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Effects of total fishing prohibition on the rocky fish assemblages of Medes Islands marine reserve (NW Mediterranean)*

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SUMMARY: Visual scuba diving censuses were used to assess the effects of fishing prohibition on abundance and size structure of littoral fish populations by comparing the same benthic communities inside and outside the protected area of Medes Islands (NE Catalonia, Spain). The total number of species found was 43 in the reserve and 44 outside, but the mean value of species richness per sampling station was significantly higher in the protected area. However, H'were diversity, heavily affected by the presence or absence of large schools of pelagic species, showed no significant differences between sites. The prohibition of fishing for 6 years is the first factor affecting the qualitative and quantitative structure of fish populations ("reserve effect"), and depth is the second factor. Thus, except in the cases of *Serranus cabrilla* and *Mullus surmuletus*, all other vulnerable species are highly sensitive to the protection measures. The size structure of all vulnerable species was found to be absolutely different at the reserve sites than in the unprotected zones, and the modal size classes of size frequency distributions were always higher in the reserve than outside. The reserve effect was significantly responsible of the differences observed in this change on size structure. Some highly vulnerable species, such as *Epinephelus guaza* and *Sciaena umbra*, have only been found in the protected area. Others, such as *Sparus aurata, Diplodus cervinus* and *Dicentrarchus labrax,* were much more frequent inside the reserve.

Key words: Fishing prohibition, rocky fish, Medes Islands, NW Mediterranean.

RESUMEN: EFECTOS DE LA VEDA TOTAL DE PESCA DE LOS PECES DE LITORAL ROCOSO DE LA ZONA DE LAS ISLAS MEDAS (MEDITERRÁNEO NOROCCIDENTAL). — Mediante censos visuales, realizados *in situ* con escafandra autónoma, se han comprobado los efectos que la prohibición total de pesca ha tenido en la abundancia y la estructura de las tallas de las poblaciones de peces litorales que caracterizaban las mismas comunidades bentónicas dentro y fuera de la zona protegida de las islas Medes (NE de Catalunya, España). El número total de especies encontrado ha sido de 43 en la zona protegida y de 44 fuera de ella. Sin embargo, la riqueza específica media por estación de muestreo, ha sido significativamente mayor en el área protegida. Contrariamente, la diversidad, muy afectada por la presencia o ausencia de bancos de especies de marcado carácter pelágico, no presentó, en general, diferencias significativas. La prohibición total de pesca, establecida en el ámbito de las islas Medes desde hace 6 años, determina un denominado «efecto reserva», que se muestra como el factor principal que afecta la estructura, tanto cualitativa, como cuantitativa, de las poblaciones de peces litorales, mientras que la profundidad se revela como el segundo factor en orden de importancia. Así, excepto en los casos de *Serranus cabrilla* y *Mullus surmuletus,* el resto de los peces considerados como vulnerables presentan una fuerte correlación con el efecto reserva, lo que implica que estas especies son altamente sensibles a las medidas de protección. La estructura de tallas de las poblaciones de las especies vulnerables se mostró como completamente dispar entre la zona protegida y las no protegidas, siendo, en todos los casos, la talla modal de las poblaciones mayor en el ámbito de la reserva. El efecto reserva fue también, de forma significativa, el responsable de las diferencias observadas. Algunas especies altamente vulnerables, como *Epinephelus guaza* y *Sciaena umbra* han sido observadas sólo en la zona protegida. Otros, como *Sparus aurata, Diplodus cervinus* y *Dicentrarchus labrax,* fueron mucho más frecuentes en la reserva.

Palabras clave: Veda, peces costeros, islas Medes, Mediterráneo NO.

INTRODUCTION

In the last decade an increasing number of marine reserves have been established around the Mediterranean coast as an useful reaction against the increase of human presure on marine littoral habitats (COGNETTI, 1986). However, despite their obvious interest, few efforts have been made to evaluate the effects of these protective measures (BELL, 1983; POLUNIN *et al.*, 1983; RUSS, 1985). Fish populations

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constitute one of the more appropiate subjects of study because of their attractive and economical value. Also, a lot of easy and accurate methods to achieve visual fish censuses have been developed in the Mediterranean (HARMELIN-VIVIEN & HARMELIN, 1975) and in coral reefs (GBRMPA, 1978, 1979; THOMPSON & SCHMIDT, 1977; SALE & DOUGLAS, 1984; DOHERTY, 1987; KIMMEL, 1985; BOHNSACK & BANNEROT, 1986; GALZIN, 1986); and recently tested on Mediterranean coasts (BELL, 1983; HARMELIN, 1987). A good review of all these methods is given by HARMELIN-VIVIEN *et al.* (1985).

