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The role of juveniles in structuring demersal assemblages in trawled fishing grounds

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ABSTRACT

The capture of large amounts of small, immature fish of commercial species is a serious problem particularly in multispecies fisheries. Moreover, considerable and increasing interest is being devoted by fishery scientists to identify the distribution and habitat needs of species throughout their life cycle. To elucidate species composition, the abundance of juveniles in the demersal assemblages and the role of different life history (juvenile and adult) stages of target species in structuring demersal communities, two bottom trawl surveys were carried out during the autumn 2003 and 2004. Multivariate analyses were performed on density indices of adults and juveniles life stages of 30 target species and total density indices for the remainder of the catch species. Juveniles represent more than 61% of the total catch in both the years investigated and their abundance and spatial distribution was strictly related to the sea bottom biocoenotic features. Most juveniles were concentrated in the coastal shelf area and in particular in the hauls performed on the Coastal Terrigenous Mud biocoenosis (CTM). The demersal assemblages located in the slope stratum showed, in general, a lower concentration of juvenile specimens; however, some facies of the Bathyal Mud biocoenosis that characterizes the deep layer of our study area showed a very high percentage of juveniles. This information improves our understanding of ecosystem functioning and represents a useful basis for providing advice on the management of multispecies demersal fisheries within an ecosystem approach.

1. Introduction

The capture of large amounts of small, immature fish of commercial species is a serious problem that threatens the bio-economic sustainability of fisheries and the renewability of resources (Kennelly, 1995; Ward et al., 2012), particularly in multi-species fisheries (such as Mediterranean fisheries). Despite the adoption of several technical measures (gear and fishing operation) aimed at protecting juveniles, the problems related to the excessive removal of immature specimens are far from being solved (Carbonell, 1997; Stergiou et al., 1998). Moreover, the classical regulation of fisheries has thus far been based on limitations of the fishing capacity (licences), minimum landing sizes, and net mesh sizes, together with temporary fishing closures, but the establishment of no-fishing zones, particularly within nursery areas, has been increasingly advocated as a further component of the fishery management strategy (Maggs et al., 2013). As the selectivity of trawl fisheries cannot be improved beyond a certain level in multi-species demersal fisheries, such as those of the Strait of Sicily, spatial closures on nursery grounds are advocated as a more effective means of limiting the capture of juveniles and enhancing the long-term sustainability of the fishery (Caddy, 2010). Thus, the establishment of networks of fishery restricted areas (FRAs) or marine protected areas (MPAs) to protect target species and the habitats in which they are known to aggregate during the critical phases of their life cycle (e.g., spawning and nursery areas), seems a suitable and recommended management tool within an ecosystem approach (Caddy, 2010; Rijnsdorp et al., 2012). Moreover, within the general framework of an Ecosystem Approach to Fishery Management (EAFM), considerable and increasing interest is being devoted by fishery scientists to identify the distribution and habitat needs of species throughout their life cycle (Tuckey and Dehaven, 2006). Although these studies are conducted at a population level and focus on the fishery target species, they encompass habitat

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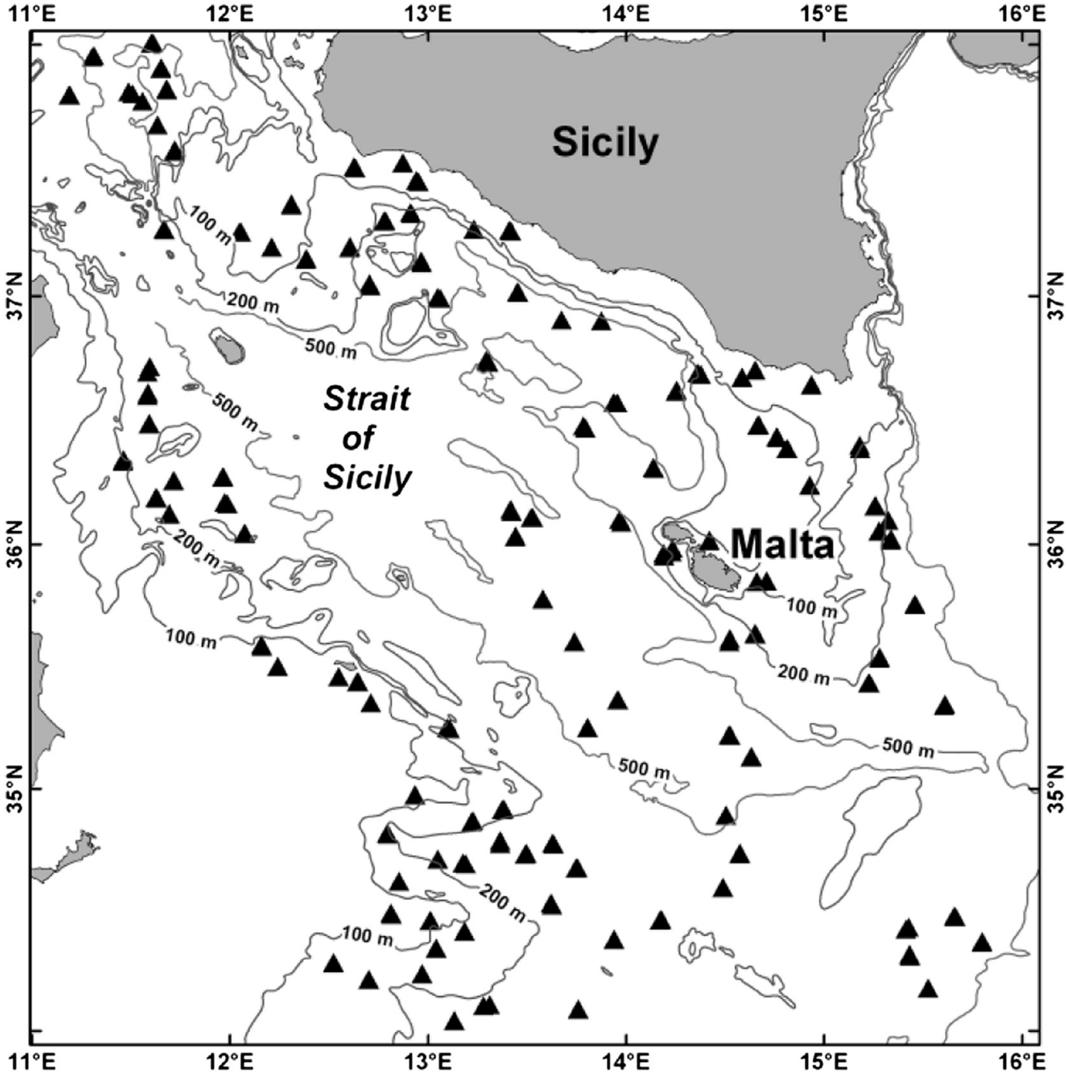


Fig. 1. Map of the Strait of Sicily showing the location of the hauls investigated.

