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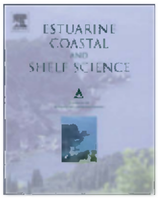

Do Mediterranean fish assemblages associated with marine caves and rocky cliffs differ?

S. Bussotti*, P. Guidetti

Department of Biological and Environmental Sciences and Technologies, University of Salento, Via Provinciale Monteroni, CoNISMa, I-73100 Lecce, Italy

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ABSTRACT

Fish assemblages associated with marine caves and rocky cliffs were investigated in the Salento Peninsula (SE Italy, Mediterranean Sea) by using visual census methods. Sampling was done at three sites, each of which included 4 habitat types: the external and the internal portions of caves, and shallow and deep rocky cliffs. 10 and 13 species were found exclusively inside cave habitats (e.g. *Corcyrogobius lichtensteini*, *Thorogobius ephippiatus* and *Grammonus ater*) or in rocky cliffs (e.g. *Diplodus annularis*, *Sarpa salpa*, *Sparisoma cretense*, *Spondyliosoma cantharus*), respectively. The four habitat types shared 10 species, and the external portions of the caves shared the most species (both with the internal cave portions and the external rocky cliffs). As a general rule, dissimilarity in the fish assemblage structure between habitats was far greater than dissimilarity between sites. *Apogon imberbis* (mostly associated with caves) and *Chromis chromis* (typifying rocky cliffs, mainly the deep ones) mostly contributed to dissimilarities between caves and rocky cliffs. *Apogon imberbis* (mostly associated with internal caves) and *Coris julis* (mainly associated to external cave portions) contributed strongly to dissimilarities between internal and external cave portions, while *C. chromis*, *Symphodus mediterraneus* and *C. julis* (associated with the deeper cliffs) and *Thalassoma pavo* (mostly present in shallow cliffs) differentiated deep and shallow cliffs. *Diplodus vulgaris*, *Oblada melanura* and *Mullus surmuletus* showed a marked increase in density during the cold season in the caves. These results show that fish assemblages associated with rocky reefs rich in marine caves (in terms of relative densities, species composition, species richness, exclusive species and presence of juveniles of some valuable species) may be affected by the peculiar ecological conditions within caves, which could provide additional resources for fishes (e.g. food availability, refuge against predators, sand patches within a rocky matrix) compared to rocky reefs without caves. These results suggest that stretches of rocky coasts rich in marine caves should be considered within management/conservation programs (e.g. when establishing Marine Protected Areas).

1. Introduction

In temperate rocky reefs throughout the world fish assemblages are relevant components of the coastal biodiversity, crucially contributing to ecosystem functioning and representing important marine resources for humans. All these issues stress the importance of fish populations in generating ecosystems services and goods (Holmlund and Hammer, 1999). Environmental conservation programs and/or resource management policies concerning fish assemblages are therefore extremely important and should be based on rigorous quantitative assessments at appropriate spatial and temporal scales (Guidetti, 2002; Anderson and Millar, 2004; Núñez-Lara et al., 2005).

In the Mediterranean Sea, studies on littoral fish assemblages associated with rocky habitats have mostly dealt with the evaluation of the effectiveness of Marine Protected Areas (e.g. Harmelin, 1987; Garcia-Rubies and Zabala, 1990; Vacchi et al., 1998; Guidetti, 2006), partitioning of space and food resources (e.g. Fasola et al., 1997; Sala and Ballesteros, 1997), association with specific habitat types and relationships with habitat structure (e.g. Spanier et al., 1989; Harmelin, 1990; García-Charton and Pérez-Ruzafa, 1998, 2001; Guidetti, 2000; Goren and Galil, 2001; Bussotti et al., 2002; Guidetti et al., 2002). The habitat structure of Mediterranean rocky reefs is characterized by habitat complexity per se (i.e. the three-dimensional complexity due to the contribution of physical structure and biotic cover; García-Charton et al., 2000; Guidetti et al., 2004) and habitat heterogeneity (i.e. the way in which rocky reefs are interspersed with patches of other habitat types, such as sand and/or seagrasses). In SW Spain, for instance, García-Charton and Pérez-Ruzafa (2001) found that the physical complexity of reef habitats (i.e. rugosity, verticality, number and size of boulders) was positively related with species richness and abundance of fish. These authors also found significant relationships between habitat

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* Corresponding author.
E-mail address: simona.bussotti@unile.it (S. Bussotti).

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heterogeneity and species richness of associated fish assemblages. The most intuitive explanation is that if different habitat types host different species and assemblages of fish (e.g. Connolly, 1994; Guidetti, 2000; Valesini et al., 2004), then mosaics of different habitats are likely to display greater species richness than any single habitat alone. In addition, due to the occurrence of ontogenetic shifts in the habitat use for many coastal fishes (Harmelin-Vivien et al., 1995; Macpherson, 1998), species richness tends to be higher wherever habitat heterogeneity is high, because mosaics of different habitats allow the persistence of those fish species that need different habitat types during their life history, including the habitats suitable for juvenile stages (Beck et al., 2001). All the above issues are increasingly considered as relevant in determining marine conservation policies due to the increasing awareness that the protection of all habitat types is crucial for the maintenance of functional links and the biodiversity of fish assemblages in coastal areas (e.g. Beck et al., 2001; Jackson et al., 2001; Sala et al., 2002; Kendall et al., 2004; Mumby, 2006).

In the Mediterranean Sea there are long stretches of calcarenitic rocky coast characterized by the presence of many, often unexplored, submarine caves (Cicogna et al., 2003) that contribute strongly to the heterogeneity and complexity of rocky cliffs. In karstic regions marine caves may extend for hundreds of meters (Bussotti et al., 2006), magnifying rocky reefs by increasing the suitable rocky surface per length unit of coastline for both benthic and nektonic assemblages, and by offering special environments in terms of ecological conditions (e.g. light, water motion and trophic resources; Riedl, 1966). Due to their ecological importance and vulnerability to human pressures, marine caves have been recognised as priority habitats for conservation purposes (Iliffe, 1979; Roff and Evans, 2002; Bussotti et al., 2006).

