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Deep-Sea Research II

Effects of deep-water coral banks on the abundance and size structure of the megafauna in the Mediterranean Sea

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A R T I C L E   I N F O

A B S T R A C T

The Santa Maria di Leuca (SML) coral banks represent a rare example of living *Lophelia-Madrepora*-bearing coral mounds in the Mediterranean Sea. They are located between 350 and 1100 m in depth, in the northern Ionian Sea (eastern-central Mediterranean). Using a multi-beam echo sounder, side-scan sonar, high-resolution seismics and underwater video, the zones were identified for the sampling demersal fauna without damaging the coral colonies. During September–October 2005 experimental samplings were carried out with longlines and trawl nets inside the coral habitat and outside, where fishery exploitation occurs. No significant differences were shown between the abundance of fish recorded using longlines in the coral and non-coral habitat even though some selachians and teleosts were more abundant in the former than in the latter. Large specimens of rockfish (*Helicolenus dactylopterus*) and blackspot seabream (*Pagellus bogaraveo*) were commonly caught using longlines in the coral habitat. Data from trawling revealed refuge effects in the coral habitat and fishing effects outside. Significant differences were detected between the recorded abundances in the two study areas. Greater densities and biomasses were obtained inside the coral area, and fish size spectra and size distributions indicate a greater abundance of large fish inside the coral habitat. The SML coral habitat is a spawning area for *H. dactylopterus*. The remarkable density of the young-of-the-year of the deep-water shark *Etmopterus spinax* as well as of *Merluccius merluccius*, *Micromesistius poutassou*, *Phycis blennoides* and *H. dactylopterus*, indicates that the coral habitat also acts as nursery area for these demersal species, which are exploited outside. Considering the evidence of the negative impact of bottom trawling and, to a lesser extent, of longlining, the coral banks can provide a refuge for the conservation of unique species and habitats as well as in providing benefit to adjacent fisheries through the spill-over effect both of eggs, larvae, juveniles and adults.

1. Introduction

The Santa Maria di Leuca (SML) coral banks represent a rare example of living *Lophelia-Madrepora*-bearing coral mounds in the Mediterranean Sea. Dead and living colonies are widespread in an area of about 900 km², between 350 and 1100 m depth, in the northern Ionian Sea (southern Italy) (Tursi et al., 2004; Taviani et al., 2005). Although its species diversity is lower than for its Atlantic counterparts, this area represents a biodiversity "hotspot" within the bare muddy bottoms of the Mediterranean bathyal grounds (Rosso, 2003; Tursi et al., 2004; Longo et al., 2005; Mastrototaro et al., 2010). The complexity and diversity of the SML coral habitat are most probably linked to the energetic trophic system and to hydrographic factors in the northern Ionian Sea, where an important coupling between the water column production process and the transfer of particulate matter to the bottom has been recorded (De Lazzari et al., 1999).

Fishing activities using mostly trawl nets and longlines are carried out around the SML coral area. The presence of coral banks is known to the local fishermen, who experience gear damage and losses; but they often fish close to this area ("fishing the line", Roberts and Hawkins, 2000) with the aim of catching large specimens. In fact, side-scan sonar and underwater video images show the characteristic seabed scars of otter trawls ploughing through the coral banks, and some investigations have found corals with entangled longlines and pieces of coral branches on the bottom (Tursi et al., 2004; Taviani et al., 2005).

Considering the impact of trawling and, to a lesser extent, of other fishing gears on the white coral banks (Roberts and Anderson, 2000; Hall-Spencer et al., 2001; Koslow et al., 2001; Fosså et al., 2002; Reed, 2002), the General Fisheries Commission for the Mediterranean (GFCM) decided in January 2006 on recommending the prohibition of towed gears (dredges and trawl nets) in the deep-water coral banks of SML. Moreover, for conservation objectives, two other deep-sea sites in the Mediterranean High Seas were selected: the chemosynthesis-based cold-seep ecosystem near the Nile Delta and Eratosthenes seamount, offshore from Cyprus. In order to protect all these

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sites the GFCM has created the new legal category of "Deep-sea fisheries restricted area". The GFCM recommends members to notify the appropriate authorities in order to protect these ecosystems from the impact of any other activities jeopardizing the conservation of the features that characterize these particular habitats.

The protection measures for coral habitats can combine biodiversity conservation and fisheries management objectives (Reed, 2002). Several studies report that many fish species use coral habitats for shelter, feeding, spawning and/or nursery areas (Fosså et al., 2002; Heifetz, 2002; Husebo et al., 2002; Krieger and Wing, 2002; Reed, 2002; Costello et al., 2005; Morgan et al., 2005; Ross and Quattrini, 2007). In the coral habitats individuals of the associated fauna live longer and grow larger, their density increases, and the production of offspring is enhanced. Thus, the fisheries can be supplemented through "spill-over" of juveniles and adults into adjacent fishing grounds. The species collected inside and close to the SML coral banks provide evidence that such habitats would play an important role as a refuge and replenishment area for deep-water species, both commercial and otherwise (Tursi et al., 2004). In contrast, the species and communities exploited on the shelf and upper slope grounds around these coral banks generally exhibit the typical effects of fishing (Jennings and Kaiser, 1998; Stergiou, 2002 and references therein), such as decrease in stock abundance, reduction in body size, truncated age structure, and increase in variability with time (Tursi et al., 1998; Mytilineou et al., 2001; D'Onghia et al., 2003).

Recently, the SML coral area has been investigated as part of the Apulian PLAteau Bank Ecosystem Study (APLABES) project, funded for the FIRB programs by the Italian Ministry of Universities and Research (MIUR) and coordinated by Consorzio Nazionale Interuniversitario per le Scienze del Mare (CoNISMa). During this project the team from the Department of Animal and Environmental Biology (University of Bari) collected information on benthopelagic fish, crustaceans and cephalopods inside and outside the coral area. The aim was to examine the effects of such an area, where fishing occurs in peripheral zones, on the distribution, abundance and size structure of these deep-water megafauna, compared to a nearby area without corals, where fishing is fully developed. The lack of a suitable control area, that is an area without corals and unexploited, on the upper slope muddy bottoms along the north-western Ionian Sea, implies the consideration of two main factors in the objective of this work: the corals and the fishing. In particular (1) the presence of corals and the virtual absence of fishing inside the SML coral area and (2) the absence of corals and active fishing outside the SML coral area.

2. Demersal fisheries resources around the coral banks

The white coral banks are located about 25–45 km from the coast off Cape Santa Maria di Leuca (Fig. 1). The fisheries belonging to the marine administrative district of Gallipoli (Compartimento Marittimo di Gallipoli) operate around the coral banks. Although different fishing gear is used, like trawl nets, gillnets and longlines, trawling is the main fishing technique employed in the fishery. The trawlers are equipped with Italian-type trawl nets, with 40-mm stretched mesh size in the cod-end (European legal mesh size). Fishing occurs from Monday to Friday during day-light hours only. Trawlers generally work on daily trips; they set off at 03.00–04.00 h in the morning and return to the harbour at 15.00–16.00 h or at 18.00–19.00 h in winter and summer, respectively. Commercial hauls are carried out at different depths, generally from 200 to 750 m. Fishing is not allowed at night or on weekends.
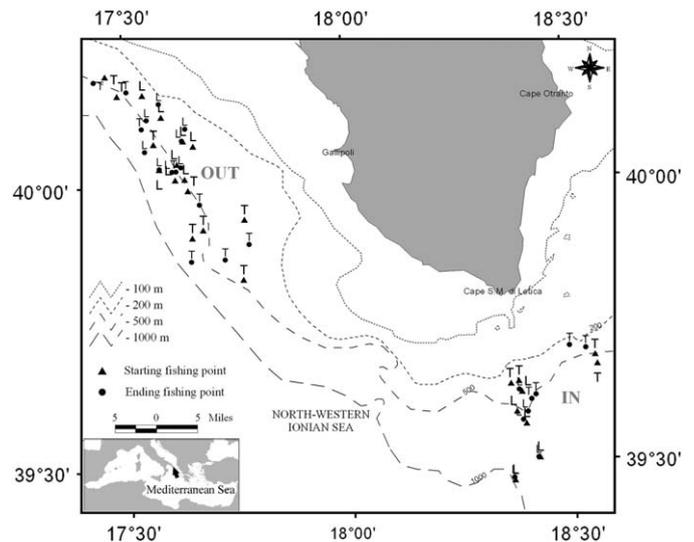

Fig. 1. Map of the stations sampled by longline (L) and trawl net (T), inside (IN) and outside (OUT) the coral habitat in the north-western Ionian Sea.