conservation concerns and attempt to explain the spatial organisation of the key life history stages of species by investigating the biotic (benthic biocoenosis, availability of prey, presence of predators) and abiotic factors (hydrological features, sediments, availability of shelters) that may affect them. In particular, the spatial distribution of different life history stages is strictly related to the biotic and abiotic characteristics of the sea bottom, and several reports describe the role and the importance of the following structural habitats to juvenile fish: *Posidonia oceanica* meadows (Francour, 1997; Guidetti, 2000), seagrass (Thayer et al., 1999), oyster reef (Meyer and Townsend, 2000), pelagic Sargassum (Dempster and Kingsford, 2004), mangrove (Laegdsgaard and Johnson, 2001), marsh (Beck et al., 2001) and rocky reefs (Lindeman et al., 2000; Lloret and Planes, 2003). Within this framework, to support fishery management in the Strait of Sicily, which represents one of the most productive areas for demersal resources in the Mediterranean (Fiorentino et al., 2008), the stable nurseries and spawning areas of main commercial species in which the young of the year (YOY) and spawners aggregate, respectively, were mapped in recent years (Fiorentino et al., 2003; Fortibuoni et al., 2010; Garofalo et al., 2010).

However, although information on the spatial distribution of critical phases of the life cycle (e.g., spawning and nursery areas) of commercially valuable species represents a useful tool to manage demersal fishery resources (Berkeley et al., 2004; Kritzer and Sale, 2004), fishery and management research need to bridge several gaps in those regions (such as the Mediterranean) where fisheries are multispecies. In particular, we need to evolve from a single-species paradigm toward a multi-specific approach (Garcia et al., 2003) by analysing more than one nursery or critical habitat at time (Garofalo et al., 2011). In addition, the previous nursery studies were mainly focussed on the spatial distribution of the newly recruited individuals in commercial stocks, i.e., the YOY, thus underestimating the immature portion of the population and the impact of trawl fisheries. Although the YOY spatial distribution of the main portion of the target species is clearly separate from the adults, the spatial distribution of the juveniles usually overlaps with the adult fraction of the population. Attempting to overcome such challenges, this study analysed the demersal assemblages of the shelf and slope strata of the Sicilian side of the Strait of Sicily (South Mediterranean Sea), incorporating information on the abundance of two life stages of the main commercial species (30 target species): the juvenile (from YOY to sub-adult) and adult stages. The distinction of the target species into two different life stages allows us to highlight the relative importance of the life stages (juveniles and adult) of species in structuring demersal

Table 1
Cut-off (mm) for the 30 target species for the two years. The number of individuals (ind./km^2) per life stage (juvenile and adult) and per year are shown. Depth range (min., max., mean) and occurrence % per each species is also reported.

	Medits code	Cut-off (mm) 2003	Juveniles	Depth range			C.V.	Occurrence %	Adults	Depth range			C.V.	Occurrence %
				Min.	max.	Mean				Min.	max.	Mean		
Survey 2003														
Osteichthyes														
Aspitrigla cuculus	Aspicuc	165	12920.3	61	272	107.67	3.51	26.7	4455.4	63	295	37.13	3.55	25.0
Chelidonichthys lastoviza	Triples	170	7278.7	33	134	60.66	4.45	15.8	1742.0	52	134	14.52	4.10	12.5
Citharus linguatula	Cithmac	149	6933.7	35	225	57.78	3.16	22.5	7642.4	53	309	63.69	4.78	25.0
Helicolenus dactylopterus	Helidac	155	25010.1	95	629	208.42	2.59	57.5	12205.7	176	673	101.71	4.28	40.0
Lepidorhombus boscii	Lepmbos	219	703.6	184	616	5.86	3.24	19.2	224.3	194	616	1.87	4.32	11.7
Lophius budegassa	Lophbud	283	794.4	53	584	6.62	2.17	32.5	635.2	83	633	5.29	1.95	34.2
Merluccius merluccius	Merlmerl	200	61523.9	33	591	512.70	1.64	77.5	20388.1	33	673	169.90	1.88	81.7
Micromesistius poutassou	Micmpou	229	829.3	173	443	6.91	6.00	13.3	250.3	176	633	2.09	3.57	12.5
Mullus barbatus	Mullbar	173	59131.9	33	378	492.77	4.92	40.8	12059.9	33	407	100.50	2.13	46.7
Mullus surmuletus	Mullsur	173	9509.7	33	308	79.25	7.47	22.5	4185.2	38	413	34.88	2.77	29.2
Pagellus acarne	Pageaca	131	852.8	35	54	7.11	9.41	15.8	1196.0	33	252	9.97	5.43	10.8
Pagellus erythrinus	Pageery	172	4769.6	33	134	39.75	5.16	16.7	2656.8	33	194	22.14	4.73	18.3
Peristedion cataphractum	Pericat	190	10780.8	94	606	89.84	3.23	66.7	16815.2	94	517	140.13	4.20	30.8
Phycis blennoides	Phyible	188	19854.7	71	682	165.46	2.05	68.3	3594.9	131	682	29.96	1.81	48.3
Trisopterus minutus capelanus	Triscap	162	15997.2	61	309	133.31	3.29	22.5	327.4	41	309	2.73	5.01	9.2
Zeus faber	Zeusfab	171	2438.8	33	261	20.32	5.00	33.3	482.5	38	314	4.02	4.84	18.3
Chondrichthyes														
Galeus melastomus	Galumel	350	4565.6	356	682	38.05	3.52	25.8	4659.0	378	682	38.82	3.52	20.8
Raja clavata	Rajacla	449	4786.7	83	606	39.89	3.40	34.2	1882.0	71	537	15.68	2.05	39.2
Raja miraletus	Rajamir	287	1793.1	71	324	14.94	4.46	15.0	3714.5	52	324	30.95	3.54	18.3
Scyliorhinus canicula	Scyocan	270	13983.5	71	517	116.53	3.89	33.3	16844.8	63	606	140.37	1.88	52.5
Cephalopods														
Eledone cirrhosa	Eledcir	60	2010.9	89	407	16.76	2.18	31.7	803.0	89	419	6.69	3.39	20.8
Eledone moschata	Eledmos	80	2331.5	33	130	19.43	5.09	19.2	1340.7	33	124	11.17	3.00	17.5
Illex coindetii	Illecoi	105	26925.1	61	407	224.38	2.45	55.8	15094.4	61	591	125.79	2.29	71.7
Loligo vulgaris	Lolivul	102	1684.4	33	194	14.04	4.94	8.3	615.0	33	232	5.12	3.20	19.2
Octopus vulgaris	Octovul	80	2523.0	33	106	21.03	5.14	15.0	1356.3	33	212	11.30	3.87	19.2
Sepia officinalis	Sepioff	110	1031.6	33	83	8.60	5.87	9.2	351.2	41	129	2.93	5.80	9.2
Crustaceans														
Aristaeomorpha foliacea	Arisfol	34	1831.5	419.0	682.0	15.26	4.63	13.3	3740.1	419.0	682.0	31.17	3.29	15.0
Aristeus antennatus	Aritant	43	405.7	546	682	3.38	7.49	5.0	169.4	546.0	682.0	1.41	6.70	4.2
Nephrops norvegicus	Neprnor	34	5665.4	173	682	47.21	2.82	42.5	7021.9	215	682	58.52	2.11	47.5
Parapenaeus longirostris	Papelon	27	90769.1	33	638	756.41	1.93	61.7	85854.0	71	682	715.45	1.88	67.5
	Total		399,637						232,307					
Survey 2004														
Osteichthyes														
Aspitrigla cuculus	Aspicuc	155	10695.6	33	272	96.36	0.35	30.6	7246.7	67	272	65.29	2.5	31.5
Chelidonichthys lastoviza	Triples	170	7127.7	33	107	64.21	0.60	18.0	3808.3	52	113	34.31	3.9	14.4
Citharus linguatula	Cithmac	136	16388.7	53	253	147.65	0.58	26.1	6803.1	61	242	61.29	3.5	23.4
Helicolenus dactylopterus	Helidac	155	45940.8	95	629	413.88	0.66	63.1	12979.5	162	682	116.93	3.1	47.7
Lepidorhombus boscii	Lepmbos	189	1178.9	194	633	10.62	0.02	32.4	665.0	192	616	5.99	2.3	27.0
Lophius budegassa	Lophbud	251	873.8	77	625	7.87	0.01	31.5	786.9	77	682	7.09	1.6	43.2
Merluccius merluccius	Merlmerl	180	80829.8	33	629	728.20	1.16	76.6	25753.6	33	682	232.01	1.5	91.9
Micromesistius poutassou	Micmpou	173	1317.5	222	413	11.87	0.03	7.2	242.0	222	629	2.18	3.9	11.7
Mullus barbatus	Mullbar	180	98980.7	33	324	891.72	2.75	45.0	43097.4	33	407	388.26	5.6	54.1
Mullus surmuletus	Mullsur	180	4061.5	35	407	36.59	0.09	27.0	6795.9	54	479	61.22	3.9	36.0
Pagellus acarne	Pageaca	131	60.5	33	53	0.54	0.01	2.7	259.8	33	365	2.34	3.0	11.7
Pagellus erythrinus	Pageery	161	12818.8	33	117	115.48	0.99	16.2	2177.2	33	176	19.61	3.9	21.6
Peristedion cataphractum	Pericat	180	8504.6	176	537	76.62	0.14	31.5	19437.4	106	584	175.11	3.9	34.2