The Salento Peninsula (SE Italy, Mediterranean Sea) is characterized by a karstic geological system responsible for the formation of numerous large caves. Along approximately 100 km of rocky coast, about 70 submarine caves have been mapped (see http://www.tamug.tamu.edu/cavebiology/Research/research.html) and many others are still unrecorded. Various studies have investigated the associated benthic and planktonic assemblages (Bussotti et al., 2006; Todaro et al., 2006; Denitto et al., 2007; Moscatello and Belmonte, 2007). Such investigations have raised increasing awareness about the uniqueness and fragility of these ecosystems. As regards the fish fauna, previous studies have provided evidence of the ecological roles that cave habitats may exert for fish (including for commercial species; Bussotti et al., 2002) or have investigated distribution patterns of single species inside the caves (Bussotti et al., 2003). No information is available, however, on the distribution patterns of whole fish assemblages associated with rocky cliffs rich in marine caves, nor have assessments been done to evaluate the possible contribution of cave habitats to local fish species richness and distribution in the rocky sublittoral. Such information is crucial in order to plan any spatially defined conservation measure or resource management program of marine ecosystems (e.g. establishment of marine reserves according to ecological criteria; Roberts et al., 2003; Agardy, 2005) in regions rich in marine caves. The objective of this study, therefore, is to determine the spatial and the temporal patterns of distribution of fish assemblages associated with Mediterranean rocky cliffs and caves, and to evaluate the factors that control them, in a sector of the SE Italy particularly rich in marine caves.

2. Methods

2.1. Study sites and habitat types

Visual censuses of the fish fauna were carried out at four periods (thereafter named as 'times') throughout one year of sampling (T1, T2: July, November 2000; T3, T4: February, June 2001). Three random stretches of coast, hereafter called 'sites' (about 400–1000 m apart from each other) were chosen near "Capo di Leuca" (Southern Apulia, SE Italy; Fig. 1). Fish assemblages were sampled inside a submarine cave and at a rocky cliff outside, chosen randomly from a set of possible caves and cliffs within each site (for a total of three submarine caves and three rocky cliffs). Sampling was performed in both the external and the internal portions of the caves, and in shallow and deep rocky cliffs. From an operational point of view, we treated any combination of habitat type (cave/outside) and position (external/internal position for caves; shallow/deep cliffs for outside) as a different 'habitat type' (hereafter referred as CE = cave external, CI = cave internal, OS = outside shallow, OD = outside deep) in the analyses.

2.1.1. Submarine caves

The three marine caves studied (Fig. 1) were characterized by a comparable general morphology (simple horizontal narrow tunnels, single semi-submerged entrance, presence of air chambers) and opening at similar depth (8–10 m): CIO ("Grotta Piccola del Ciolo" 39°50′38″ N; 18°23′11″ E, about 100 m long); MAR ("Grotta di Marinella" 39°49′00″ N; 18°23′24″ E, 65 m long); PRI ("Galleria della Principessa" 39°48′18″ N; 18°22′43″ E, 85 m long). The caves host rich benthic faunal assemblages on the rocky walls (Bussotti et al., 2006) and sediment floors (Todaro et al., 2006).

2.1.2. Rocky cliffs outside

The three rocky cliffs investigated here are characterized by calcarenitic vertical-sub-vertical slopes. From the surface to about 5–6 m depth the rocky substrate is steep and covered by articulated coralline algae and the brown algae of the genus *Cystoseira*. From 6–7 m to about 12–15 m depth there is a more gently sloped plateau covered by macroalgal dominated assemblages with numerous medium–large boulders. Deeper, from about 15 to 25 m, vertical/sub-vertical slopes can be observed and the substrate is constituted by biogenic formations. At about 30 m depth, the slope decreases and biogenic constructions alternate with sand patches.

2.2. Sampling procedures and design

A modified transect visual census method (Harmelin-Vivien et al., 1985) was adapted to cave habitats (Bussotti et al., 2002). Each cave was subdivided into an external position about 30 m long from the entrance (CE) and a more internal position along the easily accessible inner portions (CI: to 60 m in MAR, and 80 m in CIO and PRI). In each position, fishes were counted along transects 10 m long and 2 m wide (20 m^2) run along each side of the rocky wall.

At rocky cliffs, the identification of habitat types was based on the predominant features that create structural complexity in the environment: i.e. macroalgal dominated assemblages between the bathymetric range 5–15 m (OS) and bio constructors (called 'coralligenous formations' in the Mediterranean Sea; Ballesteros, 2006) between the bathymetric range 15–30 m (OD). Visual censuses in rocky cliffs were carried out along 25 m long and 5 m wide transects (see Harmelin-Vivien et al., 1985) randomly placed within each bathymetric range.

For both caves and outside rocky cliffs, abundance of fish was estimated using a scale based on a geometric progression factor of approximately 2 (1, 2–5, 6–10, 11–30, 31–50, 51–100, 101–200, 201–500, >500 individuals) following criteria determined by Harmelin-Vivien and Harmelin (1975) and Harmelin-Vivien et al. (1985). Fish density was estimated by considering the midpoint of each abundance class (e.g. the midpoint of the abundance class 101–200 is 150 individuals; see Harmelin-Vivien et al., 1985 for details). Values were then converted to number of individuals 100 m^{-2}. At each sampling period and site, four replicate censuses

