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Interaction between depth and protection in determining the structure of Mediterranean coastal fish assemblages

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Abstract – Patterns of spatial and temporal variability of coastal fish assemblages were compared between areas subjected to different levels of protection at two different depths using a visual census technique. A no take reserve was compared with recreational fishing areas around a small Mediterranean island at 5 m and 20 m depth. Univariate and multivariate statistical techniques were used to test the hypothesis that protection could have different effects at different depths. A total of 56 species were identified during the survey. The most represented families were Sparidae and Labridae. Results showed an interaction between depth and levels of protection that was not persistent across the study period. This result was consistent for the whole fish assemblage and for the target species; most species showed higher abundance in protected areas at 20 m depth.

Key words: Fish assemblages / Marine protected areas / Visual census / Islands / Mediterranean Sea

Résumé – Interaction entre profondeur et niveau de protection dans la détermination de la structure d'un assemblage de poissons côtiers en Méditerranée. Les variabilités spatiales et temporelles d'assemblages de poissons côtiers ont été comparées entre zones soumises à différents niveaux de protection et à deux profondeurs différentes par une technique sous-marine d'observation visuelle. Une zone de réserve est comparée à une zone de pêche récréative autour d'une petite île de Méditerranée à 5 m et 20 m de profondeur. Des techniques univariées et multivariées sont utilisées pour tester l'hypothèse que la protection pourrait avoir des effets différents à différentes profondeurs. Un total de 56 espèces sont identifiées dans cette étude. Les Sparidae et les Labridae sont les plus représentés. Les résultats montrent une interaction entre la profondeur et les niveaux de protection mais non persistante au cours de la période d'étude. Ce résultat correspond à l'ensemble de l'assemblage de poissons et aussi pour les espèces-cibles ; pour la plupart des espèces, leur abondance est plus élevée en zones protégées à 20 m de profondeur.

1 Introduction

Due to their economic value and ecological role in coastal areas, fish assemblages have been widely studied in order to predict population dynamics, to evaluate biodiversity and productivity, and to manage the stocks as resources for human needs (Jennings and Polunin 1995; Lorance et al. 2002; Baron et al. 2004). Moreover, fish assemblages are considered valuable indicators of several kinds of human impacts (Smith et al. 1999; Guidetti et al. 2002, 2003). In particular, these organisms represent the best indicators of the effects of environmental protection for their sensitivity to human disturbance, the rapidity of their responses to changes in environmental conditions and for the possibility to be studied through non-destructive methods (Polunin and Roberts 1993; Harmelin et al. 1995; Wantiez et al. 1997). Visual-census techniques are widely used in studies concerning effectiveness of marine protected areas (MPAs) (Garcia-Rubies and Zabala 1990; Francour 1994; Rakitin and Kramer 1996; Parnell et al. 2005). Due to the large natural variability of fish assemblages results of these studies are often difficult to interpret (Anderson and Millar 2004). Moreover, difficulties arise considering that protection can affect the structure of the whole assemblage, the mean size and the abundance of fishes (Bennett and Attwood 1991; Polunin and Roberts 1993; Jouvenel and Pollard 2001; Westera et al. 2003), but also it can influence the spatial distribution and behaviour of species (Bell 1983; Dufour et al 1995). Finally, protection can have different effects according to the species and to the habitat considered (Paddack and Estel 2000; McClanahan and Arthur 2001; Frielander et al. 2003). Thus, studies aimed at evaluating effects of protection on fishes should consider not only the total composition and abundance of assemblages, but also their patterns of spatial distribution in relation to depth, fish size, temporal patterns, physical properties of the substratum and characteristics of the adjacent benthic assemblages. Other important aspects to be considered are the periodicity and the kind of human activities. These issues are particularly important considering that

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Table 1. List of fish taxa censused around Giannutri Island, NW Mediterranean Sea. Mean of the number of individuals (SE, n = 48). * indicates target A species