Changes in diversity and structure of fish populations are to be expected within marine reserves when fishing is forbidden as the fishing pressure alters them. Changes in both behavioural patterns and depth distributions of vulnerable species may also be expected. Thus, despite the fact that shallow waters offer more food resources (PÉRÈS & PICARD, 1964), refuges have been observed in deep waters in some target species (HARMELIN, 1987) due to direct human predation (spearfishing), that by itself implies a depth limit to fishing pressure. So, a change in depth distribution of some vulnerable species may be expected when the pressure of direct fishing disappears in the protected area.

This study accounts for both abundance and size class structure of all the fish species visually censused outside and inside the marine reserve of Medes Islands (NE Catalonia; NW Mediterranean). The aims of the present study were: (1) to provide reference data on the structure of fish populations within the reserve for further monitoring of changes related to protective measures; (2) to determine the effects of the reserve by comparing the structure of fish populations and benthic communities at the same depths inside and outside the protected area; (3) to test the hypothesis of a change in depth preferences according to direct fishing pressure (spearfishing).

METHODS

Study area

This study was undertaken on the NE Spanish Mediterranean shores within the Medes Islands protected area and the adjacent unprotected coast (Fig. 1). The reserve is located one mile off the town of l'Estartit (3° 13′ E, 42° 16′ N) and it encompasses a small archipelago (less than 2 Ha in surface) comprised of two islets and a lot of small emergent rocky reefs. The protected area extends only 75 m off the outer points of the archipelago. Despite their reduced limits, the bottoms around the islands contain almost all the littoral benthic community types described in the Mediterranean (PÉRÈS & PICARD, 1964; ROS, OLIVELLA & GILI, 1984), and they attract a great number (50 000 per year) of scuba-diving visitors. All kinds of fishing have been prohibited within these boundaries since November, 1983. The fish fauna of these islands has previously been studied qualitatively by BORI (1984).

Outside the reserve, sampling points were selected in two adjacent areas: Punta Salines (1 mile nord ward from Medes), and Cap Begur (10 miles soreth ward from Medes) (Fig. 1).

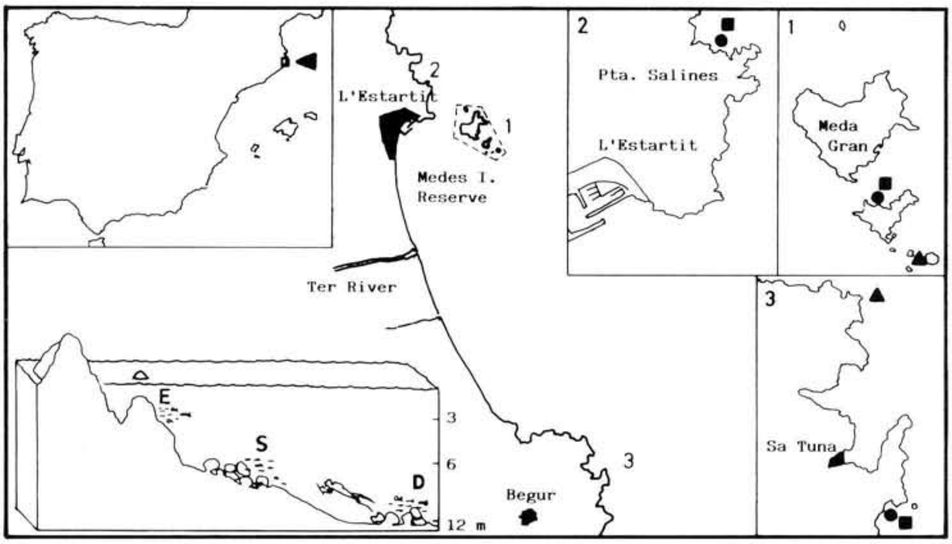

FIG. 1. — Map of Medes Islands protected area and surrounding coastline showing the location of sampling stations: 1) Medes Islands; 2) Punta Salines; 3) Cap Begur. Dots, shallow sites (S); Squares, deep sites (D); Triangles, exposed sites (E). At left a diagram of the selected depths.

Description of sites

The effects of protection on fish populations should be assessed only on equivalent bottoms, outside and inside the reserve, carefully selected for similar biota, rugosity and depth.