The most important resources in the area are represented by the deep-water shrimp (*Aristeus antennatus* and *Aristaeomorpha foliacea*), which constitute up to about 60% of the weight and 66% of the economic value of the total catch (D'Onghia et al., 1998a, 1998b; Carlucci et al., 2003). Other important ground-fish resources are hake (*Merluccius merluccius*), blue whiting (*Micromesistius poutassou*), greater forkbeard (*Phycis blennoides*), rockfish (*Helicolenus dactylopterus*), deep-water rose shrimp (*Parapenaeus longirostris*) and Norway lobster (*Nephrops norvegicus*), which can often provide an important contribution to the whole catch (Tursi et al., 1994, 1998; D'Onghia et al., 2003). Some other commercial deep-water species found in the area are anglerfish (*Lophius piscatorius* and *Lophius budegassa*) and golden shrimp *Plesionika heterocarpus*, *Plesionika edwardsii* and *Plesionika martia*. Cephalopods provide a small contribution to the total commercial catch; the horned octopus (*Eledone cirrhosa*) and squid, such as *Illex coindetii* and *Todaropsis eblanae*, are the main cephalopod species caught by the trawl nets (Tursi et al., 1994, 1998). In addition, many other species are generally caught and discarded due to their lack of economic value. Among them, the most abundant species are the selachians *Galeus melastomus* and *Etmopterus spinax* and the teleosts *Hoplostethus mediterraneus*, *Caelorinchus caelorhincus*, *Nezumia sclerorhynchus* and *Hymenocephalus italicus* (D'Onghia et al., 1998c, 1998d, 2000a, 2003; Sion et al., 2000, 2003).

Longlines target hake, greater forkbeard, blackspot seabream (*Pagellus bogaraveo*), the bluntnose sixgill shark (*Hexanchus griseus*), piper (*Trigla lyra*), tub gurnard (*Trigla lucerna*), European conger (*Conger conger*) and silver scabbardfish (*Lepidopus caudatus*) (D'Onghia et al., 2000b).

3. Materials and methods

Data were collected inside (IN) the coral habitat, where fishing is not performed, and outside (OUT) the coral habitat where fishing is frequent (Fig. 1). During May–June 2005 a bathymetric and geomorphologic survey was carried out inside the coral area (Savini and Corselli, 2010) using the research vessel "*Universitatis*" from CoNISMa. A multi-beam echo sounder, a side-scan sonar, high-resolution seismics, and underwater video were used to identify zones suitable for the sampling of demersal fauna without damaging the coral colonies. Indeed, the structural

Table 1
Sampling stations with mean depth and geographic coordinates, carried out inside (IN) and outside (OUT) the coral habitat.

	Gear	Station	Depth (m)	Fishing starting point		Fishing ending point	
				Latitude	Longitude	Latitude	Longitude
Coral habitat							
IN	Trawl net	1	549	3940080N	1833520E	3936527N	1824415E
IN	Trawl net	2	317	3938274N	1821686E	3942040N	1829809E
IN	Trawl net	3	520	3941045N	1833233E	3936970N	1824998E
IN	Trawl net	4	340	3938517N	1822792E	3941762N	1832008E
IN	Longline	1	367	3937387N	1823167E	3937574N	1822789E
IN	Longline	2	520	3933998N	1823613E	3935207N	1823843E
IN	Longline	3	525	3935329N	1822403E	3934352N	1823207E
IN	Longline	4	649	3930396N	1825317E	3930366N	1825089E
IN	Longline	5	799	3928033N	1821847E	3928300N	1821705E
Non-coral habitat							
OUT	Trawl net	1	311	3956450N	1746180E	3953800N	1746740E
OUT	Trawl net	2	368	4011910N	1727650E	4010200N	1730500E
OUT	Trawl net	3	407	3950110N	1745850E	3952220N	1743420E
OUT	Trawl net	4	536	4004610N	1734080E	4006250N	1732470E
OUT	Trawl net	5	537	4009820N	1729230E	4011280N	1726060E
OUT	Trawl net	6	541	3959660N	1738600E	4001660N	1737020E
OUT	Trawl net	7	548	3955450N	1740540E	3958110N	1740110E
OUT	Trawl net	8	551	3954620N	1739050E	3952090N	1738810E
OUT	Longline	1	300	4009850N	1732700E	4008870N	1734910E
OUT	Longline	2	337	4004330N	1739460E	4006180N	1738400E
OUT	Longline	3	412	4004920N	1738080E	4004900N	1737910E
OUT	Longline	4	466	4000850N	1738210E	4002100N	1737710E
OUT	Longline	5	479	4007490N	1735190E	4007170N	1733200E
OUT	Longline	6	535	4002450N	1737200E	4003840N	1732810E
OUT	Longline	7	712	4000800N	1736930E	4001640N	1736480E
OUT	Longline	8	749	4001960N	1734760E	4001960N	1734750E

habitat complexity of the white coral banks made it difficult to perform and standardize sampling. Three sites with muddy bottoms between the mounds were selected in the coral area. The sampling of demersal fauna, using a bottom longline and trawl net, both inside (IN) and outside (OUT) the coral area, was carried out during September–October 2005. However, a greater number of replicates were taken outside of the coral area, due to the more regular seafloor where commercial fishing usually occurs. Thus, five experimental hauls with a longline and four tows with a trawl net were carried out inside the coral area (IN), while eight experimental hauls with a longline and eight tows with a trawl net were conducted outside (OUT) the coral habitat (Table 1). The longline sampling covered depths between 300 and 800 m, while the trawls were carried out between 300 and 560 m, the only feasible depth interval in the coral area.

The longline was a bottom type about 4000–5000 m long, with 500 hooks set at a distance of 6–9 m. *Sardina pilchardus* was used as bait and each longline was installed for about 4–5 h. The trawl net was a nylon otter trawl with a stretched mesh-width of 40 mm in the cod-end. The horizontal and vertical net opening, measured by means of the SCANMAR sonar system and depending on various factors (depth, warp length, towing speed, etc.), ranged from 12 to 16 m and from 0.6 to 0.7 m, respectively. The longlines and trawls were employed using a commercial vessel from the Santa Maria di Leuca fishery.

Length (mm), weight (g) and sex were recorded for each collected fish, crustacean and cephalopod. Abundance in number and weight of the megafauna collected by each gear was standardised to N/100 hooks and kg/100 hooks for the longline and to N/km² and kg/km² for trawling (Pauly, 1983).

Multivariate analysis was performed to detect significant differences between the faunal assemblage of the upper slope coral area (IN) and of the muddy fishing grounds (OUT). Matrices of abundance per species-station were compiled using fourth root transformation. Classification and ordination of the sampling stations were performed by means of Cluster Analysis and non-metric Multidimensional Scaling (nMDS), respectively, based on the Bray–Curtis similarity index using the PRIMER 5 software (Clarke and Warwick, 2001). The nMDS preserves the rank order of the inter-sample distance, as opposed to the linear relationship of classical metric scaling. This analysis is not sensitive to outliers and it has been widely used to explain the space ordination of samples (in this paper two-dimensional space ordination was used). Moreover, the stress values obtained from nMDS have been utilized as an adequacy measure of representation for two-dimensional ordination (preservation of the original inter-sample distance, increasing adequacy-decreasing stress value) in order to minimise potential misinterpretation of the data (Clarke and Warwick, 2001). ANalysis Of SIMilarities (ANOSIM) was applied to test the differences between the groups of the species-station identified by the nMDS analysis. Individual species contributions (up to about 90%) to average dissimilarity between the groups identified were examined using the SIMPER procedure (Clarke and Warwick, 2001).

Fish size spectra were plotted for species collected by trawling inside and outside the coral habitat. Since trawl fishing causes a decrease in the abundance of large-sized specimens and species and an increase in the small-sized specimens and species, the fish size spectrum was regarded as a broad indicator of the combined refuge-fishing effects (Rice and Gislason, 1996; Rochet and Verena, 2003). Thus, we expected to observe different size spectra parameters between the fish assemblage inside the coral area (refuge area) and that outside (fishing area). The fish size spectra were plotted as the relationship between the logarithm of abundance and the sizes of fish species grouped by size classes (Gislason and Rice, 1998; Bianchi et al., 2000). This relationship was evaluated by means of linear regression and the relative set of parameters for the two habitats was compared statistically using the Chow-test (Koutsoyiannis, 1977). This test verifies if there is a significant difference between the slope (b) and the intercept (a)

of two regression lines estimated from two different sample groups. In the fish size spectra, a steeper slope and a greater intercept indicate a decrease in the abundance of larger fish (Gislason and Rice, 1998; Bianchi et al., 2000).

Finally, length–frequency distributions were computed for the most abundant species, which displayed the greatest dissimilarity in abundance between the two habitat types. Statistical differences between these size distributions were evaluated by means of the Kolmogoroff–Smirnov test (Möller, 1979).

4. Results

4.1. Distribution and abundance of the megafauna collected by longline

The abundance of specimens increased with depth in both study areas (Fig. 2). A total of 22 species (1 cephalopod, 6 elasmobranches and 15 teleosts) were caught with comparable average values between the two areas (Table 2). The only cephalopod species (Todarodes sagittatus) was captured outside the coral banks, while all the elasmobranch species were caught inside. Only E. spinax and G. melastomus were collected both IN and OUT with comparable abundance. Although eight and five hauls were realized outside and inside, respectively, even for the teleosts a greater number of species was caught IN than OUT. The blackspot seabream (P. bogaraveo), was only collected in the coral area where big specimens were also observed on underwater video-footage (Fig. 3). The rockfish (H. dactylopterus) was exclusively caught within the coral area, with a noteworthy number of specimens of large size, some of which in maturing and mature conditions (Figs. 4 and 5). The teleosts Mora moro and P. blennoides were caught with greater average abundance

inside than outside the coral habitat while other teleosts were sampled with comparable mean abundance values in the two areas. Multivariate analyses did not provide significant differences between the analyzed samples. Large specimens of G. melastomus, E. spinax, M. merluccius and P. blennoides were caught both IN and OUT. No significant differences were observed between the size distributions of the two areas.