	−5 m				−20 m			
TAXA	High protected area		Low protected area		High protected area		Low protected area	
	mean	SE	mean	SE	mean	SE	mean	SE
ANGUILLIFORMES								
Muraenidae								
**Muraena helena* Linnaeus, 1758	0	0	0	0	0.3	0.1	0.1	0.1
CLUPEIFORMES								
Clupeidae								
Sardina pilchardus (Walbaun, 1792)	0	0	0	0	0	0	0.1	0.1
Engraulidae								
Engraulis encrasicolus (Linnaeus, 1758)	4.0	1.7	2.1	1.5	0	0	0	0
GADIFORMES								
Gadidae								
**Phycis phycis* (Linnaeus, 1758)	0	0	0	0	0.1	0.1	0	0
ATHERINIFORMES								
Atherinidae								
Atherina spp.	2.7	1.6	6.9	2.4	1.0	1.0	3.8	1.4
SCORPAENIFORMES								
Scorpaenidae								
Scorpaena notata Rafinesque, 1810	0.1	0.1	0	0	0	0	0	0
**Scorpaena scrofa* Linnaeus, 1758	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
PERCIFORMES								
Moronidae								
**Dicentrarchus labrax* (Linnaeus, 1758)	0.1	0.1	0	0	0	0	0	0
Serranidae								
Anthias anthias (Linnaeus, 1758)	0	0	0	0	9.1	1.9	2.3	1.1
**Epinephelus marginatus* (Lowe, 1834)	0.1	0	0.1	0.1	0.1	0.1	0	0
Serranus cabrilla (Linnaeus, 1758)	1.5	0.2	1.5	0.2	3.2	0.2	2.1	0.2
Serranus scriba (Linnaeus, 1758)	0.4	0.1	0.7	0.1	0.1	0.1	0	0
Apogonidae								
Apogon imberbis (Linnaeus, 1758)	1.6	0.8	0.5	0.2	0.6	0.1	0.5	0.2
Menidae								
Spicara flexuosa Rafinesque, 1810	0	0	0.3	0.2	1.1	0.7	4.4	1.7
Spicara maena (Linnaeus, 1758)	2.0	1.2	0.3	0.2	4.1	1.6	2.7	1.2
Spicara smaris (Linnaeus, 1758)	1.5	1.1	2.0	1.2	3.0	1.4	4.4	1.7
Sparidae								
Boops boops (Linnaeus, 1758)	13.4	3.0	5.1	1.6	1.0	1.0	2.8	1.2
**Dentex dentex* (Linnaeus, 1758)	0.2	0.2	0.1	0.1	1.8	1.1	0.2	0.1
Diplodus annularis (Linnaeus, 1758)	0.2	0.1	0.3	0.1	0.1	0.1	0.1	0
**Diplodus puntazzo* (Cetti, 1777)	0.1	0.1	0.1	0	0.5	0.4	0	0
**Diplodus sargus* (Linnaeus, 1758)	0.3	0.1	0.3	0.2	0.6	0.4	0.8	0.6
**Diplodus vulgaris* (Geoffroy Saint Hilaire, 1817)	1.2	0.4	1.3	0.4	2.8	0.6	0.5	0.2
Oblada melanura (Linnaeus, 1758)	4.3	1.4	2.3	0.5	0.3	0.3	0.1	0.1
**Pagellus erythrinus* (Linnaeus, 1758)	0.5	0.3	0.4	0.4	0.1	0	0.1	0.1
Sarpa salpa (Linnaeus, 1758)	4.0	1.3	4.4	1.6	0	0	0.9	0.5
**Spondyliosoma cantharus* (Linnaeus, 1758)	1.8	0.5	3.7	1.0	3.0	1.1	1.5	0.5
Mullidae								
Mullus barbatus Linnaeus, 1758	0	0	0	0	0.1	0.1	0.1	0
Mullus surmuletus Linnaeus, 1758	0.2	0.1	0.1	0.1	0.3	0.1	0.4	0.1
Mugilidae								
Mugil sp.	0.7	0.3	0.2	0.2	0	0	0	0
Pomacentridae								
Chromis chromis (Linnaeus, 1758)	27.3	2.8	45.2	1.4	31.8	2.9	23.4	2.8
Labridae								
Coris julis (Linnaeus, 1758)	14.5	2.1	12.1	1.2	27.3	2.4	24.1	1.5
**Labrus merula* Linnaeus, 1758	0.1	0	0	0	0.1	0	0	0
Labrus mixtus Linnaeus, 1758	0	0	0	0	0.1	0.1	0.1	0.1
**Labrus viridis* Linnaeus, 1758	0.1	0.1	0.1	0	0.1	0	0.1	0.1
Symphodus cinereus (Bonnaterre, 1788)	0.4	0.2	0.1	0.1	0.1	0.1	0.2	0.1
Symphodus doderleini Jordan, 1891	1.6	0.4	0.7	0.1	0.5	0.1	0.7	0.2
Symphodus mediterraneus (Linnaeus, 1758)	0.9	0.2	1.2	0.2	2.2	0.3	2.4	0.3
Symphodus melanocercus (Risso, 1810)	0	0	0.1	0.1	0.2	0.1	0.3	0.1