In each one of three selected sampling areas (1 in the reserve; 2, 3 outside the reserve) fish assemblages from three of the shallower rocky benthic Mediterranean communities have been studied: shallow-sheltered boulders; deep-sheltered boulders, and exposed subemergent rocky outcrops. Several reasons have determined this selection. Shallow bottoms are the most accessible, hence the most sensitive to different fishing methods, where spearfishing adds to amateur angling and professional fishing. In bottoms shallower than 50 m depth, there are mainly three kinds of fishing, and each one has its main range of depths: shallow to medium (spearfishing); shallow-medium to deep (angling); medium to deep (professional fishing). In the shallowest areas, where spearfishing tends to be dominant, strong differences of direct human predation pressure above and beyond 10 m depth should be expected. The comparison of two depths, 6 m and 12 m depth ("shallow" and "deep", in what follows) has been made from this point of view. On the other hand, shallow rocky bottoms show a high degree of physical heterogeneity, mainly with respect to light and water movement. This physical heterogeneity implies a strongly patchy distribution of the benthic assemblages, and fish richness and diversity are directly related to this environmental "rugosity" (LUCKHURST & LUCKHURST, 1977). Finally, shallow benthic communities are high primary production areas with substantial secondary production, so they are able to maintain the richest littoral fish assemblages.

Bottoms from 6 m depth in sheltered protected areas (RS), and unprotected areas (NRS1 and NRS2) are comprised of beds of medium-sized boulders covered by hemisciaphilic algal communities (BALLESTEROS, 1989); *Dictyota dichotoma, Codium vermilara, Codium bursa, Halopteris scoparia,* and *Sphaerococcus coronopifolius* are the commonest species.

Bottoms at 12 m depth in sheltered areas (RD, NRD1 and NRD2) have a similar topographic pattern but have sciaphilic algal communities (BALLESTEROS, 1989) with *Halimeda tuna, Udotea petiolata* and *Mesophyllum lichenoides* as the most characteristic species. The sessile macrofauna is represented by sponges *(Agelas oroides, Chondrosia reniformis, Ircinia fasciculata),* cnidarians *(Alcyonium acaule, Eunicella singularis),* bryozoans *(Myriapora truncata, Pentapora fascialis)* and ascidians *(Cystodites dellechiajei, Halocynthia papillosa).*

The exposed subemergent rocky reefs (RE and NRE) were covered by a photophilic algae community overgrazed by sea urchins *Arbacia lixula* and *Paracentrotus lividus* (AUGIER & BOUDOURESQUE, 1970). Calcareous algae *Lithophyllum incrustans* and *Corallina elongata* are dominant species. Sponges *(Hymeniacidon sanguinea, Crambe crambe),* molluscs *(Ostraea edulis),* barnacles *(Balanus perforatus),* and tunicates *(Microcosmus sabatieri, Diplosoma spongiforme)* are the most conspicuous sessile benthic fauna.

In total, 8 stations were sampled; three in the protected area: "Reserve-Shallow" (RS) at 6 m, "Reserve-Deep" (RD) at 12 m; "Reserve-Exposed" (RE), between 3 and 10 m depth, strongly affected by S-N water currents. Outside the reserve there were 2 sampling stations in the Punta Salines area, "Non Reserve-Shallow 1" (NRS1) at 6 m deep, and "Non Reserve-Deep 1" (NRSD1) et 12 m depth; and three in the Cap Begur area, "Non Reserve-Shallow 2" (NRS2) at 6 m depth, and "Non Reserve-Deep 2" (NRD2) at 12 m depth; "Non Reserve Exposed" (NRE), a big rocky sub-emergent reef affected by strong water currents between 3 and 10 m depth (Fig. 1).

Collection of data

The stripe transect method (BELL, 1983; HARMELIN-VIVIEN *et al.*, 1985; HARMELIN, 1987) was selected from the various visual methods designed to asses the composition and size structure of fish populations (THOMPSON & SCHMIDT, 1977; BOHNSACK & BANNEROT, 1986; KIMMEL, 1985). This technique minimizes the probability of sighting the same individuals repeatedly and ensures that sufficient small sedentary necto-benthic species are observed for meaningful statistical analysis. Transects (50 m long; 5 m wide) were delimited with ropes. Sampling was conducted by the authors swimming slowly along the transect and recording the number and sizes of all fishes associated with the bottom and in the water column. The first diver counted all strongly swimming fish, with extended home-ranges (categories 1-4 of HARMELIN, 1987); the second diver, swimming more slowly and nearer the bottom, counted less mobile species (categories 5-6 of HARMELIN, 1987). A sample took around 10 minutes for the first diver and around 25 for the second.