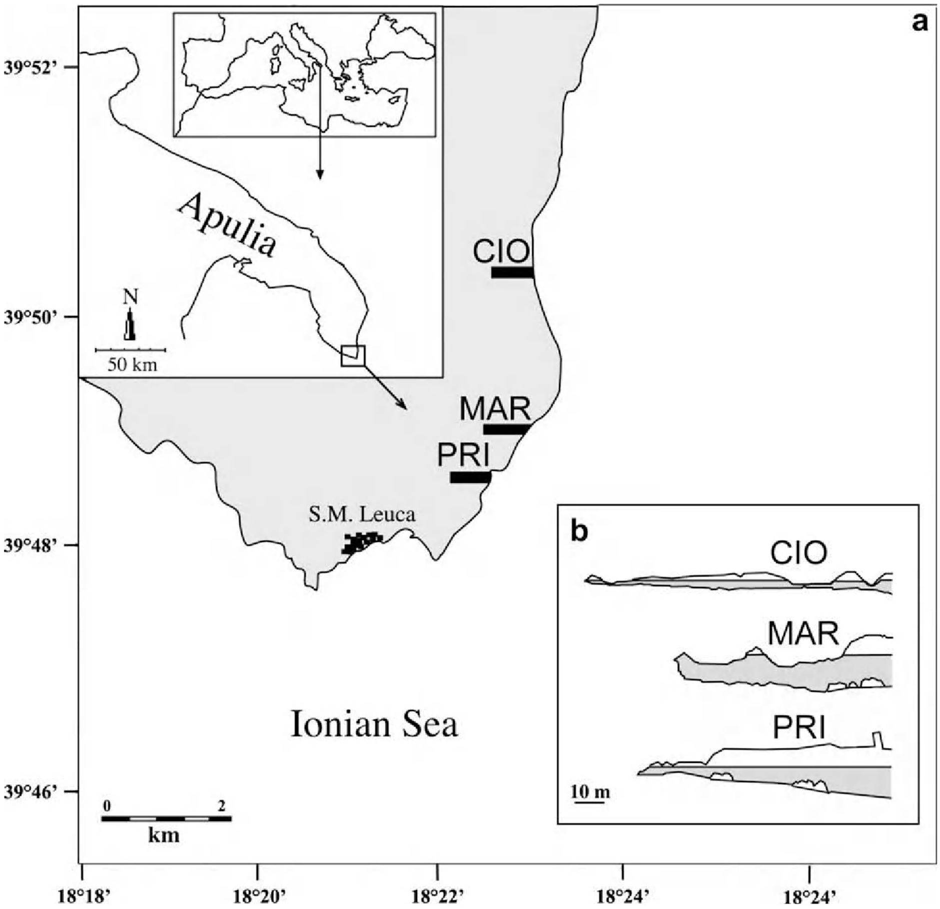

Fig. 1. a) Location of the study area; b) side view of the three caves studied (CIO: "Grotta Piccola del Ciolo"; MAR: "Grotta di Marinella"; PRI: "Galleria della Principessa").

were performed for each habitat type for a total of 192 visual censuses. As sampling surfaces were partially superimposed during the four sampling times, especially inside caves, independent tests were made on each of the four times of sampling for both caves and rocky cliffs. This allowed prevention of possible temporal dependence of data. The sampling design thus consisted of 2 factors: site (S, 3 levels, random) and habitat type (4 levels, fixed, crossed with S).

2.3. Statistical analyses

Multivariate techniques were used to analyse fish assemblage structure (taxa composition and relative abundances) using the PRIMER software package (Clarke and Warwick, 1994). Data were $\log_{10}(x + 1)$ transformed to arrange all organisms in the same range of abundance. A 2-way crossed analysis of similarity (ANOSIM) was first used to examine differences among sites and habitat types. Differences among habitat types were represented by non-metric multidimensional scaling ordinations (nMDS), considering all replicates. Stress values were shown for each MDS plot to indicate the goodness of representation of differences among samples.

The similarity percentage procedure (SIMPER) was used to identify the major taxa contributing to the differences among habitat types. Taxa were considered 'important' if they exceeded an arbitrary chosen threshold value of 5% of dissimilarity.

Analysis of variance (two-way ANOVA, using GMAV5 package) was used to assess differences in density of the most important fish species. Density data were properly transformed whenever necessary, and the homogeneity of variances was tested using Cochran's test (Underwood, 1997). In a few cases, transformation did not produce homogeneous variances, but ANOVA was used nevertheless, because it is fairly robust to departures from homogeneity when sample sizes are equal. A setting of $\alpha = 0.01$ was used in such cases to compensate for the increased likelihood of Type I error. SNK test ($p < 0.05$) was used for post hoc comparisons (Underwood, 1997).

3. Results

3.1. General description of fish assemblages

A total of 47 fish taxa belonging to 20 families were recorded throughout the study (Table 1): 13 species were found only over the rocky cliffs and 10 species exclusively inside cave habitats, whereas the four habitat types shared 10 species. The cave entrance habitat (CE) generally shared more species than the other sectors, especially with the internal portions of the caves (CI) and the external rocky cliffs (OS and OD). *Diplodus annularis*, *Sarpa salpa*, *Sparisoma cretense*, *Spondyliosoma cantharus* characterized the rocky cliffs, whereas the species found strictly inside submarine caves included many speleophilic fishes, such as *Corcyrogobius lichtensteini*, *Lipophrys nigriceps*, *Thorogobius ephippiatus* and *Grammonus ater* (this latter found only within the darkest sectors of the CI habitat).

The most abundant species were *Chromis chromis* in the rocky cliffs and *Apogon imberbis* inside the caves (Table 1). Juvenile individuals of *Coris julis* and *Thalassoma pavo* were responsible for the increase in abundance in T2 at OD and OS respectively. Small-sized *Apogon*, instead, were found to recruit inside the caves and were mostly responsible for the huge abundances observed in T1 and T2 (Fig. 3).

Table 1
Mean density (SE) (mean number of all individuals censused at each time) and frequency of occurrence of fish species recorded at the four habitats investigated. OS: outside shallow; OD: outside deep; CE: cave external; CI: cave internal.