Table 1. continued.

TAXA	−5 m				−20 m			
	High protected area		Low protected area		High protected area		Low protected area	
	mean	SE	mean	SE	mean	SE	mean	SE
Symphodus ocellatus Forsskål, 1775	0.9	0.3	0.4	0.2	0.1	0	0.1	0.1
Symphodus roissali (Risso, 1810)	1.9	0.4	0.9	0.2	0.1	0.1	0.1	0.1
Symphodus rostratus (Bloch, 1797)	0.1	0.1	0.3	0.1	0.1	0.1	0.2	0.1
Symphodus tinca (Linnaeus, 1758)	1.3	0.2	2.5	0.4	0.9	0.2	1.0	0.2
Thalassoma pavo (Linnaeus, 1758)	8.8	0.7	6.7	0.5	0.4	0.1	0.1	0.1
Tripterygiidae								
Tripterygion delaisi Cadenat & Brache, 1971	0.2	0.1	0.4	0.2	0.1	0.1	0.2	0.1
Tripterygion melanurus Guichenot, 1845	0	0	0.1	0.1	0	0	0.1	0.1
Tripterygion tripteronotus (Risso, 1810)	0.3	0.1	0.5	0.1	0.1	0.1	0.4	0.1
Blennidae								
Parablennius gattorugine (Brünnich, 1768)	0.1	0.1	0.1	0.1	0	0	0	0
Parablennius rouxi (Cocco, 1833)	0.1	0	0.1	0.1	0	0	0.1	0.1
Parablennius tentacularis (Brünnich, 1768)	0	0	0.1	0.1	0	0	0	0
Parablennius zvonimiri (Kolombatovic, 1892)	0.1	0.1	0.1	0.1	0	0	0	0
Gobiidae								
Gobius auratus Risso, 1810	0	0	0	0	0.2	0.1	1.1	0.3
Gobius buchichii (Steindachner, 1870)	0.3	0.2	0.1	0.1	0	0	0	0
Gobius cobitis Pallas, 1811	0	0	0	0	0.1	0.1	0	0
Gobius vittatus Vinciguerra, 1758	0	0	0	0	0.1	0.1	0.2	0.1
Sphyraneidae								
Sphyraena sphyraena (Linnaeus, 1758)	0	0	0.1	0.1	0.1	0	0	0
Scombridae								
**Sarda sarda* (Bloch, 1793)	0	0	0	0	1.3	1.1	1.0	1.0

most of the studies investigating effects of protection, do not separate effects due to professional fishing from those related to recreational fishing (Westera et al. 2003).

The aim of the present study was to compare patterns of spatial and temporal variability in coastal fish assemblages between areas subjected to different levels of protection at two different depths. Protected areas inside an integral reserve were compared to areas open to recreational fishing. In order to minimize potential confounding effects due to external influences other than fishing, the study was carried out around a small Mediterranean island far from urbanized continental coasts and historically characterised by a relative low human impact.

2 Material and methods

The study was carried out around Giannutri Island, a small island in the NW Mediterranean Sea with a coastline with a length of about 11 km. This island is included in the Tuscany Archipelago National Park and two different levels of protection have been established around its shores: high protected areas, where all human activities, with the exception of scientific research, are forbidden, and low protected areas, where commercial fishing is banned, while several activities including tourism, anchoring, diving, and recreational fishing are permitted. Areas subjected to different levels of protection are interspersed around the coasts of the island. The bottom around the island consists mainly of rocky slopes, separated by bays often characterized by *Posidonia oceanica* (L.) Delile beds. In this study, only rocky habitat was considered: all the sampled sites where established on gently sloping rocky bottom with the presence of rocky blocks.