Table 1 (*continued*)

	Medits code	Cut-off (mm) 2003	Juveniles	Depth range			C.V.	Occurrence %	Adults	Depth range			C.V.	Occurrence %
				Min.	max.	Mean				Min.	max.	Mean		
Phycis blennoides	Phyible	225	10049.2	95	682	90.53	0.13	63.1	2451.3	130	682	22.08	2.3	39.6
Trisopterus minutus capelanus	Triscap	145	22185.9	61	309	199.87	0.65	19.8	1817.9	53	309	16.38	4.9	15.3
Zeus faber	Zeusfab	191	1991.3	33	317	17.94	0.06	44.1	354.0	67	367	3.19	3.9	18.0
Chondrichthyes														
Galeus melastomus	Galumel	338	7200.6	288	682	64.87	0.10	26.1	3882.4	367	682	34.98	2.7	21.6
Raja clavata	Rajacla	454	3526.1	83	584	31.77	0.05	36.9	2249.4	71	591	20.26	1.8	45.9
Raja miraletus	Rajamir	287	1462.7	67	324	13.18	0.04	20.7	3885.8	52	324	35.01	2.9	25.2
Scyliorhinus canicula	Scyocan	280	15549.4	90	584	140.08	0.24	38.7	17339.0	63	606	156.21	1.4	63.1
Cephalopods														
Eledone cirrhosa	Eledcir	55	2026.2	89	374	18.25	0.05	25.2	902.8	83	443	8.13	2.7	28.8
Eledone moschata	Eledmos	75	2794.9	35	151	25.18	0.17	18.0	3146.0	33	142	28.34	3.4	26.1
Illex coindetii	Illecoi	100	16621.4	61	443	149.74	0.34	53.2	11849.2	38	673	106.75	1.4	72.1
Loligo vulgaris	Lolivul	97	2262.1	33	212	20.38	0.10	9.0	750.1	33	142	6.76	2.8	16.2
Octopus vulgaris	Octovul	76	2016.3	33	268	18.16	0.07	21.6	1032.8	33	107	9.30	5.4	13.5
Sepia officinalis	Sepioff	89	605.8	33	80	5.46	0.07	10.8	288.1	54	80	2.60	4.3	6.3
Crustaceans														
Aristaeomorpha foliacea	Arisfol	35	2755.6	517	682	24.83	0.04	11.7	5943.6	419.0	682	53.55	3.0	17.1
Aristeus antennatus	Aritant	40	210.9	546	682	1.90	0.00	5.4	318.6	546	682	2.87	5.4	5.4
Nephrops norvegicus	Neprnor	29	5031.9	225	638	45.33	0.07	41.4	8120.9	225	682	73.16	2.1	49.5
Parapenaeus longirostris	Papelon	18	191968.7	35	591	1729.45	2.93	67.6	188889.9	35	673	1701.71	1.56	75.7
	Total		577,038						383,275					

assemblages. The main aims of the present study, performed at multispecies level, were as follows: 1) to evaluate the abundance of juveniles in the demersal assemblages of the study area; 2) to evaluate the overlap between the adults and juveniles within a demersal assemblage, and 3) to analyse the relationship between the abundance of the juvenile component of demersal assemblages and the benthic biocoenosis in which it mainly occurs.

2. Materials and methods

2.1. Study area

The study area covers about 45,000 km^2 of the Italian side of the Strait of Sicily. The Strait of Sicily has complex bottom morphology, characterized by troughs down to 1500 m, and steep volcanic outcrops resulting in either rocky banks or islands (Fig. 1).

According to the definition by the General Fisheries Commission for the Mediterranean (GFCM) of Geographical Sub-Areas (GSAs) (FAO GFCM, 2005), the Strait of Sicily encompasses different fishery areas. This study concerns the grounds of GSA 16 (about 34,000 km^2) which borders the southern coast of Sicily which can be trawled. Along the Sicilian coast, the shelf is characterized by two wide and shallow banks (100 m depth) on the western (Adventure Bank) and eastern (Malta Bank) sectors respectively, separated by a narrow shelf in the middle. Commercial fishing in the Strait of Sicily began in the early 1900 but the exploitation of the biological resources became intensive in the last 40 years. In this area, demersal resources are the target of the southern Sicilian bottom trawling fishery, one of the most important industrial fleets in the Mediterranean, with about 350 boats between 12 m and 24 m length overall (LOA) and 140 boats of LOA >24 m in 2009. The main target species is the deep water rose shrimp, *Parapenaeus longirostris* (Lucas, 1841), with a global yield ranging between 8000 and 10,000 t in the last years, encompassing about 75% of the total production of the species in the Mediterranean (unpubl. data).