Families	Habitat							
Species	OS		OD		CE		CI	
	Mean (SE)	*F* (%)	Mean (SE)	*F* (%)	Mean (SE)	*F* (%)	Mean (SE)	*F* (%)
Apogonidae								
Apogon imberbis	0.03 (0.03)	1.4	0.7 (0.2)	20.8	92.7 (23.2)	97.9	197.7 (17.4)	100.0
Atherinidae	1.6 (0.9)	6.9	–	–	31.3 (15.2)	10.4	4.5 (0.4)	1.6
Blenniidae								
Lipophrys nigriceps	–	–	–	–	2.0 (0.6)	37.5	–	–
Parablennius gattoruggine	0.4 (0.2)	8.3	–	–	0.4 (0.2)	8.3	–	–
Parablennius incognitus	0.01 (0.01)	1.4	–	–	–	–	–	–
Brotulidae								
Grammonus ater	–	–	–	–	–	–	0.4 (0.03)	13.3
Centracanthidae								
Spicara maena	–	–	3.8 (1.2)	16.7	–	–	–	–
Spicara smaris	–	–	4.0 (1.7)	12.5	–	–	–	–
Congridae								
Conger conger	–	–	–	–	0.1 (0.7)	8.3	0.9 (0.1)	17.2
Gadidae								
Phycis phycis	0.01 (0.01)	1.4	–	–	0.3 (0.2)	6.2	1.2 (0.1)	19.5
Gobiidae								
Corcyrogobius lichtensteini	–	–	–	–	0.4 (0.2)	6.2	0.6 (0.01)	13.1
Gobius cruentatus	0.04 (0.02)	4.17	0.01 (0.01)	1.4	–	–	–	–
Thorogobius ephippiatus	–	–	–	–	0.1 (0.1)	2.0	0.3 (0.01)	4.7
Thorogobius macrolepis	–	–	0.03 (0.02)	2.78	–	–	–	–
Labridae								
Coris julis	4.8 (0.7)	86.1	14.9 (1.3)	100.0	8.4 (1.9)	47.9	0.3 (0.02)	4.7
Labrus merula	–	–	0.01 (0.01)	1.4	–	–	–	–
Symphodus doderleini	0.04 (0.02)	5.6	0.5 (0.1)	50.0	–	–	–	–
Symphodus mediterraneus	0.3 (0.1)	23.6	1.6 (0.1)	94.4	1.3 (0.5)	20.8	–	–
Symphodus ocellatus	0.2 (0.1)	6.9	0.4 (0.1)	15.3	–	–	–	–
Symphodus roissali	0.1 (0.5)	12.5	0.03 (0.02)	–	–	–	–	–
Symphodus rostratus	–	–	0.03 (0.02)	4.2	–	–	–	–
Symphodus tinca	0.5 (0.1)	45.8	1.0 (0.1)	68.0	0.3 (0.2)	6.2	–	–
Thalassoma pavo	15.5 (1.7)	100.0	3.4 (0.7)	54.2	0.9 (0.3)	22.9	–	–
Moronidae								
Dicentrarchus labrax	0.03 (0.02)	2.8	–	–	–	–	–	–
Mugilidae	0.1 (0.04)	5.6	0.4 (0.3)	2.8	0.1 (0.1)	2.0	0.1 (0.01)	1.6
Mullidae								
Mullus surmuletus	0.01 (0.01)	1.4	0.1 (0.04)	12.5	0.5 (0.2)	10.4	0.4 (0.03)	4.7
Muraenidae								
Muraena helena	–	–	–	–	0.1 (0.1)	2.0	–	–
Pomacentridae								
Chromis chromis	25.9 (4.3)	72.2	106.9 (14.7)	100.0	10.1 (7.9)	31.2	–	–
Scaridae								
Sparisoma cretense	0.1 (0.05)	4.2	0.4 (0.1)	20.8	–	–	–	–
Scorpaenidae								
Scorpaena notata	–	–	–	–	0.9 (0.3)	22.9	0.1 (0.01)	1.6
Scorpaena porcus	0.01 (0.01)	1.4	0.02 (0.02)	2.8	1.1 (0.4)	20.8	0.1 (0.01)	1.6
Scorpaena scrofa	–	–	–	–	0.4 (0.2)	8.3	–	–
Sciaenidae								
Sciaena umbra	–	–	–	–	0.2 (0.1)	8.3	0.2 (0.01)	2.3
Serranidae								
Anthias anthias	–	–	0.5 (0.3)	7.0	–	–	–	–
Epinephelus costae	0.02 (0.02)	2.8	0.09 (0.03)	11.1	–	–	–	–
Epinephelus marginatus	0.1 (0.03)	5.6	0.03 (0.02)	4.2	1.3 (0.3)	33.3	0.2 (0.01)	3.1
Serranus cabrilla	0.5 (0.1)	40.3	1.5 (0.1)	88.9	4.4 (0.8)	68.7	1.6 (0.1)	24.2
Serranus scriba	0.6 (0.1)	41.7	1.2 (0.1)	76.4	2.1 (0.3)	50.0	0.1 (0.01)	2.3
Sparidae								
Boops boops	–	–	19.4 (5.6)	31.9	0.2 (0.1)	8.3	–	–
Diplodus annularis	0.7 (0.2)	19.4	0.1 (0.06)	8.3	–	–	–	–
Diplodus puntazzo	0.3 (0.1)	11.1	0.04 (0.02)	5.6	0.1 (0.1)	2.1	–	–
Diplodus sargus	0.1 (0.0)	9.7	0.01 (0.01)	1.4	0.3 (0.3)	4.2	–	–
Diplodus vulgaris	0.6 (0.1)	26.3	0.5 (0.1)	20.8	4.1 (1.2)	33.3	0.9 (0.08)	3.1
Oblada melanura	0.7 (0.3)	6.9	0.3 (0.3)	1.4	–	–	3.6 (0.3)	10.9