In order to detect possible differences between different depths and levels of protection and the interactions between these factors in the structure of fish assemblages a multifactorial sampling design was performed. For each level of protection, two depths were studied: 5 m and 20 m. The study was repeated at four dates chosen at random within a one-year period (July and September 2004, March and May 2005). At each date, two locations (700 m long and about 1000 m of coastal line distant each other) were randomly selected for each level of protection. Two sites (100 m long and about 250 m distant each other) were randomly chosen in each location. In each site, three replicated samples were performed at each depth. Sampling consisted of visual census of fishes through a point-counts technique modified from Bohnsack and Bannerot (1986). Fishes were counted in an imaginary cylinder 5 m high and 10 m in diameter during a 6 min period: 5 min to sample fishes in the water column and an additional minute to search benthic species on the seafloor within a 5-m radius from the observation point (Micheli et al. 2005). The abundance of each species was recorded as number of individuals.

Data of composition and abundance of fish species were analysed through multivariate techniques such as multivariate analysis of variance based on permutations (PERMANOVA; Anderson 2001), metric multidimensional scaling ordination (MDS; Clarke and Warwick 1994) and indicator value analysis (IndVal; Dufrene and Legendre 1997). Multivariate analysis were applied to the whole fish assemblages and to the target A species indicated in Table 1. Analysis of variance (ANOVA; Underwood 1997) was used as univariate analysis on the total abundance of target A species.

PERMANOVA was used to test the hypothesis that fish assemblages differed in composition and in abundance between locations with different levels of protection, between depths,

Table 2. Results of PERMANOVA based on Bray-Curtis dissimilarity matrix of fish assemblages censused around Giannutri Island, NW Mediterranean Sea. Significant effects are indicated in bold.

Source	*df*	MS	Pseudo *F*	*p*
Time = T	3	5995	2.38	**0.001**
Protection = P	1	6117	3.02	**0.019**
Depth = D	1	51167	8.20	**0.014**
Location(TxP) = L	8	2514	1.03	0.418
Site(TxPxD) = S	16	2434	2.82	**0.001**
TxP	3	2029	0.81	0.736
TxD	3	6235	2.93	**0.004**
PxD	1	13300	2.62	0.077
PxL(TxP)	8	2125	0.84	0.748
PxS(TxPxD)	16	2526	2.92	**0.001**
TxPxD	3	5080	2.39	**0.023**
Residual	128	864		
Total	191			

Table 3. Results of ANOVA on the abundance of several type A target species (all summed) censused around Giannutri Island, NW Mediterranean Sea. See Table 1 for a list of the species. Significant effects are indicated in bold.

Source	*df*	MS	*F*	*p*
Time = T	3	1.02	0.45	0.72
Protection = P	1	3.64	1.42	0.31
Depth = D	1	0.45	0.11	0.76
Location (TxP) = L(TxP)	8	2.26	1.53	0.22
Site (L(TxP)) = S(L(TxP))	16	1.48	2.13	**0.01**
TxP	3	2.56	1.13	0.39
TxD	3	4.15	1.72	0.22
PxD	1	13.46	5.56	**0.03**
*DxL(TxP)	8	2.64		
DxS(L(TxP)	16	0.58	0.84	0.63
*TxPxD	3	1.81		
Residual	128	0.69		
Total	191			
Pooled data	11	2.42	4.12	**0.01**
Transformation	Ln(X + 1)			
Cochran,s test	C = 0.1086			
SNK test	Low protection area: –5 m = –20 m			
	High protection area: –5 m < –20 m			
SE	0.2246			

Table 4. Results of PERMANOVA based on Bray-Curtis dissimilarity matrix of several type A target species censused around Giannutri Island, NW Mediterranean Sea. See Table 1 for a list of the species. Significant effects are indicated in bold.