2.2. Sampling activity

Two trawl surveys targeting demersal species were conducted in the Strait of Sicily during autumn 2003 (GR03) and 2004 (GR04) in the framework of the Italian national programme GRUND (Gruppo Nazionale Risorse Demersali) (Relini, 2000). This programme aims to produce information on abundance and demographic structure of demersal species on the continental shelves and along the upper slopes. In addition data on macro-epibenthos are collected.

The sampling gear used is the typical Italian commercial “tartana” (mesh size of 20 mm in the cod-end), with the vertical opening ranging between 0.8 and 1 m (Fiorentini et al., 1999). The stations have been distributed applying a stratified sampling scheme with random selection inside each stratum. The stratification parameter adopted was the depth, with the following bathymetric limits: inner/mid shelf 10–50/51–100, outer shelf 101–200, upper slope 201–500 and slope 501–800 m. Sampling activities were carried out during day time and a total of 223 hauls (112 in 2003 and 111 in 2004) were carried out and analyzed in the present paper.

The catch from each haul was sorted and identified to species level; the number of individuals and the total weight were recorded for each species and standardized to 1 km^2 assuming a catchability coefficient equal to 1. Moreover, all the individuals (or a representative sample in the case of very abundant catches) of 33 important commercial species were measured and the stage of sexual maturity recorded. The macro-epibenthos was identified to species level, counted, weighed and standardized to 1 km^2.

Table 2
Benthic biocoenosis/facies (sensu Pérès, 1985) identified during the bottom trawl survey in 2003 and 2004.

Benthic biocoenoses	Code	Main benthic species
Coastal terrigenous muds	CTM	*Alcyonium palmatum*, *Pennatula rubra*, *Stichopus regalis*, *Phallusia mamillata*.
Coastal detritic bottom	CD	*Lithothamnium fruticulosum*, *Vidalia volubilis*, *Anseropoda placenta*, *Chlamis flexuosa*, *Philine aperta*.
Coastal detritic bottom, association with *Laminaria rodriguezii*	CD Lam	*Laminaria rodriguezii*, *Suberites domuncula*, *Astropecten irregularis*, *Spatangus purpureus*, *Lithophyllum racemus*.
Bathyal muds, facies with *Funiculina quadrangularis*	BM Fun	*Funiculina quadrangularis*, *Thenea muricata*, *Aporrhais* sp., *Parapenaeus longirostris*.
Bathyal muds, facies with sandy and gravel bottom	BM Sgb	*Cidaris cidaris*, *Terebratula vitrea*.
Bathyal muds	BM	*Caelorhynchus caelorhynchus*, *Gadiculus argenteus*, *Galeus melastomus*, *Hymenocephalus italicus*.
Bathyal muds, facies with *Isidella elongata*	BM Isi	*Isidella elongata*, *Aristaeomorha foliacea*, *Scalpellum scalpellum*.

2.3. Partition of adults and juveniles

For the 30 target species for which length and maturity data were collected, individuals were classified into two size classes corresponding to the juvenile (from YOY to immature) and adult life phase. The size limit (cut-off) was identified on the basis of a two step procedure. Firstly, the length frequency distribution of immature specimens (maturity stage 1) was constructed according to a macroscopic scale of gonadal development (Gristina et al., 2004). Then, in order to reduce the bias due to erroneous inclusion in stage 1 (immature) of adults which are not in a reproductive state, the size corresponding to the upper quartile of the distribution was arbitrarily selected. Hence, density indices of juveniles (J) for each species were calculated by counting the number of individuals whose total length was equal to or less than the specific cut-off. The adult fraction (A) accounted for the number of individuals whose total length exceeded the cut-off. In order to take into account of differences between years, the procedures, including the cut-off estimation, were applied keeping the year separate.

2.4. Multivariate analysis

In order to identify demersal assemblage structure, a similarity matrix was constructed using the Bray–Curtis measure of similarity on Log transformed data. To evaluate the influence of different life phases on structure and spatial distribution of the assemblages Adult (A) and Juvenile (J) specimens of the 30 target species examined were included in the matrix as different variables. For each survey nonmetric multidimensional scaling (MDS) (group average on Log-transform data) using the Bray–Curtis similarity index was applied to the similarity matrix. Dominant species of the demersal assemblages were identified using the SIMPER procedure (Clarke and Gorley, 2001), by estimating the average contribution of each species to the similarity (typifying species) between groups of samples. One-way analyses of similarities (ANOSIM) (Clarke, 1993) were used to test for significant differences between years. Multivariate analyses were carried out with the PRIMER software (Plymouth Routines In Multivariate Ecological Research) (Clarke, 1993).

To assign the hauls to one of the benthic communities characteristic of the circalittoral soft bottoms of Mediterranean Sea according to Pérès (1985), we analysed the overall catch (bony fishes, elasmobranches, crustaceans, cephalopods and macro-epibenthos). This information was used to identify a biocoenotic pattern in the MDS ordination of demersal species.

Table 3
Characteristics of the seven clusters identified in terms of the average similarity, number of hauls and depth (average ± St. dev).

Cluster/biocoenosis	N°. Hauls		Mean depth	
	2003	2004	2003	2004
CTM	5	7	40 ± 8	43 ± 14
CD	6	6	68 ± 16	57 ± 12
CD Lam	15	16	96 ± 22	98 ± 31
BM Fun	24	21	190 ± 61	197 ± 72
BM Sgb	35	29	318 ± 80	278 ± 86
BM	11	16	478 ± 83	416 ± 43
BM Isi	16	16	625 ± 46	614 ± 47

3. Results

A total of 1,592,257 specimens belonging to 30 demersal taxa (16 bony fish, 4 elasmobranchs, 6 cephalopods and 4 crustaceans) were collected from a total of 223 hauls during the two surveys carried out in autumn 2003 (112 hauls) and 2004 (111 hauls) (Table 1). Juveniles represent about the 61% of the total catch in both the years and the remainder were adults. Bony fishes accounted for approximately 49% in terms of total number of individuals, Crustaceans exceeded 37%, whilst Elasmobranchs and Cephalopods represented a minor fraction of the total catch. Bony fishes were the taxonomic group with the higher percentage of juvenile individuals accounted 73 and 71% in 2003 and 2004 respectively, followed by Cephalopods with 65 and 59% of juveniles in the two years. Crustaceans and Elasmobranchs showed the lower percentage of juveniles with about 50% in 2003 and 2004.

Among the bony fishes, *Trisopterus minutus capelanus*, *Phycis blennoides*, *Zeus faber* and *Mullus barbatus* showed the higher percentage of juveniles, whilst *Pagellus acarne* and *Peristedion cataphractum* the higher contribution of adult individuals (Table 1). *Parapenaeus longirostris* and *Aristaeus antennatus* presented >50% juveniles, while *Aristaeomorpha foliacea* and *Nephrops norvegicus* showed 56–68% adults (Table 1). Among Elasmobranchs, *Raja clavata* and *Galeus melastomus* had 50–72% juveniles, while *Raja miraletus* showed a very high percentage of adult specimens abundance both in 2003 and 2004 (68% in 2003; 72% in 2004) (Table 1). Concerning the benthic communities, seven main biocoenosis or facies were detected (Table 2).

