main species of each group: (i) *S. cabrilla*, *C. lastoviza*, *Octopus vulgaris* and *Mullus surmuletus* for group G; (ii) *Lepidotrigla cavillone*, *S. smaris* and *Scyliorhinus canicula* for group H; (iii) *Chelidonichthys cuculus*, *Scyliorhinus canicula*, *Merluccius merluccius* and *Stichopus regalis* for group D; (iv) *Plesionika heterocarpus*, *Parapenaeus longirostris*, *C. agassizi* and *G. melastomus* for group E; (v) *Plesionika martia* and *P. blennoides* for group I; and (vi) *Aristeus antennatus* and *P. martia* for group J.

The values of mean abundance and mean species richness for the different groups are shown in Table 5. The lowest values for all the parameters considered corresponded to group J. By contrast, the highest values of these parameters were obtained in group H for mean abundance and in group E for mean species richness.

Differences between geographic sectors and seasons

Due to the strong relationship between the groups of samples obtained and depth, the geographical and seasonal effects within each of the assemblages defined were examined, removing the effect of depth. MDS analysis showed geographical and/or seasonal aggregations between samples in three of the six assemblages defined (Fig. 6): G, D and E.

Geographic differences were detected (ANOSIM: R= 0.51, p= 0.8) within group G (Fig. 6a). These differences were mainly due to the higher abundance of *Mullus barbatus*, *C. lastoviza* and *M. surmuletus* in the western sector, whereas *S. smaris* and *S. cabrilla* were more abundant in the

TABLE 4. – SIMPER results: mean abundance (A as individuals/30 min; ± standard error) and percentage contribution to the similarity of each group (%) of species that contributed to at least 90% of the differences between the six groups of samples identified from cluster and MDS analyses.

	A	%		A	%
Group G			Group D		
Serranus cabrilla	94.1±25.1	24.6	*Chelidonichthys cuculus*	99.8±53.7	23.6
Chelidonichthys lastoviza	95.1±21.2	21.6	*Scyliorhinus canicula*	49.4±14.3	20.8
Octopus vulgaris	28.0±4.8	9.9	*Merluccius merluccius*	60.7±19.8	19.4
Mullus surmuletus	84.2±30.6	9.3	*Stichopus regalis*	14.5±3.6	9.3
Scorpaena notata	21.9±4.6	7.1	*Mullus surmuletus*	9.3±3.7	4.9
Scyliorhinus canicula	46.1±15.9	6.8	*Lepidorhombus boscii*	6.1±1.7	3.4
Trachinus draco	12.8±2.3	3.8	*Alloteuthis media*	92.1±80.1	2.8
Mullus barbatus	143.5±83.5	3.2	*Phycis blennoides*	3.8±1.0	1.9
Scorpaena scrofa	7.9±1.3	3.0	*Lophius budegassa*	3.2±0.9	1.9
Spicara smaris	233.4±189.0	2.2	*Macropipus tuberculatus*	9.1±5.2	1.5
			Illex coindetti	4.1±1.2	1.2
Group H			Group E		
Lepidotrigla cavillone	111.2±40.7	23.2	*Plesionika heterocarpus*	226.9±94.6	17.4
Spicara smaris	623.3±367.3	16.0	*Parapenaeus longirostris*	75.7±20.1	14.7
Scyliorhinus canicula	44.1±9.9	10.1	*Chlorophthalmus agassizi*	80.0±4.5	13.7
Alloteuthis media	361.2±196.6	6.2	*Galeus melastomus*	76.1±21.5	12.0
Merluccius merluccius	34.4±10.1	6.0	*Micromesistius poutassou*	43.2±17.0	7.6
Trachinus draco	22.0±5.0	5.8	*Plesionika gigliolii*	43.6±12.4	7.5
Stichopus regalis	22.2±6.6	5.3	*Plesionika antigai*	52.6±17.0	7.4
Chelidonichthys cuculus	49.3±16.3	4.7	*Helicolenus dactylopterus*	34.6±8.7	6.7
Mullus surmuletus	42.6±13.8	4.4	*Phycis blennoides*	26.9±6.3	5.4
Mullus barbatus	43.5±23.8	3.5	Group I		
Serranus cabrilla	18.5±4.7	3.1	*Plesionika martia*	324.6±3.0	72.5
Citharus linguatula	13.8±6.2	1.3	*Phycis blennoides*	39.9±12.4	11.6
Scorpaena notata	32.4±16.9	1.3	*Plesionika gigliolii*	31.2±14.3	7.1
			Group J		
			Aristeus antennatus	136.0±25.3	71.8
			Plesionika martia	27.5±7.6	13.9
			Phycis blennoides	9.4±1.5	5.9

TABLE 5. – Mean values (± standard error) of species richness and abundance for each group identified in the cluster and MDS analyses. Mean depth (± standard deviation), depth range and the numbers of samples of each group are also shown.