Source	*df*	MS	Pseudo-*F*	*p*
Time = T	3	7839	1.20	0.287
Protection = P	1	10 414	1.01	0.437
Depth = D	1	7303	0.79	0.587
Location(TxP) = L(TxP)	8	6491	1.39	0.095
Site(L(TxP)) = S(L(TxP))	16	4638	1.88	**0.000**
TxP	3	10 272	1.58	0.111
TxD	3	9174	1.80	**0.049**
PxD	1	13 707	2.77	**0.037**
DxL(TxP)	8	5077	1.49	0.051
DxS(L(TxP))	16	3399	1.38	**0.010**
TxPxD	3	4939	0.97	0.507
Residual = R	128	2456		
Total	191			

between dates and moreover if there were interactions between these factors (Anderson 2001). Bray-Curtis dissimilarity was calculated using untransformed data. The permutable units and the Mean Square (MS) used as denominator for each source of variability are reported in Table 2. The analysis consisted in a 5-way model with Time (4 levels) as random and crossed factor, Protection (2 levels, high and low protected areas) and Depth (2 levels, –5 m and –20 m) as fixed and crossed factors, Location (2 levels) as random factor nested in Protection x Time, Site (2 levels) as random factors nested in Location. For graphical representation of the data, a two dimensional metric multidimensional scaling (MDS) ordination, calculated over the factors Location, was carried out. Distances among centroids were obtained using principal coordinate axes from the original Bray-Curtis matrix. The same model was used to analyses both the whole fish assemblages and the target A species. Type A target species (= vulnerable species) are species favoured by highly selective spearfishing (Harmelin et al. 1995).

The program IndVal was used to identify the species most contributing to the multivariate patterns, defined as the most characteristic of each group, being found mostly in a single group or present in the majority of samples belonging to that group (Dufrene and Legendre 1997). In our study IndVal program was used on the original Bray-Curtis matrix to determine which species separated the assemblages of different depths in each level of protection and vice versa.

A 4-way ANOVA was performed on the total abundance (total number of individuals of all species) of type A target species with the same factors described for multivariate analysis. Data were Log(x + 1) transformed to eliminate the heterogeneity of variances detected by Cochran's C-test before the analysis (Underwood 1997). SNK test was used for a posteriori comparison of the means when appropriate. Pooling procedure was used following the logic described in Winer et al. (1991).

3 Results

A total of 56 species were identified during the survey (Table 1, with nomenclature authority). The most represented families were Sparidae and Labridae. The species most abundant in shallow assemblages were *Sarpa salpa*, *Oblada melanura*, *Thalassoma pavo*, *Boops boops*, *Symphodus* spp. The species most abundant in the deep assemblages were *Anthias anthias*, *Scorpaena scrofa*, *Muraena helena* and *Gobius vittatus*. *Chromis chromis*, *Coris julis*, *Spicara* spp, *Spondyliosoma cantharus*, *Diplodus vulgaris* were common at both depths surveyed.

The whole fish assemblages were related to time, depth and protection as showed in the PERMANOVA analysis by the significant interaction Time x Protection x Depth (Table 2). Moreover, PERMANOVA analysis detected significant differences

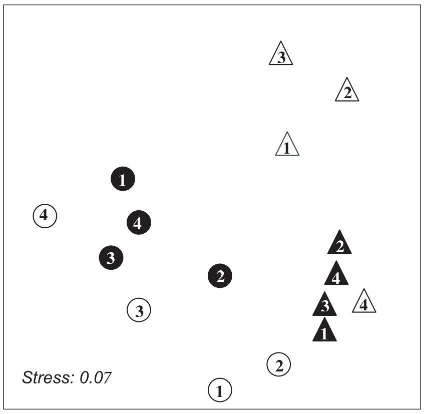

Fig. 1. nMDS plot of untransformed Bray-Curtis dissimilarities of abundance of fishes counted around Giannutri Island, NW Mediterranean Sea. Numbers in the symbols plot refer to the sampling dates (1 = July, 2 = September, 3 = March, 4 = May) in high and low protected areas.

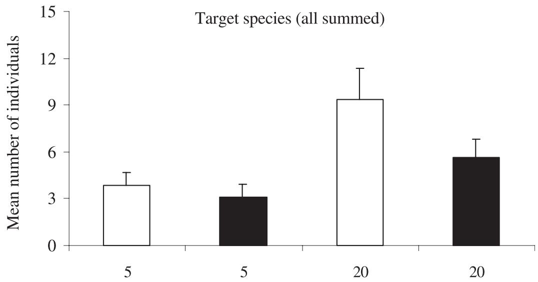

Fig. 2. Mean number of individuals (+ SE, $n = 48$) of target species (all summed) sampled at each depth (5 = 5 m depth, 20 = 20 m depth).