Environmental parameters such as water transparency, surface weather, time of the circadian cycle, seasonality and so one, have been proved to affect both the behavioural patterns of fishes and the perfomance of census takers (HARMELIN-VIVIEN *et al.*, 1985). In order to minimize these effects, five replicates of each site were made around 12.00 h., on sunny days during summer (2 July-30 August, 1988). Individual size data were recorded by using three discrete classes. These classes encompassed one third of the maximum recorded total length of each species recorded in the literature (from BAUCHOT & PRAS, 1982).

Abundance data were collected by using pre-established discrete classes which follow a roughly exponential progression with base 2: 1/2/3-4/5-10/11-30/31-50/51-100/ > 101. Values from log abundance categories community structure parameters have been repeatedly applied to characterize the structure of fish assemblages (GLADFELTER, *et al.*, 1980; BELL, 1983; HARMELIN-VIVIEN *et al.*, 1985).

Data analysis

Number of species (S) and Shannon-Weaver diversity index (H') (MARGALEF, 1974) values were calculated for each sample. Mean values for each parameter were compared using one-way ANOVA for both site and depth variables. In order to separate the community and depth effects on species abundance from the reserve effect, data from protected vs. unprotected areas were compared using samples from similar communities and depths. Qualitative similarities among samples were calculated with the Czechanovski index ($100 \times 2C/A + B$, where A = number of species in transect a; B = number of species in transect b; and C = number of species common to both transects) (MARGALEF, 1974). The similarity matrix was ordinated using a hierarchical aglommerative method (cluster) (LEGENDRE & LEGENDRE, 1982) with the program CLUSTAN 2.

Only 34 species (66 % of the whole recorded stock) were frequent enough to be used for statistical analysis. Principal component analysis (LEGENDRE & LEGENDRE, 1984) was made on the transformed [log (x + 1)] abundances of the 34 most frequent species.

Abundance data and size frequency distributions were analyzed only on the vulnerable species group. A two way ANOVA (SOKAL & ROHLF, 1979) was used to test the reserve and depth effects on the log (x+1) transformed abundance of vulnerable fishes in the three size classes.

RESULTS

Qualitative results

The whole fish community censused (Table 1) comprises 51 species. In fact, these inventories underestimate the real species richness because in-

TABLE 1. — List of species censused in the study (vulnerable species to: P, professional fishing methods; A: angling; S: spearfishing)

Family	*Species*	*Main fishing methods*
Muraenidae	*Muraena helena* Linné	P + S
Gadidae	*Phycis phycis* (Linné)	P + S
Scorpaenidae	*Scorpaena scrofa* Linné	P + S
	S. porcus Linné	P + S
	S. notata Rafinesque	
Serranidae	*Serranus cabrilla* (Linné)	A
	S. scriba (Linné)	A
	Epinephelus guaza (Linné)	P + S
	Dicentrarchus labrax (Linné)	P + A + S
Apogonidae	*Apogon imberbis* (Linné)	
Carangidae	*Seriola dumerilii* (Risso)	P + A + S
Mullidae	*Mullus surmuletus* Linné	P + A + S
Sparidae	*Diplodus sargus* (Linné)	P + A + S
	D. vulgaris (E. G. Saint-Hilaire)	P + A + S
	D. cervinus (Lowe)	P + A + S
	D. annularis (Linné)	P + A
	D. puntazzo (Cetti)	P + A + S
	Spondyliosoma cantharus (Linné)	P + A + S
	Sparus aurata Linné	P + A + S
	Pagrus pagrus (Linné)	P + A + S
	Sarpa salpa (Linné)	P
	Boops boops (Linné)	
	Oblada melanura (Linné)	A
Centracanthidae	*Spicara smaris* (Linné)	
	S. maena (Linné)	
Sciaenidae	*Sciaena umbra* Linné	S
Pomacentridae	*Chromis chromis* (Linné)	
Mugilidae	*Mugil* spp.	
Atherinidae	*Atherina* spp.	
Sphyraenidae	*Sphyraena sphyraena* (Linné)	P + A
Labridae	*Symphodus doderleini* Jordan	
	S. mediterraneus (Linné)	
	S. melanocercus (Risso)	
	S. ocellatus (Forskal)	
	S. roissali (Risso)	
	S. rostratus Bloch	
	S. tinca (Linné)	S
	Ctenolabrus rupestris (Linné)	
	Labrus merula Linné	
	L. bimaculatus Linné	
	L. viridis Linné	S
	Coris julis (Linné)	A
	Thalassoma pavo (Linné)	
Blenniidae	*Blennius gattorugine* Brünnich	
	B. rouxi Cocco	
	B. incognitus Bath	
Tripterygiidae	*Tripterygion* spp.	
IDAE	*Gobius cruentatus* Gmelin	
	G. buchichii Steindachner	
	G. auratus Risso	
Scomberomoridae	*Sarda sarda* (Bloch)	P + A