Table 1 (*continued*)

Families	Habitat							
Species	OS		OD		CE		CI	
	Mean (SE)	*F* (%)	Mean (SE)	*F* (%)	Mean (SE)	*F* (%)	Mean (SE)	*F* (%)
Sarpa sarpa	3.1 (0.8)	26.4	–	–	–	–	–	–
Spondyliosoma cantharus	–	–	0.03 (0.02)	4.2	–	–	–	–
Sphyraenidae								
Sphyraena viridensis	–	–	–	–	0.04 (0.04)	2.0	–	–
Total number of species	29		31		28		18	

3.2. *Whole fish assemblages*

The results of two-way crossed ANOSIM tests performed on data collected in each sampling time are reported in Table 2. The analyses reveal that in all sampling times the global *R* values of dissimilarity in the fish assemblage structure among habitats were greater than those among sites. The largest dissimilarity values were found for all four sampling times between the internal portions of the caves (CI) and the cliffs outside (OS and OD), but marked differences were also detected between fish assemblages in the external and the internal positions of the caves (CE vs CI). Non-metric MDS plots of replicate samples at the four sampling times reflected these general results with a clear-cut separation of fish assemblages in relation to the four different habitats (Fig. 2).

The SIMPER analyses identified seven species responsible for distinguishing spatial groups (Table 3). *Apogon imberbis* and *C. chromis* mostly contributed to dissimilarities between caves and rocky cliffs, the former typifying the submarine caves and the latter the rocky cliffs outside (mostly the deep ones). More in detail, *A. imberbis* (mostly associated with internal caves) and *C. julis* and *Serranus cabrilla* (mainly associated to external cave portions) mostly contributed to dissimilarities between internal and external cave portions, while *C. chromis*, *Symphodus mediterraneus* and *C. julis* (associated to the deeper cliffs) and *T. pavo* (mostly present in shallow cliffs) differentiated deep and shallow cliffs. *Epinephelus marginatus*, represented by small individuals, characterized in T1 the external positions of the caves.

3.3. *Variations in density of common species related to habitat type*

Densities of the most abundant fish species recorded in this study showed different values in relation to the habitat type and sampling time considered (Fig. 3), although temporal variability was not formally investigated here. The inspection of Fig. 3 reveals a marked increase at T3 in the abundance of *Diplodus vulgaris* and *Oblada melanura* in CI and of *Mullus surmuletus* in CE. Densities of these species did not vary significantly among sites except for *S. cabrilla* at T1 and T2, and *S. mediterraneus* at T4 (Table 4), whereas significant differences were related to habitat type for most species except for *S. mediterraneus*.

Table 2
Two-way crossed ANOSIM testing for differences in assemblage structures 'among sites' (averaged across habitats) and 'among habitats' (averaged across sites) at the four time of sampling. T1, T2: July, November 2000; T3, T4: February, June 2001.

	T1		T2		T3		T4	
	R value	*P*	R value	*P*	R value	*P*	R value	*P*
Global R								
Among sites	0.105	1	0.114	0.2	−0.88	99.7	−0.07	97.8
Among habitat	0.869	0.1	0.937	0.1	0.886	0.1	0.881	0.1
Pairwise tests								
OS vs OD	0.599	0.1	0.733	0.1	0.677	0.1	0.685	0.1
OS vs CE	0.91	0.1	0.892	0.1	0.739	0.1	0.745	0.1
OS vs CI	1	0.1	1	0.1	1	0.1	1	0.1
OD vs CE	0.966	0.1	0.824	0.1	0.766	0.1	0.772	0.1
OD vs CI	1	0.1	1	0.1	1	0.1	1	0.1
CE vs CI	0.624	0.1	0.904	0.1	0.761	0.1	0.768	0.1

With regard to the species for which ANOVAs showed significant differences related to 'habitat type', SNK tests revealed that *A. imberbis* and *S. cabrilla* showed significantly higher densities inside caves (both in CE and in CI) than in rocky cliffs outside in all sampling times, while the same pattern was observed only in T3 for *M. surmuletus*. This latter species, nevertheless, displayed a greater abundance inside caves than in the rocky cliffs outside at all sampling times (Fig. 3). Small-sized individuals of *E. marginatus* were mainly recorded in CE and never in CI. At T1 the density values of the dusky grouper in CE were significantly higher than in rocky cliffs outside. *Thalassoma pavo* was predominantly recorded in shallow substrates (OS) and absent in CI. *Coris julis* and *Serranus scriba*, instead, showed grater affinity for OD and CE.

4. Discussion

This study showed that the structure of littoral fish assemblages and the distribution patterns of abundance of several fish taxa associated with rocky reefs may change in relation to the habitat types considered, i.e. external and inner portions of submerged caves, shallow rocky cliffs characterized by macroalgal dominated assemblages and deep rocky reefs characterized by 'coralligenous formations'. At the spatial scale of 'site' (i.e. hundreds of meters to kilometres) we did not detect any remarkable variability. The spatial patterns observed, in general, were found to be consistent in time. The above issues suggest that, at least at the spatial scales considered here, the fish fauna of rocky reefs rich in marine caves is distributed rather uniformly in space and time within each of the habitats considered.