Coastal terrigenous muds and detritic bottom were the main benthic biocoenosis on the coastal shelf, while the Bathyal muds biocoenosis with different facies dominated on the slope. Number of hauls per year and relative mean depth (±s.d.) are reported for each of the seven Biocoenosis/facies identified (Table 3).

3.1. Multivariate analysis

The two-dimensional MDS revealed a clear separation of demersal assemblages within the ordination diagram (Fig. 2). The stress value for the two ordinations ranged from 0.1 to 0.11 and are indicated on each MDS plot. Moreover, the MDS ordination showed that demersal assemblages were grouped according to the predefined biocoenosis/facies with significant difference between them (2003: ANOSIM, $R = 0.901$, $P < 0.001$; 2004: ANOSIM, $R = 0.922$, $P < 0.001$) (Fig. 2). In both years, the characteristics of the benthic biocoenosis/facies attributed *a priori* for each hauls affects the distribution of the demersal assemblages.

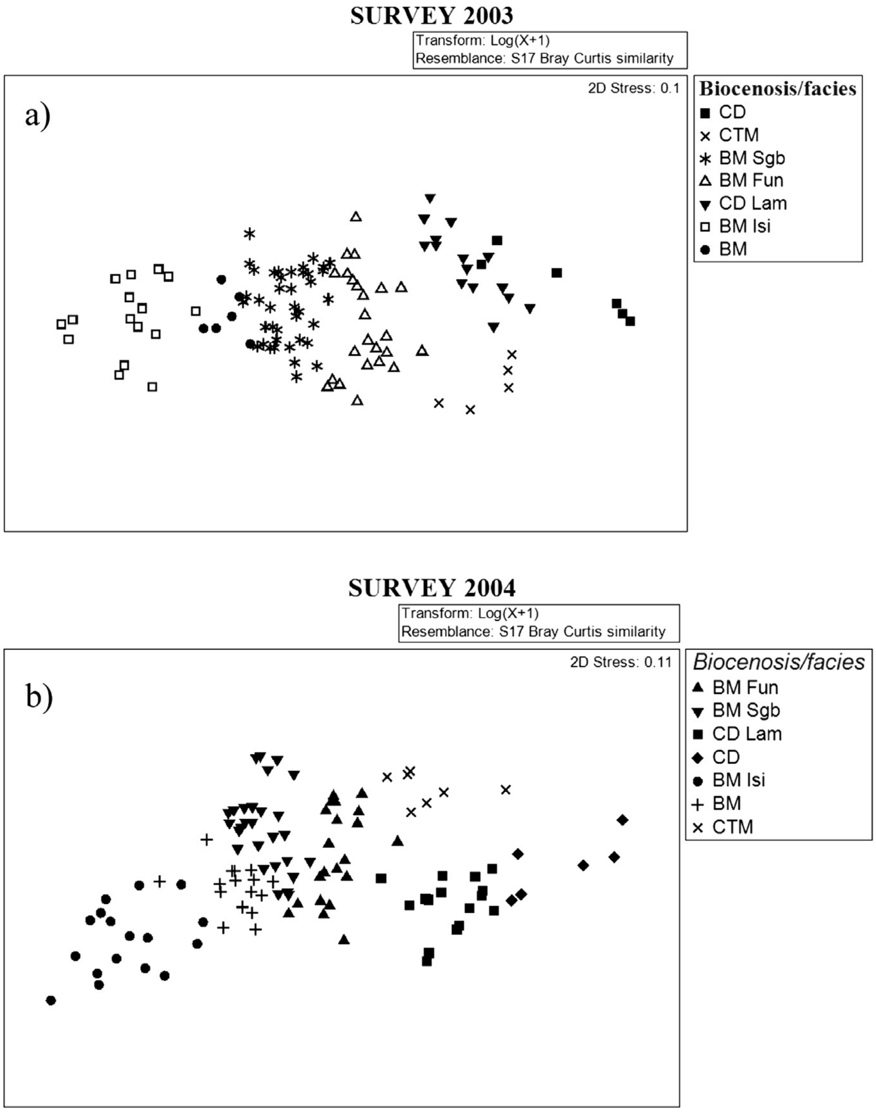


Fig. 2. MDS performed on the hauls during trawl surveys (GRUND) for 2003 (a) and 2004 (b). The benthic biocoenosis/facies identified *a priori* (symbols) are shown for each haul.

The bathymetric range occupied by the identified biocoenosis/facies are very similar between the two years (Table 3). Coastal terrigenous muds (CTM) and Coastal detritic bottom (CD) were the main benthic biocoenosis in the coastal shelf, while the Bathyal muds biocoenosis (BM) with different facies dominated in the upper slope (BM Fun and BM Sgb) and in the slope (BM and BM Isi). The one-way ANOSIM performed between surveys 2003 and 2004 showed that the identified assemblages are consistent among the years (Table 4) with no significant differences between the same clusters of the two years investigated.

Table 4
Results of the ANOSIM pairwise test to analyse the differences between the same clusters of the two years investigated using the groups resulting from the cluster analysis.

Biocoenosis	Year		Biocoenosis	Year	R_{stat}	P
CTM	2003	VS	CTM	2004	0.13	>0.3
CD	2003	VS	CD	2004	0.12	>0.5
CD Lam	2003	VS	CD Lam	2004	0.13	>0.2
BM Fun	2003	VS	BM Fun	2004	0.18	>0.5
BM Sgb	2003	VS	BM Sgb	2004	0.27	>0.5
BM	2003	VS	BM	2004	0.43	>0.5
BM Isi	2003	VS	BM Isi	2004	0.11	>0.2

3.2. Distribution of juveniles and adults per biocoenosis/facies

Fig. 3 shows the percentage of juvenile (ind/Km^2) specimens in the seven groups identified by the cluster analysis. Coastal Terrigenous Muds (CTM) biocoenosis, and Coastal Detritic (CD)