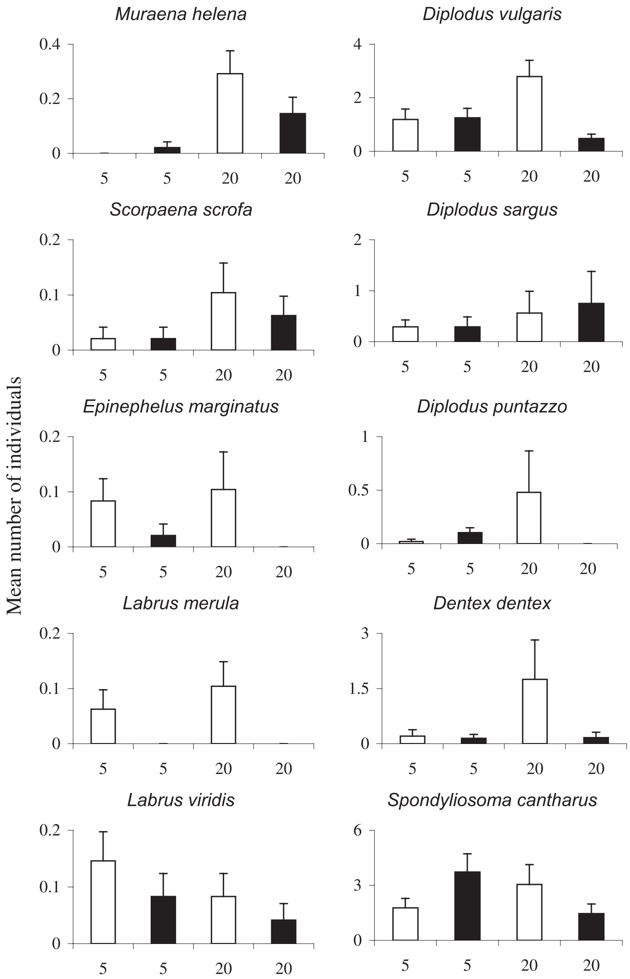

Fig. 3. Mean number of individuals (+ SE, $n = 48$) of the most abundant target species sampled at each depth (5 = 5 m depth, 20 = 20 m depth).

among sites indicating a small-scale variability of the fish assemblages (Table 2). nMDS analysis showed that the separation between deep and shallow assemblages was more evident in protected than in unprotected areas and differences between levels of protection varied among sampling dates (Fig. 1).

Among the target species, *Dentex dentex*, *S. scrofa*, *S. cantharus*, *Diplodus sargus*, *D. vulgaris*, *D. puntazzo*, *Epinephelus marginatus*, *Phycis phycis*, *Dicentrarchus labrax*, *M. helena, Labrus merula* and *Labrus viridis* were found around the island.

The analyses conducted on target species showed these latter were related to depth, protection and time.

ANOVA on the total abundance of the target species showed a significant interaction between depth and protection (Table 3). SNK test showed that target species were collectively more abundant in the protected zone at the higher deep (Fig. 2). A high variability among sites was also detected (Table 3).

PERMANOVA analysis on the target species detected as significant the interaction Protection *x* Depth and Time *x* Depth (Table 4).

IndVal analysis showed that species that mostly contribute to separate shallower and deeper assemblages were *D. vulgaris, D. dentex, M. helena* in high protected areas and *S. cantharus, D. vulgaris*, and *M. helena* in low protected areas. Species that mostly contributed to separate zones at different levels of protection were *D. vulgaris*, *D. dentex* and *L. viridis* at 20 m depth and *S. cantharus* and *L. viridis* at 5 m depth (Table 5).

Although *S. scrofa, E. marginatus, D. puntazzo, L. merula* were not detected as significant by IndVal analysis, they were mostly distributed in protected areas at 20 m of depth (Fig. 3). *P. phycis* was found only at 20 m depth in protected areas, although with very few individuals (data not shown).