The fact that there are differences in fish assemblages among habitats, especially between rocky reefs and cave habitats, is due to the exclusive presence or to differences in the relative abundances of some species in the different habitats. As far as the caves are concerned, the structure of fish assemblages was found to be clearly different between the entrances and the inner portions. Previous studies on the fish fauna associated to Mediterranean marine caves preliminarily described the assemblages or reported on small crypto-benthic fishes (Abel, 1959; Riedl, 1966; Bori, 1984; Ahnelt and Patzner, 1995; Herler et al., 1999; Kovacic, 1999; Patzner, 1999). Our results, as far as the species composition is concerned, are mostly consistent with the information reported by the above papers. In particular, we found that cryptic and shy species (e.g. *Conger conger*, *Phycis phycis*, *T. ephippiatus*, *G. ater*) were mostly or exclusively counted inside the caves and specifically within the internal portions. The external portions of the caves, conversely, hosted some species that were typical of the rocky reefs outside (e.g. the labrids *C. julis* and *S. mediterraneus*) or of the inner portions of the caves (e.g. the gobids *C. lichtensteini* and *T. ephippiatus*). From

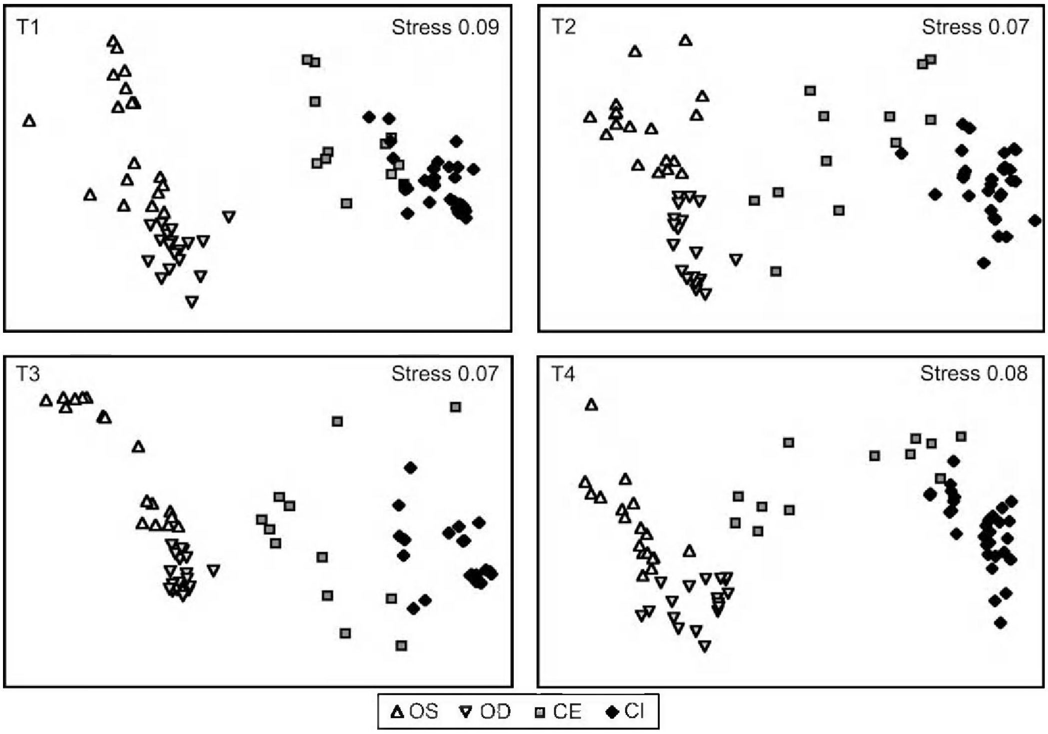

Fig. 2. Non-metric MDS plots of individual replicates (i.e. individual fish censuses) showing differences of fish assemblages among habitat types in all the four sampling times. OS: outside shallow; OD: outside deep; CE: cave external; CI: cave internal. OS: outside shallow; OD: outside deep; CE: cave external; CI: cave internal. T1, T2: July, November 2000; T3, T4: February, June 2001.

this point of view, the external portions of the caves could represent an ecotonal zone which possesses a mixed fish assemblage. Ecotones, in theory, are transition zones characterized by sharp environmental and ecological gradients, and expectedly greater species richness (Odum, 1953). However, we did not observe greater species richness at the cave entrances compared to external cliffs and inner cave portions.

Small individuals of *E. marginatus* also showed a clear affinity for cave habitats. It is worth noting that *E. marginatus* may grow bigger than 1 m in size, and that the individuals of this species classified as 'small individuals' are targeted by fishing (e.g. spear fishing). Juvenile and small groupers (*Epinephelus* spp.) are often reported in the literature as preferentially inhabiting shallow rocky habitats rich in shelters (e.g. Derbal and Kara, 1995; Harmelin and Harmelin-Vivien, 1999; La Mesa et al., 2002). Our findings, however, suggest that such ecological requirements are better satisfied by shallow marine caves than by external rocky cliffs, which suggest that caves could represent safe shelters at shallow depth than rocky reefs. Large individuals of this species, instead, are reported to move to deep waters to avoid spear fishermen (Garcia-Rubies and Zabala, 1990; Harmelin et al., 1995; La Mesa et al., 2002). We did not find large individuals of *E. marginatus* in any of the investigated habitats, including relatively deep cliffs. This result could suggests that in the studied area dusky groupers could be affected by a strong fishing impact so that large individuals are likely to live in deeper waters than those we have investigated here (down to 30 m approximately). The same could be true also for the brown meagre *Sciaena umbra*, another fish heavily impacted both by professional and recreational fishing.

A suite of species that are reported to live in subtidal rocky reefs were also found to be important, from a numerical point of view, within cave habitats. Such species include many generalist fishes that utilise a wide variety of habitat types, such as *S. mediterraneus* (e.g. Bell, 1983; García-Charton and Pérez-Ruzafa, 1998), which was found to occupy both deep rocky habitats and the external portions of the caves, or *S. cabrilla*, a typical species of rocky reefs that was

Table 3
Species contributing to dissimilarity among habitat types (averaged across sites) (OS: outside shallow; OD: outside deep; CE: cave external; CI: cave internal). T1, T2: July, November 2000; T3, T4: February, June 2001. Values of dissimilarity ≥ 5% are given in bold.