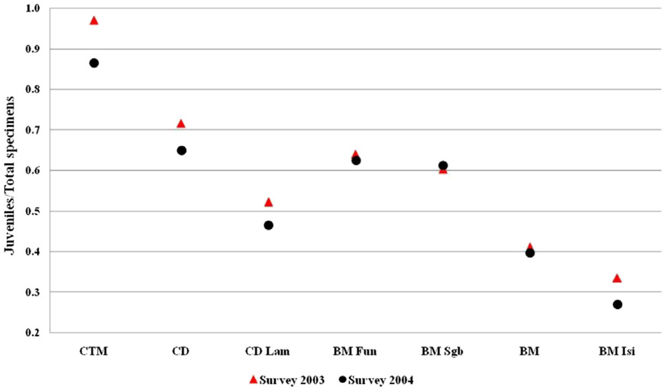
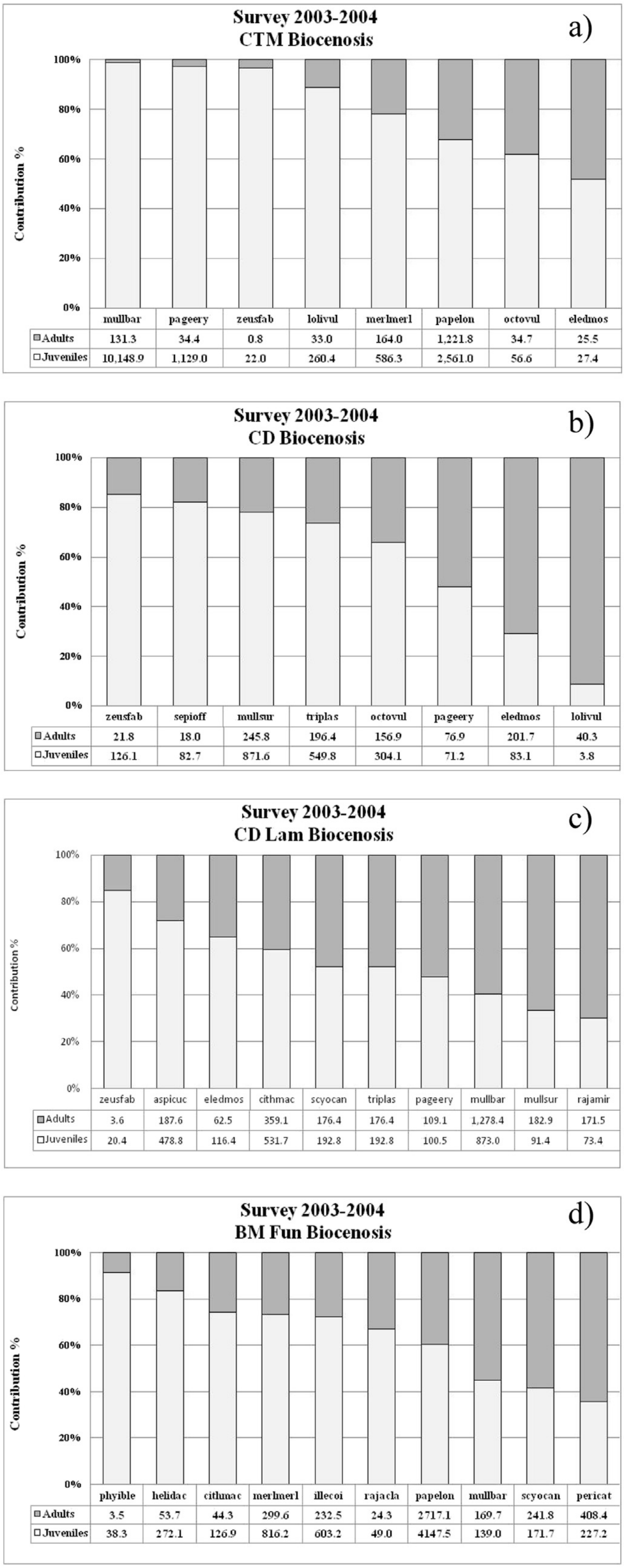


Fig. 3. Percentage of juveniles (ind./km^2) on the total catch per cluster and per survey.



Survey 2003-2004
CTM Biocenosis

	mullbar	pageery	zeusfab	lolivul	merlmerl	papelon	octovul	eledmos
▨ Adults	131.3	34.4	0.8	33.0	164.0	1,221.8	34.7	25.5
☐ Juveniles	10,148.9	1,129.0	22.0	260.4	586.3	2,561.0	56.6	27.4

Survey 2003-2004
CD Biocenosis

	zeusfab	sepioff	mullsur	triplas	octovul	pageery	eledmos	lolivul
▨ Adults	21.8	18.0	245.8	196.4	156.9	76.9	201.7	40.3
☐ Juveniles	126.1	82.7	871.6	549.8	304.1	71.2	83.1	3.8

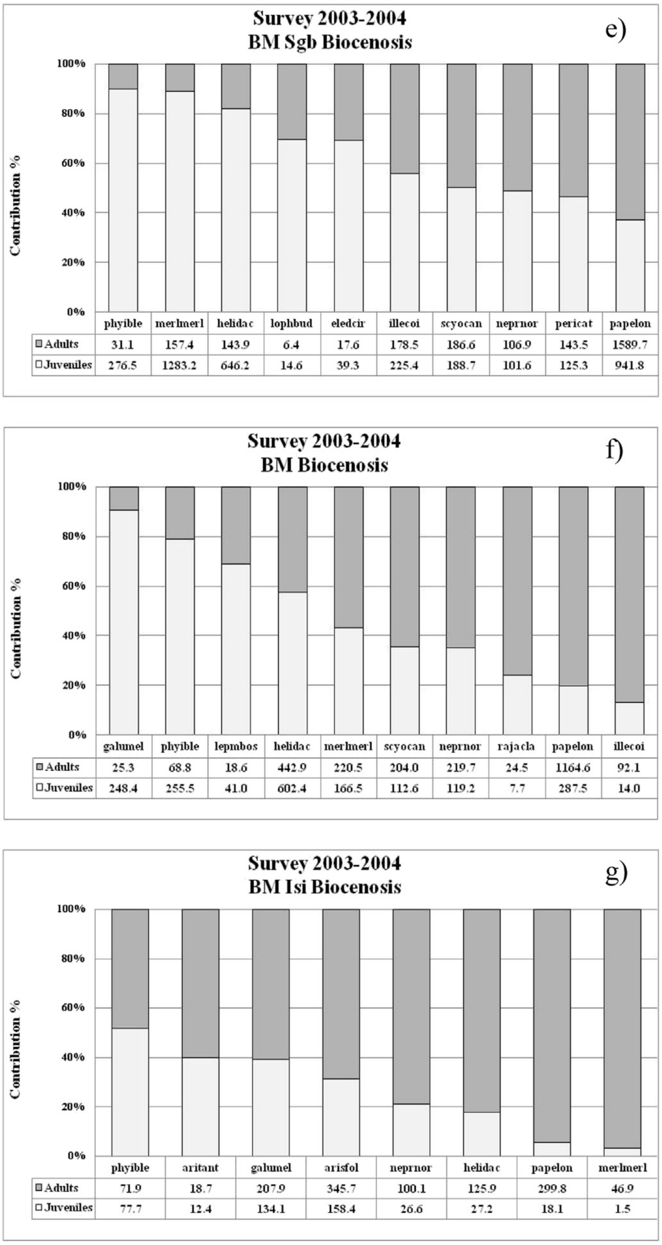
Survey 2003-2004
CD Lam Biocenosis

	zeusfab	aspicuc	eledmos	cithmac	scyocan	triplas	pageery	mullbar	mullsur	rajamir
▨ Adults	3.6	187.6	62.5	359.1	176.4	176.4	109.1	1,278.4	182.9	171.5
☐ Juveniles	20.4	478.8	116.4	531.7	192.8	192.8	100.5	873.0	91.4	73.4

Survey 2003-2004
BM Fun Biocenosis

	phyible	helidac	cithmac	merlmerl	illecoi	rajacla	papelon	mullbar	scyocan	pericat
▨ Adults	3.5	53.7	44.3	299.6	232.5	24.3	2717.1	169.7	241.8	408.4
☐ Juveniles	38.3	272.1	126.9	816.2	603.2	49.0	4147.5	139.0	171.7	227.2

Fig. 4. a–g – Percent distribution of juveniles and adults in the seven clusters identified. Only the species and life stages contributing, in total, to >80% of the average similarity are plotted.