4.2. Distribution and abundance of the megafauna collected with trawl net

Density and biomass obtained using the trawl net exhibited a decreasing trend with depth, as well as greater values were observed IN than OUT (Fig. 6). A greater number of species was collected with this gear: 14 cephalopods, 19 decapod crustaceans, 5 elasmobranches and 39 teleosts (Table 3).

Concerning cephalopods, a total of 12 and 8 species were caught inside and outside the coral area, respectively. The species collected in both areas showed greater average abundance IN than OUT. In particular, for the species I. coindetii, Pteroctopus tetracirrhus, Sepietta oweniana and T. eblanae both density and biomass values were greater inside than outside the coral habitat.

With regard to the crustaceans, all the 19 species were recovered outside the coral banks while only 7 were obtained inside. However, for some species common to both areas, like Macropipus tuberculatus, N. norvegicus and Polycheles typhlops, the average abundances were greater OUT than IN. In contrast, other crustaceans, such as P. longirostris, P. heterocarpus and P. martia, showed greater mean densities and biomass inside the coral area.

A total of 5 and 4 chondrichthyes were caught inside and outside the coral area, respectively. The average density and biomass values computed for each species were greater IN than OUT.
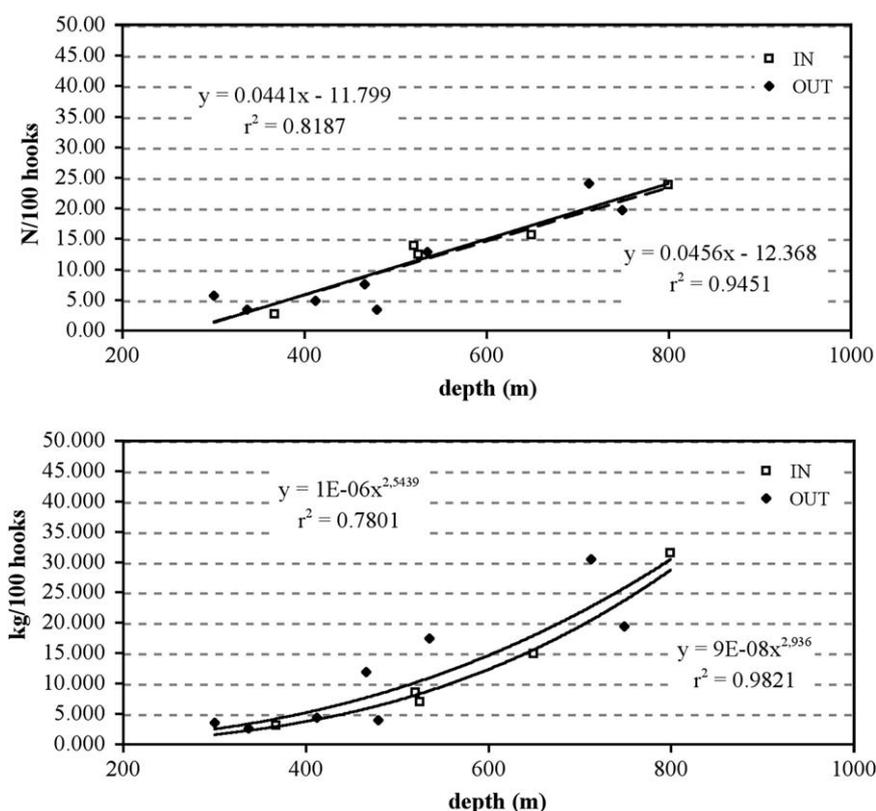

Fig. 2. Relationship of abundance versus depth, with regression lines, curves and parameters, computed for the megafauna caught by longline inside (IN) and outside (OUT) the coral habitat.
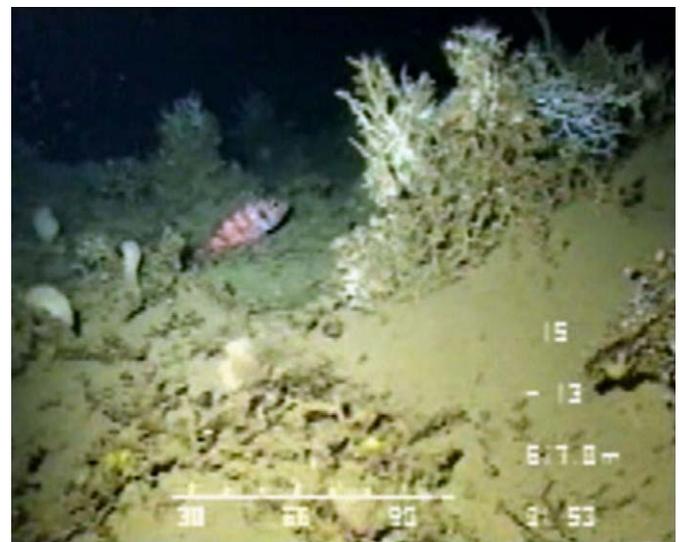
Table 2
Longline mean value of density (N/100 hooks) and biomass (kg/100 hooks) indices inside (IN) and outside (OUT) the coral habitat.

Species	N/100 hooks				kg/100 hooks			
	IN		OUT		IN		OUT	
	Mean	± s.d.	Mean	± s.d.	Mean	± s.d.	Mean	± s.d.
Cephalopods								
Todarodes sagittatus	–	–	0.03	0.08	–	–	0.02	0.05
Chondroichthyes								
Centrophorus granulosus	0.09	0.21	–	–	0.34	0.76	–	–
Etmopterus spinax	1.26	2.21	0.55	0.63	0.24	0.40	0.13	0.16
Galeus melastomus	4.64	2.80	5.02	6.84	1.49	0.87	1.88	2.63
Hexanchus griseus	0.05	0.10	–	–	2.31	5.18	–	–
Leucoraja circularis	0.05	0.11	–	–	0.13	0.30	–	–
Dipturus oxyrinchus	0.10	0.13	–	–	0.78	1.13	–	–
Osteichthyes								
Brama brama	0.05	0.11	0.04	0.11	0.14	0.32	0.03	0.08
Conger conger	1.08	1.29	1.48	1.67	2.99	4.07	6.15	7.59
Coryphaena hippurus	0.09	0.21	–	–	0.06	0.14	–	–
Helicolenus dactylopterus	2.26	2.13	–	–	0.56	0.53	–	–
Lepidopus caudatus	0.05	0.11	1.02	1.13	0.10	0.23	1.30	1.37
Merlangius merlangus euxinus	–	–	0.03	0.10	–	–	0.01	0.04
Merluccius merluccius	1.25	1.04	1.34	0.89	2.50	1.84	1.58	1.06
Micromesistius poutassou	–	–	0.20	0.30	–	–	0.07	0.11
Molva dipterygia	0.05	0.10	–	–	0.03	0.07	–	–
Mora moro	1.57	3.52	0.17	0.42	0.69	1.54	0.11	0.26
Pagellus bogaraveo	0.28	0.42	–	–	0.16	0.23	–	–
Phycis blennoides	0.80	0.80	0.27	0.34	0.44	0.53	0.27	0.31
Polyprion americanus	–	–	0.02	0.06	–	–	0.14	0.40
Ruvettus pretiosus	0.05	0.10	–	–	0.05	0.10	–	–
Chelidonichthys lucerna	–	–	0.02	0.06	–	–	0.01	0.04

s.d.=standard deviation.

Fig. 3. A large specimen of *P. bogaraveo* recorded by underwater video inside the coral habitat.

Fig. 4. A large specimen of *H. dactylopterus* recorded by underwater video inside the coral habitat.

Due to the different number of tows (8 OUT versus 4 IN), a greater number of teleost species was collected OUT (36) than IN (24). Despite this difference, the common species to the two areas showed much greater average abundance IN than OUT. In particular for *Capros aper*, *Chlorophthalmus agassizii*, *C. caelorhincus*, *C. conger*, *Gadiculus argenteus*, *H. dactylopterus*, *H. mediterraneus*, *Lepidorhombus boscii*, *M. merluccius*, *M. poutassou*, *Phycis blennoides* and *T. lyra* density and biomass average values were greater inside than outside. In the grenadiers *H. italicus* and *N. sclerorhynchus*, the average biomass values were greater IN than OUT, while it was the opposite for its density values. Among the species common to the two areas, both density and biomass average values were only greater OUT than IN for *Trachyrincus scabrus*.