	OS vs OD				OS vs CE				OD vs CE				OS vs CI				OD vs CI				CE vs CI			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
Apogon imberbis	0.0	0.0	0.0	**5.5**	**27.1**	**19.7**	**21.3**	**19.1**	**24.5**	**15.5**	**15.8**	**32.1**	**34**	**28.6**	**37**	**23.7**	**27.3**	**18.5**	**20.4**	**27.3**	**12.8**	**6.38**	**8,9**	**6.9**
Coris julis	**11.4**	**8.8**	**18.4**	**5.2**	**7.4**	**6.3**	**9.2**	7.4	**9.2**	4.9	**8.9**	**7.3**	**9.0**	**8.5**	4.4	**10.5**	**14.1**	**11.6**	**12.4**	**11.8**	**8.1**	**10.3**	**8.9**	**8.1**
Chromis chromis	**22.3**	**13.9**	**37.0**	**16.2**	**9.3**	**9.9**	**11.3**	**11.9**	**18.7**	**12.9**	**20.8**	**18.7**	**12.0**	**13.3**	**10.4**	**18.4**	**25.4**	**18.5**	**16.2**	**27.3**	3.4	**7.6**	**8.4**	**9.3**
Diplodus vulgaris	0.0	2.8	0.0	3.8	**6.0**	3.8	**5.8**	**6.0**	**5.7**	2.6	**5.0**	**5.4**	0.0	2.7	**5.8**	1.9	0.0	0.0	2.1	2.1	**10.7**	4.1	**6.7**	**8.8**
Epinephelus marginatus	0.0	0.0	0.0	0.0	**5.0**	3.5	3.5	2.2	**5.0**	3.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**5.0**	3.0	3.3	3.3
Serranus cabrilla	**5.6**	4.0	**5.9**	4.0	**7.9**	**6.2**	**7.2**	**7.3**	**6.0**	3.9	**5.4**	**5.7**	3.8	2.8	4.4	4.1	**5.3**	3.6	3.9	3.3	**14**	**8.6**	**7.2**	**11.5**
Serranus scriba	0.0	3.5	**5.3**	4.0	3.8	3.6	**5.0**	4.3	3.7	2.9	4.6	3.8	2.1	2.8	0.0	0.0	2.3	3.3	3.7	3.3	**6.0**	4.8	**5.0**	**6.5**
Symphodus mediterraneus	**6.8**	**5.0**	**5.8**	**5.0**	0.0	3.5	0.0	3.7	4.3	4.0	2.0	4.5	0.0	0.0	0.0	0.0	**5.0**	4.0	4.0	**5.0**	0.0	**5.0**	0.0	**5.0**
Thalassoma pavo	**15.3**	**11.2**	**9.3**	**12.2**	**9.0**	**9.1**	**10.6**	**8.9**	3.1	**5.2**	0.0	4.6	**13.7**	**19.7**	**13.1**	**15.4**	1.6	**5.4**	3.8	3.6	3.0	2.0	0.0	4.6

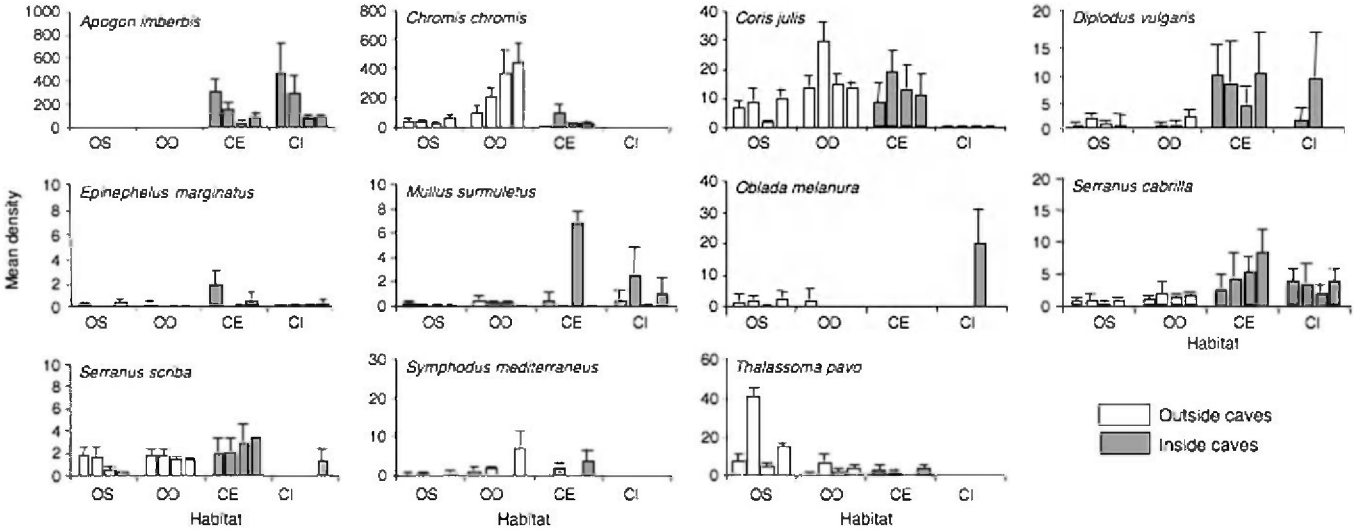

Fig. 3. Mean density (mean number of individuals 100 m^{-2} ± SE, $n = 4$) of important fish species in each habitat during the four sampling times (sites pooled due to low variability detected at the site scale). OS: outside shallow; OD: outside deep; CE: cave external; CI: cave internal.