Survey 2003-2004
BM Sgb Biocenosis

	phyible	merlmerl	helidac	lophbud	eledcir	illecoi	scyocan	neprnor	pericat	papelon
▨ Adults	31.1	157.4	143.9	6.4	17.6	178.5	186.6	106.9	143.5	1589.7
☐ Juveniles	276.5	1283.2	646.2	14.6	39.3	225.4	188.7	101.6	125.3	941.8

Survey 2003-2004
BM Biocenosis

	galumel	phyible	lepmbos	helidac	merlmerl	scyocan	neprnor	rajacla	papelon	illecoi
▨ Adults	25.3	68.8	18.6	442.9	220.5	204.0	219.7	24.5	1164.6	92.1
☐ Juveniles	248.4	255.5	41.0	602.4	166.5	112.6	119.2	7.7	287.5	14.0

Survey 2003-2004
BM Isi Biocenosis

	phyible	aritant	galumel	arisfol	neprnor	helidac	papelon	merlmerl
▨ Adults	71.9	18.7	207.9	345.7	100.1	125.9	299.8	46.9
☐ Juveniles	77.7	12.4	134.1	158.4	26.6	27.2	18.1	1.5

Fig. 4. (*continued*).

biocoenosis showed the highest percentage of juveniles in both the years investigated with a peak of 0.97 in 2003. However, when the Coastal Detritic (CD) biocoenosis was in association with *Laminaria rodriguezii* (CD Lam) the percentage of juveniles significantly decreased reaching values of approximately 50% (Fig. 3). The juvenile specimens percentage decreased in the clusters of the upper slope stratum showed values higher than 60%, whilst the clusters of the slope (BM and BM Isi) always gave a density of juveniles <40% (Fig. 3).

Simper analysis highlighted the most abundant species and life stages within each cluster and the species (or life stage) that typify the community within each cluster. Only those species (or life stages) contributing, in total, to 80% of the average similarity in the performed Simper analysis are discussed. Given the results of the ANOSIM pairwise test between the years (Table 4), we decided to analyse the contribution of each species and life stage mediating the data of 2003 and 2004.

Fig. 4a–g shows percent contribution of juveniles and adults of the species that contribute to characterizing the clusters (80% of the average similarity). *Mullus barbatus* was the species that mainly characterized the CTM biocoenosis with more than 98% of juveniles and a negligible fraction of adults. *Parapenaeus longirostris*, although having >70% juveniles, showed an important amount of adult individuals. All the species contributing to structure the assemblage showed >60% juveniles. Only the cephalopods *Eledone moschata* had a ratio of juveniles/adults close to the 50% (Fig. 4a).

The CD biocensosis also had a high percentage of juveniles but the specific composition was very different from that recorded in CTM biocoenosis. *Zeus faber* and *Sepia officinalis* had a low number of specimens but were the species with the higher percentage of juveniles (more than 80%) (Fig. 4b). *Pagellus erythrinus*, *Eledone moschata* and *Loligo vulgaris* were the only species with <50% juveniles.

When the CD biocoenosis was in association with *Laminaria rodriguezii* (CD Lam), the associated demersal assemblage showed notable differences. The percentage of juveniles strongly decreased to approximately 50% and species with high commercial value such as *Mullus barbatus* and *Mullus surmuletus* presented a consistent fraction of adult individuals (60% and 67% respectively) (Fig. 4c). However, the CD Lam facies seems to be an important area for concentration of juveniles of bony fishes (*Zeus faber*, *Aspitrigla cuculus*) and for elasmobranchs (*Scyliorhinus canicula*, *Raja miraletus*).

The demersal assemblages identified in correspondence of the biocoenosis pertaining to the slope stratum showed different patterns and a higher contribution of adult life stage. In particular, BM biocoenosis in association with *Funiculina quadrangularis* (BM Fun) showed a demersal assemblage in which the percentage of juveniles was of about 60% of the total catch. Bony fishes (*Phycis blennoides*, *Helicolenus dactylopterus*, *Merluccius merluccius*), *Illex coindetii* and *Raja clavata* mainly contributed to the juvenile fraction, whilst *Mullus barbatus*, *Scyliorhinus canicula* and *Peristedion cataphractum* showed an adult fraction always >55% (Fig. 4d).

The demersal assemblage associated to the BM biocoenosis with sandy and gravel bottom (BM Sgb) showed a similar pattern and similar juveniles percentage (about 60%). The species that contributed to the juvenile fraction were the same as that recorded in BM Fun, while the adult fraction was characterised by the very large abundance of *Nephrops norvegicus* (52%) and *Parapenaeus longirostris* (63%) (Fig. 4e). BM biocoenosis (BM) was characterised by a percentage of juveniles of only 40%. *Galeus melastomus*, *Phycis blennoides*, *Lepidorhombus boscii* and *Helicolenus dactylopterus* showed an important fraction of juveniles whilst the other species characterizing the assemblages presented the adult fraction ranging from 67% (*Merluccius merluccius*) to 98% (*Illex coindetii*). Within these, crustaceans of high commercial value such as *P. longirostris* and *N. norvegicus* were characterized by a very important fraction (65% and 81% respectively) of adult individuals (Fig. 4f).

Finally, the demersal assemblages related to Bathyal Muds biocoenosis, facies at *Isidella elongata* (BM Isi), that occupied the deeper part of the slope (Table 3) presented a very low percentage of juveniles (Fig. 4g). Only *Phycis blennoides* in this assemblage had >50% juveniles, while all the other species showed a very high contribution of the adult fraction.

4. Discussion and conclusions

The present study describes the demersal community in a wide area on the north side of the Strait of Sicily, an area that is exploited almost exclusively by a multi-species trawling fishery, and how the different life stages of the demersal commercial species (juvenile and adult) can contribute to its structuring. In particular, the division of 30 target species into two different life stages (J ad A) allows us to evaluate the abundance of juveniles and the adult component and to verify for each target species which life stage mainly contributed to the structuring of the demersal community. Due to the fine mesh size of Mediterranean bottom trawling, this information is relevant to assessment of the vulnerability of the fish assemblage to fishery impacts. More than 61% (approximately 971,277 individuals) of the 30 target species caught in surveys during 2003 and 2004 were juveniles (Table 1). The percentage of caught juveniles shows a substantial homogeneity in the two sampling years, ranging from a minimum of 60% in 2003 to a maximum of 63% in 2004. Moreover, the large amount of juveniles in the sampled demersal community could be explained by the very high recruitment of *Octopus vulgaris*, *Mullus barbatus* and *Mullus surmuletus* occurring in late summer-early autumn (Fiorentino et al., 2008).