Multivariate analysis provided significant results. In particular, the dendrograms from cluster analysis based on both density and biomass data show the presence of two main groups of species/stations according to depth ranges of 311–407 and 520–551 m (Fig. 7). Moreover, within each of these two groups a further
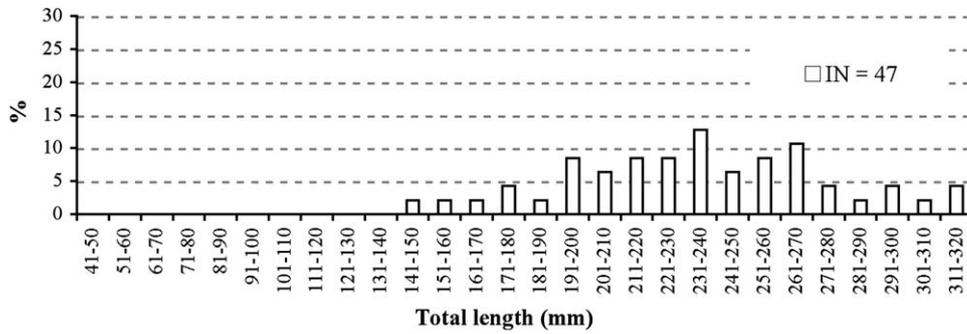
Fig. 5. Length–frequency distribution of *H. dactylopterus* caught by longline inside (IN) the coral habitat.
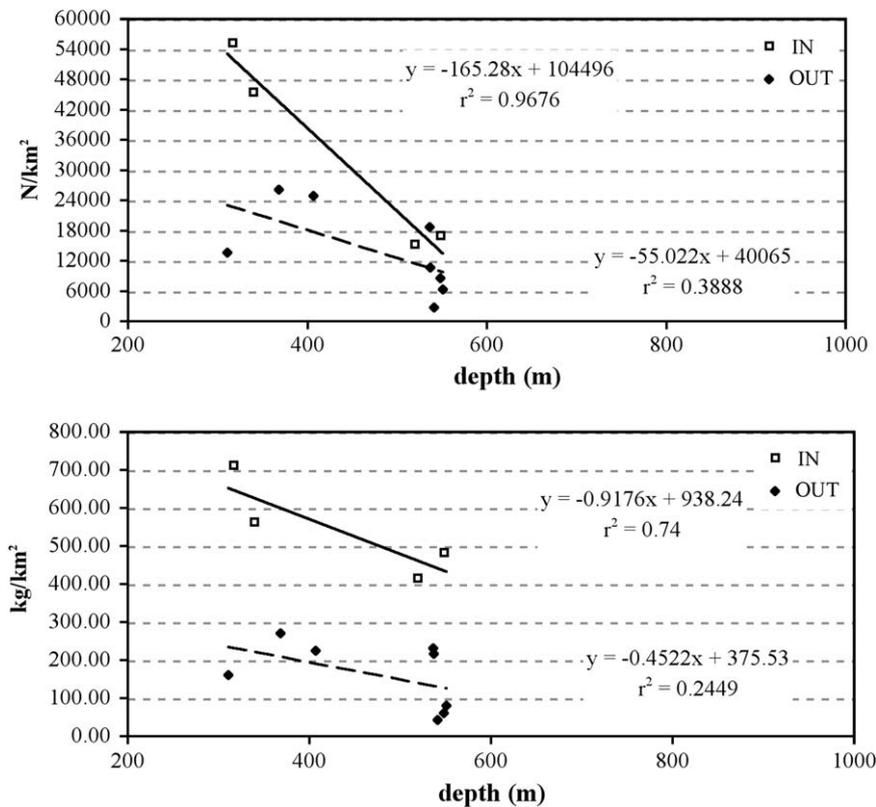

Fig. 6. Relationship of abundance versus depth, with regression lines and parameters, computed for the megafauna caught by trawl net inside (IN) and outside (OUT) the coral habitat.

separation, for a smaller value of dissimilarity, regarded the species/stations inside and outside the coral area.

Even the nMDS identified two different groups related to the two depth ranges and study areas for both density (stress=0.05) and biomass (stress=0.06) (Fig. 8). The differences between the identified groups proved to be significant by means of the ANOSIM test for both density (R=0.441, p=0.020) and biomass (R=0.375, p=0.024).

Concerning density, the greatest percentage contributions to the dissimilarity of the two groups were due to *P. heterocarpus* (34.59%), *P. martia* (16.68%), *P. longirostris* (4.53%), *P. typhlops* (4.34%) and *Phycis blennoides* (3.50%). Regarding biomass, the main role in explaining differences between the two areas was due to *G. melastomus* (20.73%), *P. heterocarpus* (19.76%), *Phycis blennoides* (9.48%), *P. martia* (5.05%), *M. merluccius* (4.44%), *M. poutassou* (3.84%), *C. caelorhincus* (3.66%) and *P. longirostris* (3.32%).

In the "fish size spectra" the log-abundance by size shows a highly significant decreasing trend in both areas ($p < 0.01$) (Fig. 9). Regression equation parameters were significantly greater OUT than IN ($p < 0.01$), indicating a greater abundance of large fish inside the coral habitat than outside.

The length–frequency distributions were computed for the species that displayed the greatest dissimilarity in abundance between the two study areas. Highly significant differences were detected through the Kolmogoroff–Smirnov test carried out for each area ($p < 0.01$). The crustacean *P. heterocarpus* was almost exclusively caught in the coral habitat, with sizes ranging between 10 and 18 mm of carapace length. Outside the coral area a smaller number of specimens with sizes between 14 and 16 mm were collected (Fig. 10). In *P. martia* and *P. longirostris* a wide size range was shown both IN and OUT in spite of the numerical differences between the two areas. A greater fraction of larger specimens was sampled in the coral habitat (Fig. 10). In *P. typhlops* a greater

Table 3
Trawl net mean value of density (N/km^2) and biomass (kg/km^2) indices inside (IN) and outside (OUT) the coral habitat.

Species	N/km^2				kg/km^2			
	IN		OUT		IN		OUT	
	Mean	± s.d.	Mean	± s.d.	Mean	± s.d.	Mean	± s.d.
Cephalopods								
Eledone cirrhosa	–	–	4	7	–	–	0.28	0.53
Eledone moschata	3	4	–	–	0.93	1.08	–	–
Heteroteuthis dispar	1	2	–	–	0.02	0.04	–	–
Illex coindetii	34	40	14	29	1.81	2.10	0.37	0.67
Loligo forbesi	5	9	–	–	0.79	1.58	–	–
Neorossia caroli	–	–	7	8	–	–	0.37	0.57
Octopus salutii	3	6	–	–	1.50	2.99	–	–
Pteroctopus tetracirrhus	12	12	5	10	2.97	3.38	0.26	0.48
Rondeletiola minor	5	9	–	–	0.03	0.06	–	–
Rossia macrosoma	32	36	–	–	1.17	1.10	–	–
Scaeurgus unicirrhus	11	15	5	10	0.58	0.75	0.26	0.48
Sepietta oweniana	587	666	14	22	3.49	3.93	0.09	0.16
Todarodes sagittatus	5	4	10	15	2.35	1.72	2.66	3.80
Todaropsis eblanae	51	65	5	7	4.29	5.24	0.43	0.70
Crustaceans								
Aristaeomorpha foliacea	371	430	369	352	6.86	7.94	5.62	5.17
Aristeus antennatus	–	–	93	152	–	–	2.57	4.16
Chlorotocus crassicornis	–	–	853	1355	–	–	1.44	2.31
Macropipus tuberculatus	47	95	294	524	0.16	0.32	1.38	2.80
Munida intermedia	–	–	54	85	–	–	0.15	0.24
Munida rutllanti	–	–	146	212	–	–	0.37	0.52
Munida tenuimana	–	–	5	13	–	–	0.01	0.03
Nephrops norvegicus	55	22	863	1484	1.58	0.28	8.33	14.49
Plesionika narval	–	–	120	274	–	–	0.35	0.88
Parapenaeus longirostris	2151	2498	284	607	20.19	23.45	3.53	7.19
Pasiphaea sivado	–	–	99	164	–	–	0.10	0.17
Plesionika acanthonotus	–	–	15	43	–	–	0.03	0.08
Plesionika edwardsii	–	–	181	418	–	–	1.11	2.60
Plesionika gigliolii	–	–	19	54	–	–	0.04	0.12
Plesionika heterocarpus	17,124	19,985	289	493	122.73	143.23	0.88	1.48
Plesionika martia	4307	4989	2808	2054	24.76	28.74	9.12	8.71
Polycheles typhlops	154	179	1454	1190	0.83	0.96	4.90	3.91
Processa canaliculata	–	–	138	144	–	–	0.30	0.33
Solenocera membranacea	–	–	964	835	–	–	2.62	2.13
Chondroichthyes								
Chimaera monstrosa	146	169	11	32	10.56	12.26	0.69	1.97
Etmopterus spinax	430	497	21	28	6.43	7.42	0.87	1.23
Galeus melastomus	629	671	227	334	103.66	109.45	25.31	43.93
Leucoraja circularis	14	17	2	6	4.22	5.09	0.32	0.91
Dalatias licha	8	12	–	–	2.97	4.07		
Osteichthyes								
Antonogadus megalokynodon	3	6	70	127	0.02	0.04	0.73	1.46
Argentina sphyraena	3	6	–	–	0.05	0.09	–	–
Arnoglossus rueppelii	19	38	24	48	0.11	0.21	0.12	0.26
Aulopus filamentosus	–	–	2	6	–	–	0.08	0.23
Benthocometes robustus	–	–	2	6	–	–	0.03	0.07
Synchiropus phaeton	–	–	2	5	–	–	0.01	0.03
Capros aper	288	346	2	5	3.47	4.16	0.04	0.10
Chauliodus sloani	–	–	2	5	–	–	0.05	0.14
Chlorophthalmus agassizi	203	226	70	87	2.04	2.32	0.39	0.47
Caelorinchus caelorhincus	780	336	501	913	18.36	19.60	2.13	2.24
Conger conger	20	19	7	7	7.40	6.47	0.69	0.83
Epigonus denticulatus	–	–	8	11	–	–	0.04	0.08
Gadiculus argenteus	558	650	292	605	2.02	2.37	1.65	2.68
Glossanodon leioglossus	–	–	3	6	–	–	0.02	0.05
Gnathophis mystax	–	–	232	512	–	–	7.84	17.67
Helicolenus dactylopterus	617	584	345	606	11.17	2.28	6.90	9.58
Hoplostethus mediterraneus	290	340	76	114	14.13	16.55	1.33	1.37
Hymenocephalus italicus	323	64	640	638	5.37	4.69	2.09	2.05
Lampanyctus crocodilus	–	–	13	16	–	–	0.08	0.10
Lepidopus caudatus	2	3	17	22	2.21	4.41	1.83	2.11
Lepidorhombus boscii	120	140	14	25	2.88	3.35	1.61	3.08
Lesueurigobius friesii	–	–	58	137	–	–	0.10	0.23
Lophius budegassa	63	55	76	97	11.25	4.31	10.28	11.98
Lophius piscatorius	2	3	–	–	1.34	2.68	–	–
Macroramphosus scolopax	3	6	–	–	0.04	0.08	–	–
Merluccius merluccius	452	523	30	59	26.43	31.15	8.08	12.39