	G	H	D	E	I	J
Mean species richness	16.9 (±0.8)	15.9 (±0.6)	18.3 (±0.7)	20.4 (±0.5)	16.0 (±2.2)	9.8 (±0.6)
Mean abundance (individuals/30')	882.5 (±234.9)	1217.7 (±392.7)	429 (±99.7)	842.8 (±176.2)	481.9 (±134.2)	203.4 (±29.7)
Mean depth (m)	60 (±11.4)	106 (±26.4)	167 (±25.0)	377 (±33.9)	537 (±88.4)	678 (±39.4)
Depth range (m)	41-76	69-147	139-235	326-444	472-686	649-745
Number of samples	15	24	14	14	7	14

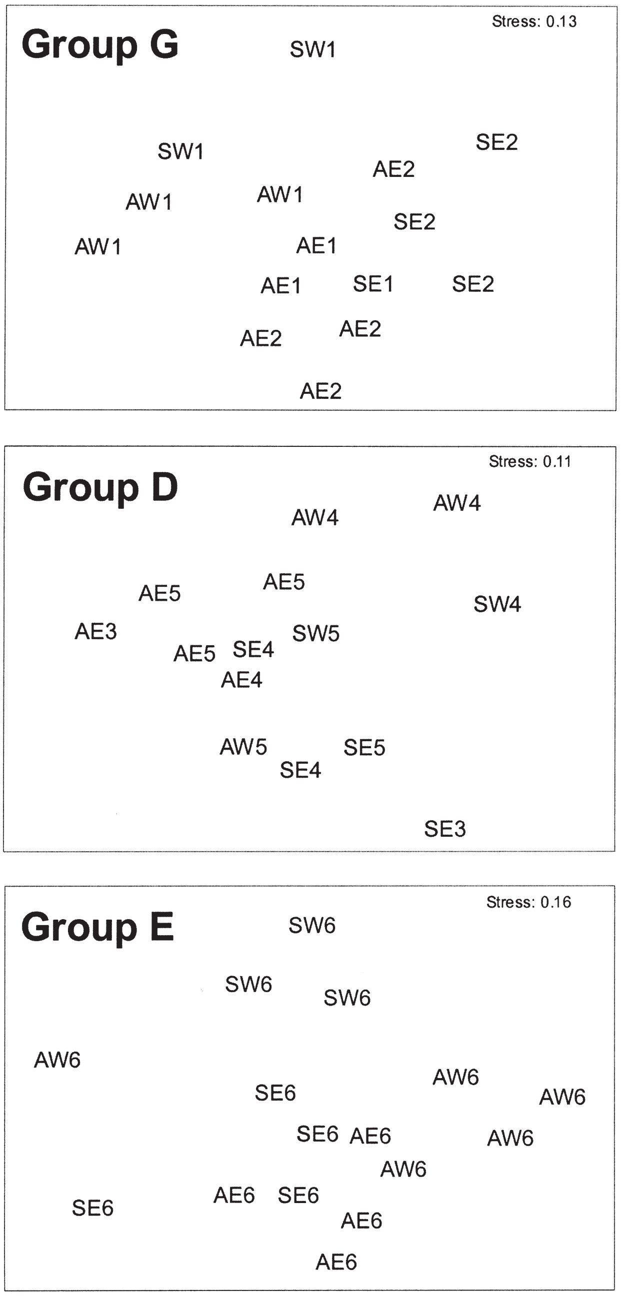

FIG. 6. – MDS diagram applied to the groups of samples C, D and E, identified from the cluster and MDS analyses (see Figure 5), which showed seasonal (S: spring; A: autumn) and/or geographical (W: west; E: east) differences. The benthic community found (numbers; see Table 1 for details) are shown for each station. The stress of MDS ordination is indicated.

eastern sector. Although group G was found on sandy and gravel detritic bottoms, all samples from the western sector were associated with soft red and green algae, while samples from the eastern sector were distributed mainly on calcareous red algae.

Group D (Fig. 6b) showed geographical (ANOSIM: R= 0.42, p= 1.2) and seasonal (ANOSIM: R= 0.40, p= 0.8) differences, with five species accounting for nearly 65% of this dissimilarity. In autumn, higher abundances were shown by *C. cuculus* and *S. canicula* in the eastern sector and by the cephalopod *Alloteuthis media* in the western sector. On the other hand, *M. merluccius* was more abundant in the eastern sector and showed a weak increase in spring.