Seven assemblages were identified in terms of the species component and percent contribution of the juvenile or adult fractions of the target populations. The juvenile and adult phases of the commercial species overlap at the community level, with different fractions on the shelf-break and slope strata (Fig. 3). In the CD Lam, BM Fun and BM Sgb demersal assemblages, the juveniles represent more than 50% of the total catch. Instead, in the deeper stratum (BM and BM Isi assemblages), more than 60% of the community is represented by adult specimens, whereas we observe an absolute dominance of the juvenile individuals in the shallower stratum (CTM and CD assemblages).

Due to the specific ecological requirements (food type, temperature range, availability of shelter) of the different life stages of each species (Fracour et al., 2001), the benthic biocoenosis that characterises the sea bottom for each cluster plays a fundamental role in aggregating the adult and juvenile fractions of the population. Within this context, several previous studies (Colloca et al., 2003a; Massutì and Renones, 2005; Brokovich et al., 2006; Tissot et al., 2006) described benthic biocoenosis as a fundamental factor driving the spatial distribution of demersal assemblages. Moreover, information on the aggregating role of biocoenosis on the demersal organisms are usually concentrated in the upper coastal shelf (Guidetti, 2000; Thayer et al., 1999; Lloret and Planes, 2003), whereas currently there is little or no information on shelf break and slope (both upper and deep).

The Coastal Terrigenous Mud (CTM) benthic biocoenosis was demonstrated to be an appropriate habitat for the early life-history stages of many species. In particular, the *Mullus barbatus* juveniles provided a significant contribution to this assemblage in terms of abundance and of percent contribution to the average similarity. In line agreement with previous studies, the CTM biocoenosis is the preferred habitat for the early life-history stages of *M. barbatus* in the late summer/early autumn (Lombarte and Aguirre, 1995; Levi et al., 2003). Moreover, the high abundance of juvenile stages of species with a high commercial or recreational importance (*Merluccius merluccius*, *Parapenaeus longirostris* and *Pagellus erythrinus*) were associated with this biocoenosis in both years, whereas the presence of adult specimens is mainly due to the cephalopods (*Octopus vulgaris* and *Eledone moschata*) (Fig. 4a).

In agreement with several previous papers (Keegan, 1974; Hall-Spencer and Moore, 2000), the Coastal Detritic Bottom (CD) biocoenosis also represents a very important habitat for the juveniles of many coastal species (*Zeus faber*, *Sepia officinalis* and *Mullus surmuletus*). In contrast, our data show that the CD biocoenosis associated with *Laminaria rodriguezii* (CD Lam) presents the minimum juvenile concentration in the coastal shelf habitat but represents a valuable habitat for the adult specimens of *Mullus barbatus*, *M. surmuletus*, *Pagellus erythrinus* and *Raja clavata*.

Bathyal Mud (BM), with different facies, characterised the biotic aspect of the hauls conducted on the shelf break, upper slope and slope. However, facies also seem to play fundamental roles in structuring the demersal assemblages and aggregating the different life stages in the deeper strata. Bathyal Mud biocoenosis with facies of *Funiculina quadrangularis* (BM Fun) and sandy and gravel bottom (BM Sgb) facies, showed the maximum percentage of juveniles on the slope. In this habitat, the juvenile specimens of *Phycis blennoides*, *Helicolenus dactylopterus*, *Callionymus maculatus* and *Merluccius merluccius* presented a high density. Furthermore, in agreement with Peres and Picard (1964), BM Fun seems to be an appropriate habitat for the adult phase of *Mullus barbatus*, *Scyliorhinus canicula* and *Peristedion cataphractum*.

Instead, in facies of BM Sgb, juveniles coexist with a relevant fraction of the adult population for *Scyliorhinus canicula*, *Nephrops norvegicus*, *Peristedion cataphractum* and *Parapenaeus longirostris*.

The deepest clusters associated with Bathyal mud biocoenosis (BM) and Bathyal mud facies of *Isidella elongata* (BM Isi) are characterised by a general decrease of the mean catch. Increasing depth is associated with a decrease in the abundance and biomass at the community level (Pérès, 1982) but in the deeper biocoenosis (and in both the BM and BM Isi facies), the demersal community is characterised by approximately 70% adult specimens of high commercial value (*Merluccius merluccius*, *Scyliorhinus canicula*, *Raja clavata*, *Illex coindetii*, *Aristaeus antennatus*, *Aristaeomorpha foliacea*, *Parapenaeus longirostris* and *Nephrops norvegicus*) and by a very small fraction of juveniles (*Galeus melastomus* and *Phycis blennoides*).

Our results describe on a wide bathymetric range (10–800 m depth) the amount of juveniles and their fraction of the total catch by different assemblages/biocoenoses. These values can be considered as a measure of the potential vulnerability of the community to the effect of the low selectivity that characterises the fine-mesh multispecies trawling fisheries (up to 40 square/50 diamond mesh opening in the cod-end) in the Mediterranean (Regulation EC1967/2006). The opportunity given by this study to identify the demersal assemblages in which the juvenile life stage of species with a high commercial value are concentrated can represent a useful tool to develop a management plan aimed at a sustainable exploitation of the biological resources. To protect the juveniles stages, strategies based on both the seasonal closure of the nursery areas and/or the adoption of gear with a selectivity higher than that current gear (grid and other devices) could be pursued.

Moreover, our study associates the main fish assemblages and their life stage component to a specific biocoenosis/facies. This link represents a major step in the general framework of the Ecosystem Approach to Fisheries Management. Although the growing effort to incorporate the effects of habitat on the early life-stage survival into stock assessments (Beck et al., 2001; Peterson, 2003), the importance of certain biocoenosis/facies to juvenile fish aggregation/production remains unknown. Management measures should recognise the high vulnerability to fine-mesh trawling of the VTC and CD communities in terms of a high catch of juveniles and undersized fish of these habitats and the necessity to regulate trawling activities in these areas.

The Green paper of the European Common Fishery Policy (2009) to reduce the impacts of fishing on the marine Ecosystem proposed major measures to discourage fishermen catching undersized, over-quota and non-marketable species and also severe regulations to protect sensitive habitats (e.g., Coralligenous, Maerl Beds, *Posidonia* meadows). Thus, the link between species and habitats is both a speculative exercise widely accepted by scientists and conservationists and also an important management tool to be developed and monitored in the general framework of EU policy.

Further studies, seasonal surveys in particular, are needed to describe better the contribution of the two life stages (A and J) in structuring demersal assemblages and to produce a management plan based on the periodic rotation of closed areas as a function of the biological cycle and the spatial distribution of the critical life stages of species or pool of species that need protection.

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