Table 3 (*continued*)

| Species | N/km^2 | | | | kg/km^2 | | | |
| | IN | | OUT | | IN | | OUT | |
	Mean	± s.d.	Mean	± s.d.	Mean	± s.d.	Mean	± s.d.
Micromesistius poutassou	661	765	16	26	23.64	26.97	2.21	3.70
Molva dipterygia	25	18	39	73	2.94	2.23	3.15	4.76
Mora moro	9	11	5	10	0.09	0.11	0.10	0.19
Nettastoma melanurum	–	–	25	36	–	–	0.44	0.70
Nezumia sclerorhynchus	536	619	883	1041	8.08	9.33	4.22	4.80
Notacanthus bonaparte	–	–	11	24	–	–	0.20	0.47
Ophidion barbatum	–	–	11	30	–	–	0.02	0.07
Phycis blennoides	1847	1301	530	490	73.08	59.67	26.41	17.08
Stomias boa	–	–	2	5	–	–	0.03	0.07
Symphurus nigrescens	–	–	3	6	–	–	0.02	0.03
Trachyrincus scabrus	25	29	295	604	0.07	0.08	2.24	4.69
Trigla lyra	143	169	5	10	1.22	1.43	0.06	0.13
Zeus faber	–	–	2	5	–	–	0.10	0.28

s.d.=standard deviation.
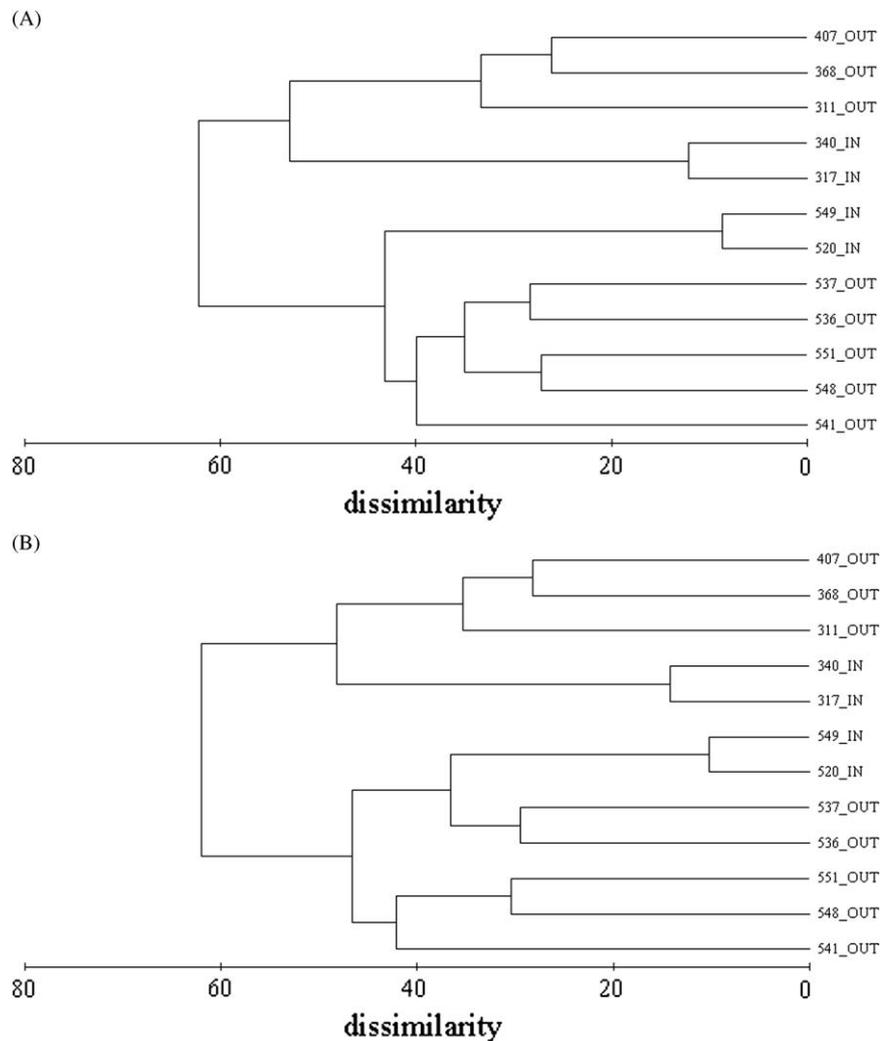
Fig. 7. Dendrograms related to the density (A) and biomass (B) obtained by trawling in the stations inside (IN) and outside (OUT) the coral habitat.

number of specimens and a wider size range was found outside the coral area (Fig. 10).

In the blackmouth catshark *G. melastomus* a wide range of sizes was observed both IN and OUT, though with different abundances. However, in the IN samples the percentage of larger specimens was significantly greater than that in the OUT samples (Fig. 11). The shark *E. spinax* was almost exclusively caught inside the coral area, with a multi-modal size distribution mostly made up of small individuals with sizes between 100 and 160 mm in total length (Fig. 11).

The size composition of the teleosts examined (*M. merluccius*, *M. poutassou*, *P. blennoides*, *H. dactylopterus*, *H. mediterraneus*, *C. caelorhincus*, *N. sclerorhynchus* and *H. italicus*) showed the occurrence of very small individuals belonging to the recruitment. In particular, in *M. merluccius* and *M. poutassou* recruits were almost exclusively sampled in the coral habitat and only a negligible fraction of large individuals was caught both inside

and outside the coral bank (Fig. 12). In *P. blennoides* the samples consisted of small individuals both IN and OUT though with a significantly greater number in the coral habitat (Fig. 12). *H. dactylopterus* was caught with similar size distribution as *P. blennoides* in the two areas, though with significantly greater numbers of recruits and adults within the coral habitat than outside (Fig. 13). The size distribution of *H. mediterraneus* consisted of large individuals inside the coral habitat and mostly of small ones outside (Fig. 14). Finally, in macrourid fish (*C. caelorhincus*, *N. sclerorhynchus* and *H. italicus*) significant greater sizes were collected in the coral area than outside (Fig. 15).

5. Discussion and conclusions

Although the structural complexity of the SML coral habitat prevents the adoption of a standardised sampling design, the present study demonstrates clear differences between the coral habitat (IN) and the non-coral habitat (OUT). Distribution, abundance and size structure of the megafauna in the coral habitat, where fishing occurs in some peripheral zones, differ significantly from those of a non-coral habitat where fishing is fully developed. Indeed, the present results show refuge effects in the coral habitat and fishing effects on the exploited bottoms.

The most significant results were obtained using the trawl net, even though its utilization is extremely difficult due to the risk of damaging both the coral biocoenosis and the gear itself. Even though the use of the longline, being a species-size selective gear, gave different results than trawling, the information collected on the chondrichthyes species and *H. dactylopterus* improves the knowledge on the role of the SML coral habitat for the deep-sea megafauna.