Geographical (ANOSIM: R= 0.30, p= 2.4) and seasonal (ANOSIM: R= 0.27, p= 3.9) differences were also detected in group E (Fig. 6c). These seasonal differences were due mainly to the greater abundance of the decapods *P. heterocarpus*, *Plesionika edwardsii* and *P. martia* during autumn, together with the fishes *G. melastomus* and *C. agassizii*. In addition, all of them, except for this latter species, were more abundant in the western sector.

Accompanying macro-epibenthos

Clear differences were observed by comparing mean standardised total catch and the proportion and composition of non commercial macro-epibenthic species between the different groups identified from the cluster and MDS analyses (Fig. 7).

Group G showed the highest catch rates and percentages of non-commercial species, in which algae and echinoderms clearly predominated, while the lowest values of these parameters were obtained in groups I and J, in which fish, echinoderms and molluscs predominated within non-commercial species. The percentage of non-commercial species was also important and similar in groups H and D, with echinoderms as the main important group, but differences were observed in the catch rate, whose value in group H was higher than in group D.

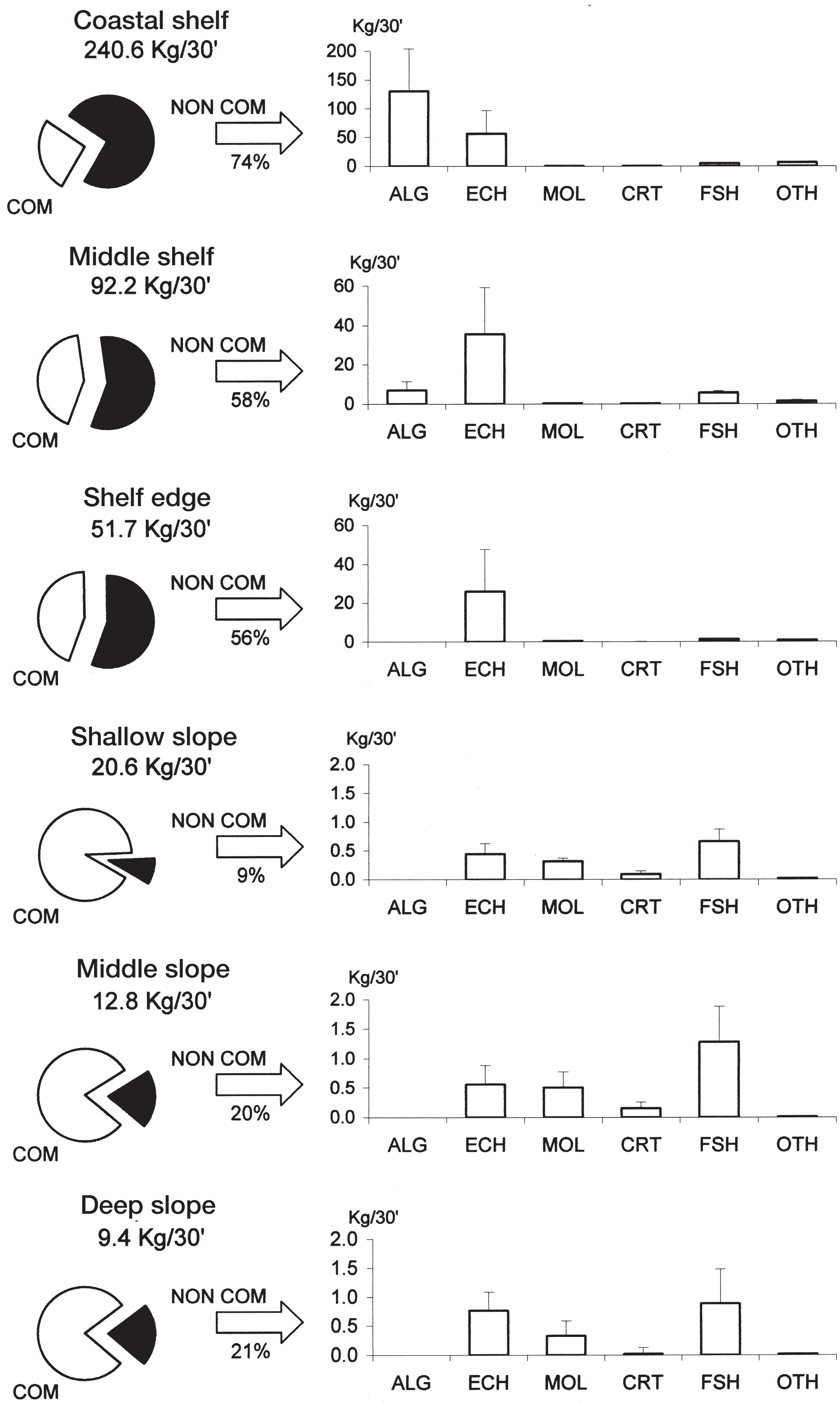

FIG. 7. – Mean standardised total catch (kg/30 min), proportion and composition of non-commercial macro-epibenthic species for each group identified in the cluster and MDS analyses. The main taxonomic groups algae (ALG), echinoderms (ECH), molluscs (MOL), crustaceans (CRT), fishes (FSH) were considered. The less abundant taxons were grouped as "others" (OTH; see Material and Methods for details).

DISCUSSION

The quantitative analysis of the demersal resources distributed in the trawl fishing grounds on the continental shelf and upper slope off Mallorca and Menorca Islands revealed the existence of six main species assemblages, which could be related to the following approximate depth intervals: (i) 40-80 m; (ii) 80-150 m; (iii) 150-250 m; (iv) 250-450 m; (v) 450-600 m; and (vi) 600-800 m. Thus, the bathymetric gradient was the principal factor for these species associations. Depth is generally considered as the most important environmental gradient in the sea and has been shown to be the main factor determining the distribution of marine fauna (e.g. Gage and Tyler, 1991). Seasonal differences in the bathymetric distribution of the species, shown by a displacement of their centre of gravity and a change in habitat width, have also been found. The possible explanatory causes of these temporal changes are far from being well known, but some causes, probably inter-correlated, can be argued. According to Kallianiotis *et al*. (2000), "water temperature over the continental shelf starts to increase in early spring and fish that winter there, gradually migrate to their spawning grounds. After spawning most fish begin their feeding migration in summer and during autumn the massive recruitment migration occurs. The fish populations return to wintering areas as the temperature decrease". Upward-downward movements of some species along the slope to feed in more productive zones and migrations linked to their life cycle (e.g. spawning and recruitment) have also been suggested for fish and decapods (e.g. Sardà *et al*., 1994a, 1994b).