4 Discussion

Results of the present study showed an interaction between depth and level of protection to determine fish assemblages around a small Mediterranean island. This result was consistent for the whole fish assemblage and for the targeted fishery species, though results varied with sample period.

Previous studies carried out around Giannutri Island 5 years after an MPA was established showed differences in size and abundance of target fish species between areas with different levels of protection (Micheli et al. 2005). Four years

Table 5. Results from IndVal using Bray-Curtis dissimilarity matrix of fish assemblages censused around Giannutri Island, NW Mediterranean Sea. For each level or partition, the listing gives the species that are indicator of the groups that are subdivided by the IndVal index and the result of a Student t−test (t) computing the weighted distance between randomised values and the observed values.

SHALLOW ASSEMBLAGES			**DEEP ASSEMBLAGES**		
Between levels of protection			**Between levels of protection**		
Taxa	**IndVal**	***t***	**Taxa**	**IndVal**	***t***
Spondyliosoma cantharus	42.4	2.9	*Diplodus vulgaris*	49.8	6.3
Labrus viridis	6.3	1.7	*Dentex dentex*	17.1	2.3
			Labrus viridis	10.4	2.8
HIGH PROTECTED AREAS			**LOW PROTECTED AREAS**		
Between depths			**Between depths**		
Taxa	**IndVal**	***t***	**Taxa**	**IndVal**	***t***
Diplodus vulgaris	40.9	3.2	*Spondyliosoma cantharus*	44.9	3.2
Muraena helena	22.9	5.4	*Diplodus vulgaris*	28.6	2.4
Dentex dentex	16.8	2.3	*Muraena helena*	10.9	2.1

later, the present study confirmed this observation, also underlining the importance of depth. The relationship between protection and depth has been investigated previously with variable results. While Bell (1983) detected differences between protected and unprotected fish assemblages at each of two depths considered, in most cases, the effects of protection were particularly evident in shallow habitats (Garcia-Rubies and Zabala 1990; Dufour et al. 1995). Nevertheless, deeper waters can represent a refuge for fished species, such as *Diplodus sargus, Diplodus vulgaris and Labrus merula* (Harmelin 1987; Pelaprat 1999).

The present study showed that, around Giannutri Island, differences in the abundance of target species were more evident at 20 m than at 5 m depth. This result could be explained considering the different life traits of the species involved and the characteristics of the MPA. In fact, some species are more linked to the bottom, showing a territorial behaviour (*Scorpaena scrofa, Epinephelus marginatus, Phycis phycis, Muraena helena, Labrus merula*), while other species exhibit a higher mobility (*Spondyliosoma cantharus, Diplodus sargus, Dicentrarchus labrax*) (Harmelin 1987; Dufur et al 1995); in a small MPA, such as the present one, where areas with different levels of protection are interspersed, the effect of protection could be most evident for sedentary species. These latter are principally related with the higher depth considered in this study, thus the interaction Protection *x* Depth documented is not surprising. However, mobile species common at the higher depth investigated, such as *Diplodus vulgaris, Diplodus puntazzo* and *Dentex dentex*, were also more abundant in protected areas. Results of the present study underline the difficulties related to the interpretation of data obtained by studies on fish assemblages. In fact, patterns of fish distribution may be influenced by sources of disturbance other than fishing and changes in fish behaviour determined by human activities may be different according to the different species (Pelaprat 1999). Moreover, behaviour of fishes may change also in relation to their life stages and reproductive cycle. Thus, it is important to detect the most suitable species and habitats to evaluate and monitor MPA effects (Harmelin et al. 1995).

In unprotected areas of Giannutri Island, only recreational fishing was permitted, allowing investigation of the effects of a kind of fishing rarely studied. In fact, the most studies on effect of MPAs compared protected areas with areas exploited by commercial fishing (Rakitin and Kramer 1996; Paddack and Estes 2000). Westera et al. (2003) showed that recreational fishing may have a relevant importance for shaping the structure of fish assemblages in tropical systems. The present study showed this finding also for the Mediterranean Sea, confirming previous observations on a few spearfishing target species (Jouvenel and Pollard 2001) and suggesting that this aspect needs to be much more consideration in the management of MPAs.

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