The majority of the species collected in both study areas showed greater values of density and biomass inside the coral habitat, than in the non-coral habitat. These two habitats show also two different faunal assemblages linked to the depths and to the different ecological conditions and anthropogenic impacts. The role of depth in the megafauna-zonation has been previously investigated in the northern Ionian Sea (D'Onghia et al., 1998, 2003) and is well known in the Mediterranean (e.g. Abellò et al., 1988; Cartes and Sardà, 1993; Stefanescu et al., 1993; Moranta et al., 1998; Ungaro et al., 1998; Kallianiotis et al., 2000; D'Onghia et al., 2004) and the Atlantic (e.g. Haedrich et al., 1980; Snelgrove and Haedrich, 1985; Haedrich and Merrett, 1990; Hecker, 1990; Koslow, 1993; Merrett and Haedrich, 1997). Concerning the role played by the coral habitat, this first insight from the Mediterranean
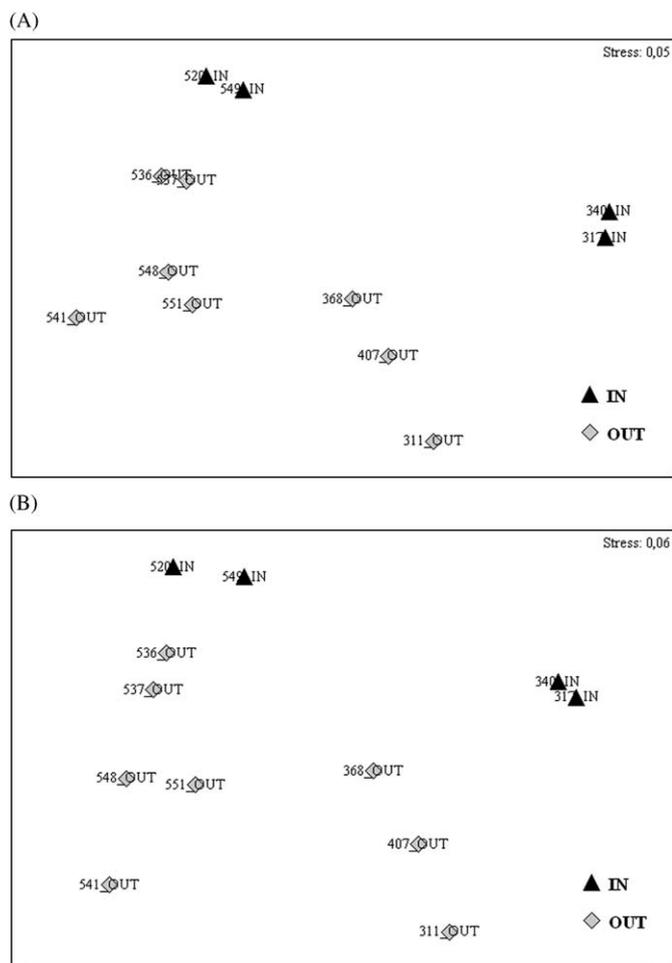

Fig. 8. Multi-dimensional-scaling computed for the density (A) and biomass (B) obtained by trawling in the stations inside (IN) and outside (OUT) the coral habitat.
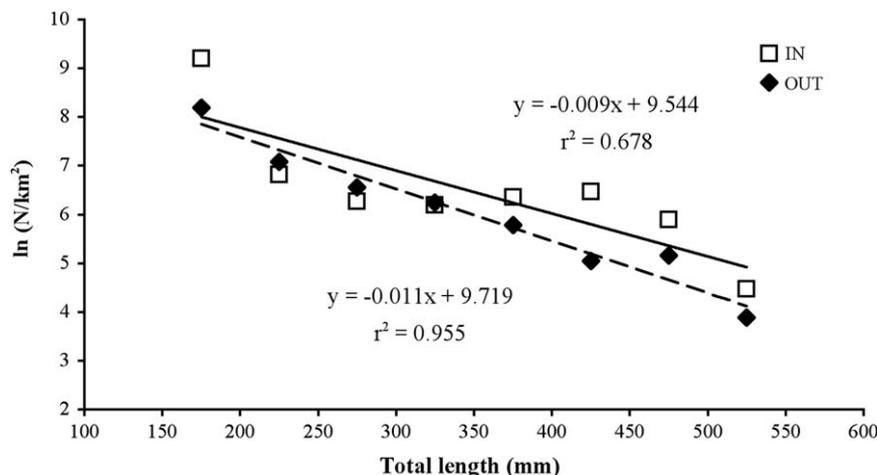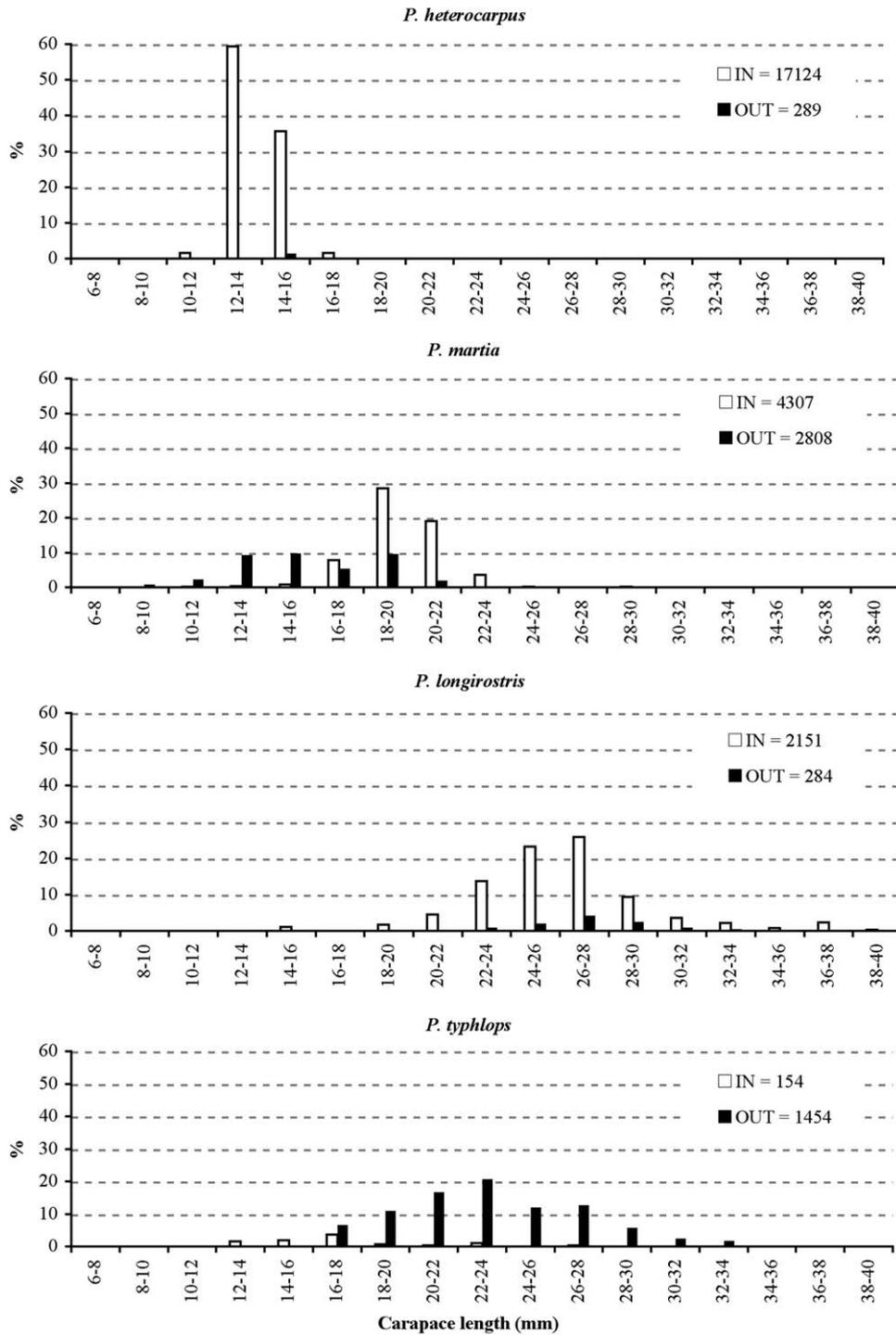

Fig. 9. "Fish size spectra" computed for the stations inside (IN) and outside (OUT) the coral habitat.

Fig. 10. Length–frequency distributions of the crustaceans *P. heterocarpus*, *P. martia*, *P. longirostris* and *P. typhlops* caught by trawl net, inside (IN) and outside (OUT) the coral habitat.

is in agreement with Atlantic observations that such a habitat acts as a refuge area for many species often exploited in surrounding muddy bottoms (Fossà et al., 2002; Heifetz, 2002; Husebo et al., 2002; Krieger and Wing, 2002; Reed, 2002; Costello et al., 2005; Morgan et al., 2005; Ross and Quattrini, 2007). This is further confirmed by the results of the fish size spectra as well as the size distributions which showed a significantly greater fraction of large specimens in the coral area than outside. All these results can be explained as combined effects of the protection from the fishing inside the coral habitat and those of fishing in the non-coral habitat.