The influence of depth is revealed not only at a species level but also by considering major taxonomic groups. Fish and cephalopods show a decrease in density with increasing depth, from their maximum on the continental shelf, where they are the dominant demersal resources, whereas decapods dominate on the upper slope, where they reach their maximum abundance. Similar trends have been obtained in the central (Colloca *et al*., 2003) and eastern Mediterranean (Labropoulou and Papaconstantinou, 2000). In the same study area, the bathymetric segregation of different assemblages has already been demonstrated for different taxonomic groups (Massutí *et al*., 1996; Quetglas *et al*., 2000). However, the comparison of our results with these studies, which only made a qualitative analysis of fish and cephalopod species respectively, revealed that the distribution of the demersal resources is more complex than that previously found (only four assemblages). Moreover, the comparison of our results with those obtained from the quantitative analysis of different taxonomic groups undertaken in other areas of the Mediterranean also shows that the bathymetric distribution of demersal resources, considered as a whole, is also more complex than those associations found within the separated groups of cephalopods, crustaceans and fishes (González and Sánchez, 2002; Maynou and Cartes, 2000; Demestre *et al*., 2000; respectively). On the other hand, our results are similar to those obtained from the analysis of the whole demersal macrofauna developed in the central (Biagi *et al*., 2002; Colloca *et al*., 2003) and eastern (Kallianiotis *et al*., 2000) Mediterranean, which identified assemblages on the coastal shelf, middle shelf, shelf-edge, shallow upper-slope and deep upper-slope.

The different types of macro-epibenthic communities are also an important factor for the association of demersal resources. The coastal assemblage is found on detritic sandy and gravel bottoms, characterised by a large amount of algae and echinoderm biomass (larger than those of the exploited species). In fact, it has been estimated that non-commercial species represent up to 75% of the biomass captured, but discarded, in the trawl fishery carried out in these fishing grounds (Carbonell *et al*., 1998). These coralligenous and maërl communities are very characteristic of the Mallorca-Menorca shelf up to 85-90 m depth (Canals and Ballesteros, 1997) and could be the reason for some differences observed in the coastal demersal resource structure of the Balearic Islands and the Iberian coast. *M. surmuletus* is more abundant than *M. barbatus* in insular shelf assemblages and the opposite situation is found closer to the mainland (Lombarte *et al*., 2000; Tserpes *et al*., 2002). *M. surmuletus* prefers the narrow continental shelf off the Balearic Islands, where rocky, carbonate and gravel bottoms predominate, while *M. barbatus* prefers areas where the shelf becomes wider and muddy bottoms of a terrigenous origin, which are more common off the Iberian coast.