also found within marine caves. Several large individuals of *S. cabrilla*, from this perspective, were seen to prey upon juvenile *A. imberbis*. Marine caves, therefore, could represent important nursery habitats for juvenile *A. imberbis* (Bussotti et al., 2003), whose presence and abundance can attract fish predators specialised in preying juvenile fish, such as *S. cabrilla* (Tortonese, 1975). Another common species of subtidal rocky reefs, i.e. *D. vulgaris* (Tortonese, 1975), was found to be fairly abundant inside caves (both adult and small-sized individuals). *Mullus surmuletus*, whose affinity to sandy bottoms is well known (García-Charton and Pérez-Ruzafa, 1998), was frequently recorded inside the caves. This association with cave habitats suggests that *M. surmuletus* could find a suitable habitat in the sediment floors of the caves that can be considered as a sort of 'patch of sandy habitat' embedded within a rocky matrix represented by the rocky cliffs, and cave walls and roofs. *Oblada melanura* is reported to be chiefly associated with shallow rocky substrates (Bell, 1983; García-Charton and Pérez-Ruzafa, 1998). We observed high densities of this fish during the cold season (T3) especially within the inner portions of the caves. This result is consistent with the observations reported by Kotrschal (1983), who found permanently dense aggregations of *O. melanura* inside shelters (crevices and very small caves) during winter in the Northern Adriatic Sea. Similarly, *M. surmuletus* was recorded inside caves at all the times investigated, but densities were greater in T3. These findings may confirm that some common littoral fishes may use caves to seek shelter (Riedl, 1966; Harmelin et al., 1985; Bussotti et al., 2002), in particular during the cold season.

The distribution pattern of the two labrid species *C. julis* and *T. pavo* observed here is of interest. The former was more associated to deeper substrates and the external portions of caves, while the latter was found to characterize the shallower rocky bottoms. This result confirms the preliminary observations reported by Guidetti and D'Ambrosio (2004), who provided suggestive evidence of depth segregation between the two labrids in rocky reefs in SE Apulia. Our results, moreover, highlight that caves situated at shallow depth can be suitable habitats for *C. julis* and not for *T. pavo*. The presence of shallow caves, therefore, could allow *C. julis* to persist in shallow rocky reefs even though *T. pavo* is abundant, whereas this latter species seems to over compete with *C. julis* in shallow rocky cliffs deprived of cave habitats. It is worth noting that these issues take into account the structure of the fish fauna recorded daytime. During the night, however, this picture could change. We found, for instance, that *C. chromis* mostly contributed to characterize deeper rocky cliffs, in accordance with the literature (Bell, 1983). This species, however, is known to use cavities as nighttime shelters (Harmelin, 1987; Fasola et al., 1997). Thus, further investigations could highlight whether or not marine caves may serve as suitable nightly shelters for species like *C. chromis*.

It may be concluded that the heterogeneity/complexity of rocky cliffs due to the presence of cave habitats may affect local species richness and distribution patterns of fish associated with rocky reefs. This is an important ecological aspect to be considered in coastal areas such as SE Italy due the high number of marine caves characterizing rocky reefs. The availability of a greater rocky surface along with the presence of habitats with peculiar conditions

Table 4

Summaries of ANOVAs on fish density of each relevant fish species testing for effects of site (S) and habitat (H) in the four sampling time: ns = not significant; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$.

Species	Factor	Time 1	Time 2	Time 3	Time 4
Apogon imberbis	Site	ns	ns	ns	ns
	Habitat	***	**	**	***
Chromis chromis	Site	ns	ns	ns	ns
	Habitat	*	*	***	***
Coris julis	Site	ns	ns	ns	ns
	Habitat	**	*	ns	*
Diplodus vulgaris	Site	ns	ns	ns	ns
	Habitat	***	*	*	ns
Epinephelus marginatus	Site	ns	ns	ns	ns
	Habitat	*	*	**	ns
Mullus surmuletus	Site	ns	ns	ns	ns
	Habitat	ns	ns	*	ns
Oblada melanura	Site	ns	ns	ns	ns
	Habitat	*	*	*	*
Serranus cabrilla	Site	ns	ns	*	ns
	Habitat	*	*	**	*
Serranus scriba	Site	ns	ns	ns	ns
	Habitat	**	**	**	*
Symphodus mediterraneus	Site	ns	ns	-	*
	Habitat	ns	ns	-	ns
Thalassoma pavo	Site	ns	ns	ns	ns
	Habitat	ns	***	*	***

(i.e. light, water motion, etc.), in fact, may provide additional resources for fishes, in terms of food available or refuge against predators. As stressed by García-Charton and Pérez-Ruzafa (2001), most of the coastal Mediterranean fishes do not live exclusively associated to a single habitat type, but they need heterogeneous and connected habitats during their life history. Habitat connectivity in the marine environment is more and more recognised as an important point in several studies around the world as it involves beneficial relationships among different ecosystems/habitats that are just possible in mosaics of different but interconnected habitats (Unsworth et al., 2008).

Marine caves are among the few marine habitats under protection for the European Community (Habitat Directive 92/43 EEC). Bussotti et al. (2006), who reported information on sessile organisms from the same caves considered in this study, documented the uniqueness of these assemblages thus stressing the importance for their conservation. The present study improves our knowledge about these environments and adds further implications for conservation and management of coastal rocky areas. Many fish species found inside the caves, like *A. imberbis*, are also common in the rocky cliffs outside. The fraction of the local population of this fish that inhabits the caves may have a paramount ecological role for the cave's benthic communities. Its movements inside and outside caves during the day/night cycle can have a great functional importance for the transfer of organic matter into the caves: they eat small crustaceans during the night outside the caves, to then defecate daytime when they come back into the caves, similar to some mysid species (i.e. *Hemimysis speluncola*; Coma et al., 1997). The presence of exclusive species and of small-size individuals of commercial fishes (e.g. groupers), the different fish assemblages compared to rocky cliffs, along with the important role of some fish for maintenance of trophically limited benthic communities into the caves, suggests that marine caves should be included within Marine Protected Areas, as their features fit the ecological criteria (e.g. representativeness, peculiarity; see Roberts et al., 2003) that make a place or a habitat worth to be protected.

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