The case of the selachians, which were caught with greater numbers of species and greater abundances inside the coral area, is representative of such combined effects. In fact, since these organisms are particularly vulnerable to exploitation due to their *k*-selected life-history strategies (slow growth, delayed maturity, low fecundity), the reduction in abundance of many species, mostly on the continental shelf, seems to be related to the
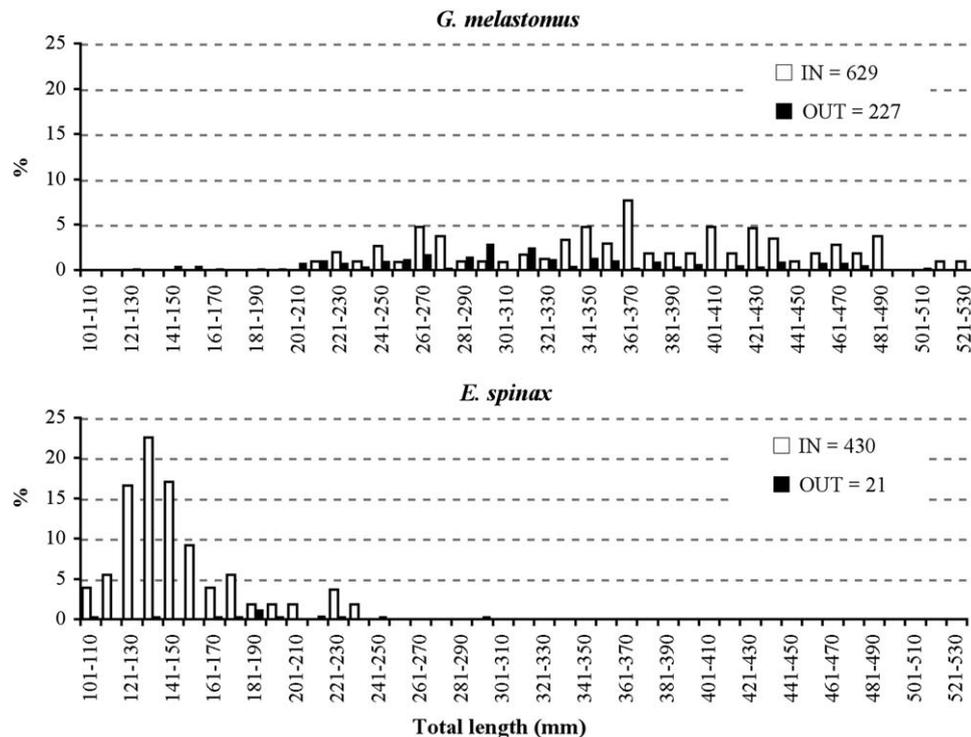
Fig. 11. Length–frequency distributions of the elasmobranches *G. melastomus* and *E. spinax* caught by trawl net inside (IN) and outside (OUT) the coral habitat.

development of trawl fishing (Relini et al., 2000; Sion et al., 2004). Indeed, several species of shark and skate that were once widespread and abundant are now uncommon to rare in the Mediterranean (Vacchi and Notarbartolo di Sciara, 2000). The fact that the teleosts were also captured with greater abundance and greater sizes in the coral habitat while both selachians and teleosts are reduced in abundance and size on the fishing bottoms would confirm a change in the trophic structure of the ecosystem on these latter sea floors explained as "fishing down marine food webs" by Pauly et al. (1998). According to this change, the relatively mature and efficient upper slope ecosystem charac-terised by relatively stable biomass of long-lived vertebrates (*k*-strategist) turns into a relatively unstable and less efficient system characterised by low biomass stock in which the role of opportunistic invertebrates (*r*-strategist) markedly increases. Such conditions on the fishing bottoms would explain the greater abundance of many crustacean species, many of which are not of commercial value, such as *P. typhlops*. However, other factors should be considered to explain the differences between the two areas concerning the crustacean species. The differences in the number of species cannot be explained as a bias from the differential sampling of the two habitat types, since a greater number of hauls were carried out on the fishing bottoms than in the coral area. The greater abundance of some species collected outside this area than inside could be linked to their different distribution according to the type of sediment. In fact, the Norway lobster (*N. norvegicus*) is a species with a typical burial habit and probably the firm ground between the coral mounds, with rubble of dead coral, sponges and many other benthic organisms prevents such a habit. On the contrary, some commercial species, such as *P. longirostris* and *P. martia*, were found to be more abundant inside than outside probably due to the effect of protection from the fishing.

The SML coral habitat represents a spawning area for the rockfish (*H. dactylopterus*), which was caught with a noteworthy number of adult specimens exclusively inside this habitat. Several observations in the Atlantic report that rockfish, such as those of the genus *Sebastes* and *Sebastolobus*, are preferentially distributed in deep-water coral habitats (Pearcy et al., 1989; Heifetz, 2002; Husebo et al., 2002; Krieger and Wing, 2002; Costello et al., 2005). The occurrence of adults of *H. dactylopterus* recorded in the coral area and the corresponding scarcity of these individuals on the fishing grounds of the Ionian Sea (D'Onghia et al., 1996) is remarkable. This could be related to their preferential habitat selection, which is probably linked to spawning in the coral grounds. This predominant occupation of coral bottoms might be additionally accentuated by their reduction caused by exploitation on the upper slope bottoms. In the geographic area of Blake Plateau (southeastern United States), *H. dactylopterus* was re-corded from trawls as the most abundant fish, in both transition and the off-reef habitats. Submersible observations showed this fish species to be the most abundant one in the reef habitat (Ross and Quattrini, 2007).

H. mediterraneus is a benthopelagic fish, which is widespread on the muddy bottoms of the Ionian Sea with both juveniles and adults (D'Onghia et al., 1998c). The exclusive presence of adults in the SML coral habitat and the occurrence of both adults and juveniles outside could be explained as a preferential distribution of juveniles on the muddy bottoms without corals. Indeed, Ross and Quattrini (2007) using trawl collected only juveniles in off-reef habitat and no other individuals in any other habitats.

The remarkable abundance of small individuals belonging to the recruitment both in the shark *E. spinax* and teleost fish *M. merluccius*, *M. poutassou*, *P. blennoides* and *H. dactylopterus* would suggest that the banks of S. Maria di Leuca act as nursery areas for these deep-water species which find suitable environmental conditions in their early life stages and refuge from fishing. In some of these species the adults dwell both on the muddy upper slope bottoms and in the coral habitat which, considering the present results, has the role of a replenishment and spreading area for these species. Thus, the juveniles can recover in the coral habitat and can move outside after their growth phase, thereby restocking the fishing grounds (spill-over effect). This would explain the fishing pattern adopted by the local fishermen, which
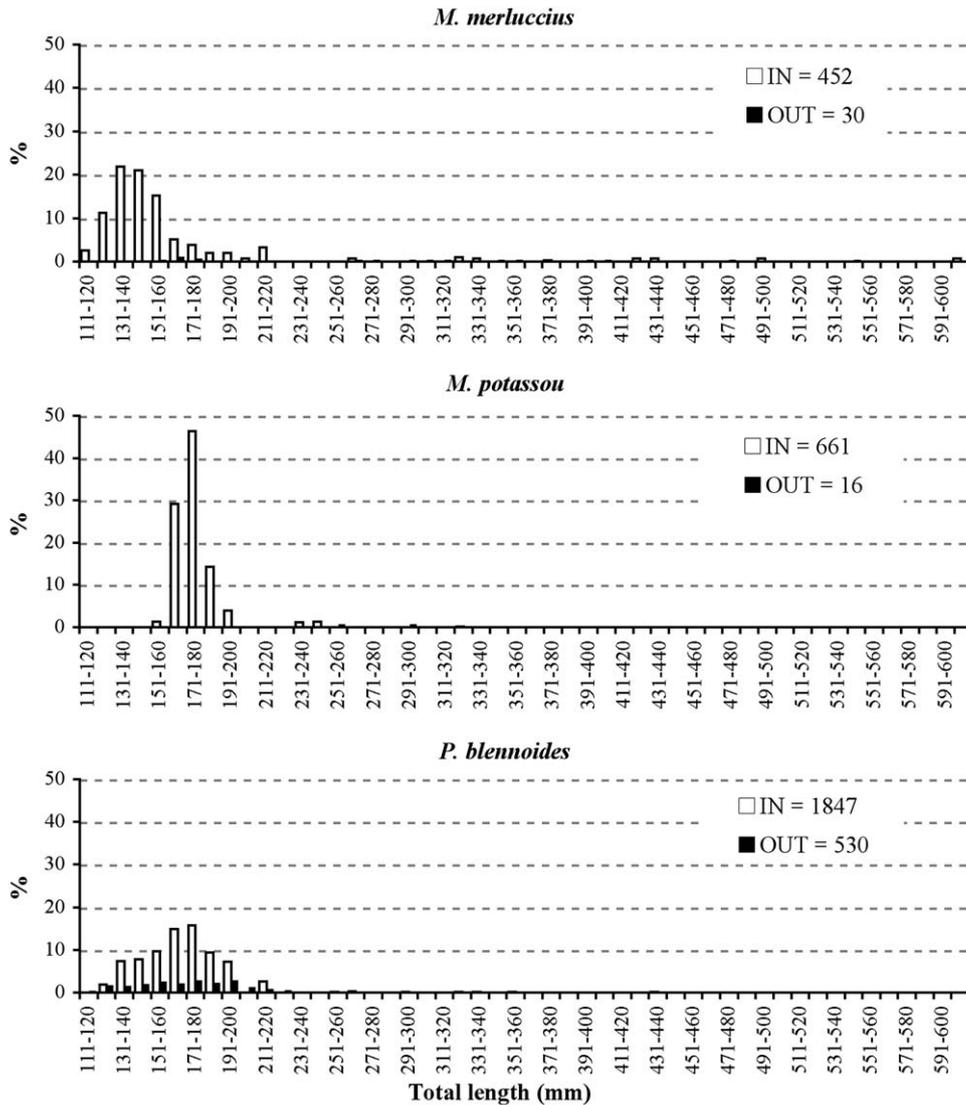
Fig. 12. Length-frequency distributions of the gadiformes *M. merluccius, M. potassou* and *P. blennoides* caught by trawl net, inside (IN) and outside (OUT) the coral habitat.
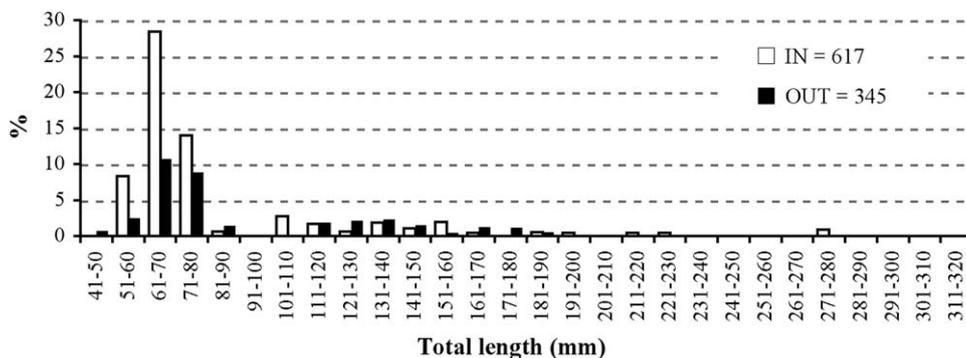