Two facies differentiated by Pérès (1985) in the coastal detritic community have been found, with some differences in their distribution. One is dominated by calcareous red algae (maërl) and is mainly found on the east coast of Mallorca and the channel between Mallorca and Menorca. The other one is dominated by soft red and green algae, located mainly on the west and south coast of Mallorca. These differences in habitats, that could be on the basis of the geographical variations found in the coastal assemblage, can be related to different hydrodynamic conditions. The channel between Mallorca and Menorca is more affected by strong northerly winds and offshore currents (Pinot *et al*., 1995), therefore being a favourable area for the development of the maërl facies (Pérès, 1985). On the other hand, the bay of Palma is more affected by southerly winds, being a region of weakened currents more favourable for the accumulation of particles (Werner *et al.*, 1993) and hence for amassing the less dense soft red algae, a facies that only develops at the mouth of open bays (Pérès, 1985).

Middle shelf and shelf edge assemblages are mainly distributed on muddy-detritic and shelf-edge detritic communities, in which echinoderms (mainly large sea urchins) are very abundant. Non-commercial and commercial species are captured in a similar proportion in these fishing grounds, where the sediment consists of a mixture of gravel together with some sand, mud and many remnants from benthic organisms (Pérès, 1985). Similar bottoms, but characterised by the presence of *Gryphus vitreus*, have been found on the outer continental shelf and upper slope. These bottoms with large brachiopods have been described in straits between large islands or between an island and the continent (Pérès, 1985). The three characterised upper slope assemblages are distributed on bathyal muddy soft fishing grounds, which show a clear reduction in biomass and in the proportion of non-commercial species. In the western Mediterranean, an association of decapods on *Funiculina quadrangularis* and *Isidella elongata* prairies has been observed at these depths, although the effect of trawling on these bottoms, removing these large erect cnidarians, has changed their bionomy (Gili *et al.*, 1987).

The geographic and seasonal differences found in the shelf edge and the shallower upper slope assemblages could be related to different abiotic and biotic factors. The higher abundance of *Plesionika* species in the western sector could be due to the absence of submarine canyons in this area (the only submarine canyon is located on the southern coast of Menorca; Canals and Ballesteros, 1997), which can contribute to a distinct trophic web structure and energy flow in deep-sea ecosystems. According to Maynou and Cartes (2000), deposit and infaunal feeder species are more characteristic of communities in which the inputs of organic carbon via submarine canyons are an additional source of food resources, while the pandalids dominate on demersal communities whose trophic resources are of planktonic origin. In addition, the seasonal differences in species of the genus *Plesionika* can be related to their reproductive pattern. The major abundance of *P. edwardsi* and *P. martia* during autumn could be due to the fact that their maximum reproduction occurs during spring and summer (Company and Sardà, 1997), which therefore leads to the subsequent recruitment of these species in autumn. Recruitment could also be on the basis of the predominance in spring of *M. merluccius*, a species that in the northwestern Mediterranean shows a maximum recruitment during this season (Maynou *et al.*, 2003). Similarly, the recruitment in the study area of *S. canicula*, which shows higher abundance in autumn, has been reported during summer-winter (Carbonell *et al.*, 2003). These authors also estimated a higher abundance for the species in the eastern sector, suggesting that it could be caused by a lesser fishing effort in this area.

In conclusion, the existence of well-defined demersal resource assemblages, distributed on different macro-epibenthic communities, should be taken into account for future assessment and management of trawl fishery in the Balearic Islands. It could contribute to the development of multispecies and mass-balance models for the assessment of this fishery, a methodology that has increasingly been considered for the study of fisheries (e.g. Sánchez and Olaso, 2004). It could also complement the identification of fishing strategies within the fishery (Alemany and Álvarez, 2003). The management of trawl fishery should be based more on the ecosystem, with the objective of maintaining both resources and communities. This is especially necessary for coastal detritic bottoms and their maërl community, which are widespread and characteristic of the coastal fishing grounds off the Balearic Islands. This community hosts nursery areas for many species of commercial interest (Keegan, 1974), it is characterised by a high biological diversity and is high sensitive to anthropic impacts (Hall-Spencer and Moore, 2000). In fact, the importance of maërl beds has led to their inclusion in the European Union Habitats Directive 92/42/EEC and the Red Book of Threatened Seascapes (UNEP/UICN/GIS Posidonie, 1990). Lastly, from the above, it is considered necessary to undertake future research to study the quantitative aspects and biological production of these bottoms off the Balearic Islands.

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