Fig. 13. Length-frequency distribution of *H. dactylopterus* caught by trawl net inside (IN) and outside (OUT) the coral habitat.

often fish very close to the SML coral area, with the aim of catching a greater number of large specimens.

The different sizes recorded in macrourids (*C. caelorhincus, N. sclerorhynchus* and *H. italicus*) between the two investigated areas seems to be a consequence of fishing effect in the non-coral area. In fact, on the fishing grounds of the Ionian Sea the

size distributions of these fish, mostly of the larger species *C. caelorhincus*, are truncated due to the removal of large individual by trawling (D'Onghia et al., 2000a).

The SML coral banks represent a rare example of living *Lophelia-Madrepora*-bearing coral mounds in the Mediterranean (e.g. Taviani et al., 2005). Growing at very low rates, over
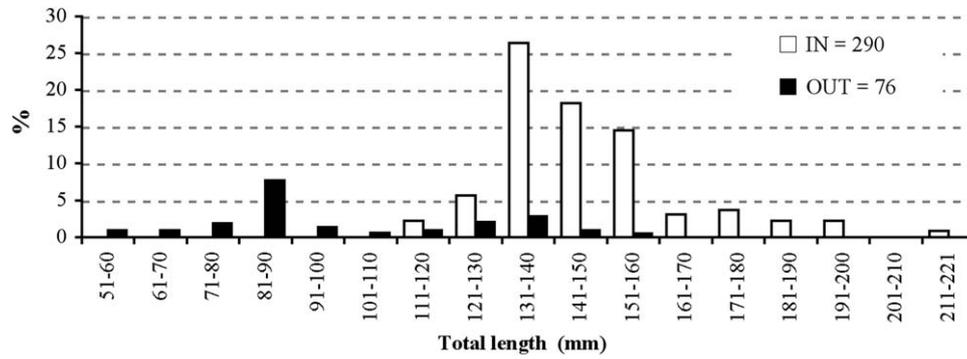
Fig. 14. Length-frequency distribution of *H. mediterraneus* caught by trawl net inside (IN) and outside (OUT) the coral habitat.
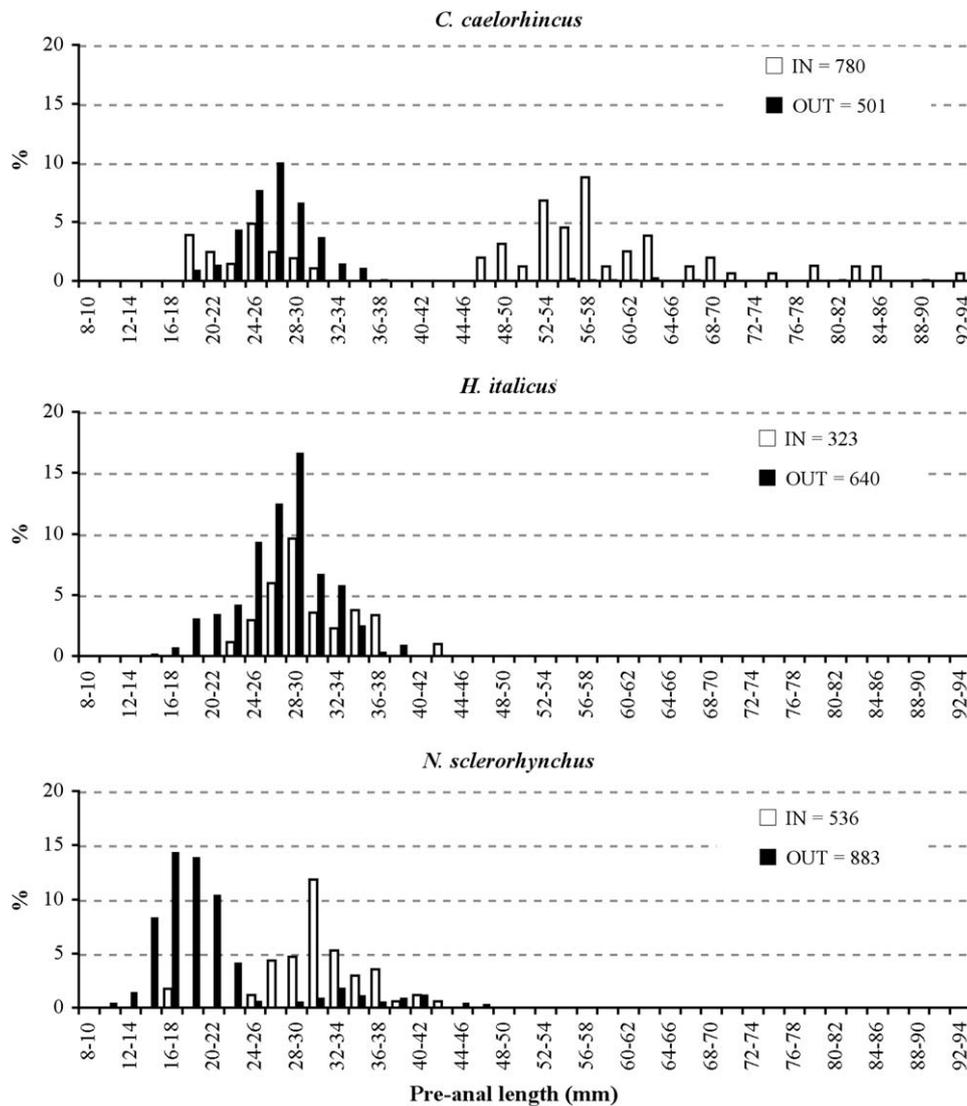

Fig. 15. Length-frequency distributions of the macrourid fish *C. caelorhincus*, *N. sclerorhynchus* and *H. italicus* caught by trawl net inside (IN) and outside (OUT) the coral habitat.

millennia, the corals have built reef-like mounds of different sizes that constitute irreplaceable and vulnerable biota. Thus, as for other deep-water reefs (Fosså et al., 2002; Reed, 2002; Morgan et al., 2005), the establishment of a Marine Protected Area (MPA) off Cape Santa Maria di Leuca will serve primarily for conservation objectives (Tudela et al., 2004). Although the coral area seems to be unsuitable for trawling, the enforcement of a fishing and trawling ban in the area, with the indication of a buffer zone, will provide a further contribution to sustainable fisheries management. In fact, according to Roberts and Hawkins (2000) and the presented results, a fully protected area may provide refuges for exploited species allowing them to recover, increase biomass and

restock fishing grounds through the spill-over of egg-larvae, juveniles and adults.

Biological resources in the Mediterranean have been managed until now by means of "input" regulation measures, such as licence limitation, time closure and gear restrictions while the results obtained from the application of stock-oriented models, which indicate a marked reduction of fishing effort, have not been implemented in practice. Since fishing affects the whole ecosystem and not only the target species, the idea of marine protected areas as fishery management tools has gained worldwide attention with developing interest in ecosystem-based management. Marine protected areas, in which no fishing is allowed, represent an available and promising management strategy, which is robust to uncertainties, suitable for multi-species management and that incorporates ecosystem objectives (Cochrane, 1999; Gislason et al., 2000; Stergiou, 2002; Gell and Roberts, 2003). Observations of incidental fishery benefits from reserves established for conservation are emerging from a wide range of habitats and fisheries (Roberts and Hawkins, 2000 and references therein).

In agreement with Reed (2002), the establishment of an offshore MPA corresponding to the "coral area" in the northern Ionian Sea, should have the following main objectives: (1) to protect and conserve the unique and fragile coral habitat, (2) to provide a refuge for demersal species in order to replenish commercial stocks, (3) to create public awareness, education and research and (4) to regulate human activities which could harm the habitat. The outline of this MPA should include a buffer zone to the north, at shallower depths, which are more easily available to commercial fishing. Furthermore, due to the distance offshore and the time needed for an enforcement vessel to engage in the area, self-regulation and surveillance by the fishing community appear to be fundamental to meet the abovementioned objectives.

Acknowledgment

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