dividuals belonging to the genera *Tripterygion* and *Atherina* and the family Mugilidae were not identified at the species level. Labridae (13 species), Sparidae (11 species), and Serranidae (4 species) are the more important families. Gobiidae, which are represented by three species outside the reserve, have never been observed inside the protected area where Blenniidae seem to be more frequent. The most attractive species for spearfishing in the Mediterranean Sea, such as groupers *(Epinephelus guaza)*, gilt-head breams *(Sparus aurata)*, brown meagre *(Sciaena umbra)* or sea-bass *(Dicentrarchus labrax)* were almost entirely confined to the protected area. Despite the fact that they may be occasionally encountered outside the reserve, low density and escape and depth refuge behaviour explain why they have not been encountered within the transects.

These results agree well with those reported by other authors in similar studies from neighbouring areas in the Mediterranean Sea (BELL, 1983; HARMELIN, 1987).

Effects of protection on species richness and diversity

A similar overall species richness was noted in the two zones censused: 44 species were found outside and 43 species inside the reserve.

TABLE 2. — Summary of one-way ANOVA showing the effect of reserve on mean number of species per comparable sampling stations and on the mean number of species inside and outside the reserve (RS = Reserve shallow; NRS1 = Non-reserve shallow 1; NRS2 = Non-reserve shallow 2; RD = Reserve deep; NRD1 = Non-reserve deep 1; NRD2 = Non-reserve deep 2; RE = Reserve exposed; NRE = Non-reserve exposed) (*$p < 0.05$; **$p < 0.025$; ***$p < 0.005$; NS = Not significative).

Source of variation	*d.f.*	*SS*	*MS*	*Fs*
RS-NRS1	1	62.4	62.4	12.117 ***
Error	8	41.2	5.15	
Total	9	103.6		
RD-NRD1	1	2.5	2.5	0.926 NS
Error	8	21.6	2.7	
Total	9	24.1		
RS-NRS2	1	19.6	19.6	3.35 NS
Error	8	46.8	5.85	
Total	9	66.4		
RD-NRD2	1	52.9	52.9	6.08 ***
Error	8	69.6	8.7	
Total	9	122.5		
RE-NRE	1	108.9	108.9	29.04 ***
Error	8	30	3.75	
Total	9	138.9		
Reserve-Non reserve	1	59.875	59.875	32.295 ***
Error	6	11.125	1.854	
Total	7	71		

TABLE 3. — Summary of ANOVA showing the effect of reserve on mean specific diversity (H') between comparable samplig stations (RS = Reserve shallow; NRS1 = Non-reserve shallow 1; NRS2 = Non-reserve shallow 2; RD = Reserve deep; NRD1 = Non-reserve deep 1; Non-reserve deep 2; RE = Reserve exposed; NRE = Non-reserve exposed) (*$p < 0.05$; **$p < 0.025$; ***$p < 0.005$; NS = not significant).

Source of variation	*d.f.*	*SS*	*MS*	*FS*
RS-NRS1	1	0.147	0.147	1.301 NS
Error	8	0.9	0.113	
Total	9	1.047		
RD-NRD1	1	2.809	2.809	6.885 ***
Error	8	3.230	0.408	
Total	9	6.039		
RS-NRS2	1	0.055	0.055	0.495 NS
Error	8	0.885	0.111	
Total	9	0.94		
RD-NRD2	1	0.002	0.002	0.011 NS
Error	8	1.499	0.187	
Total	9	1.501		
RE-NRE	1	4.199	4.199	23.199 ***
Error	8	1.447	0.181	
Total	9	5.646		

Mean richness, expressed as the mean value of the whole census at each station, is significantly higher inside than outside the reserve ($p < 0.01$) (Table 2). One way-ANOVA between each pair of sites with equivalent effect on richness in all but two cases (Table 2). The exposed outcrop sites (RE and NRE) show the most important differences and the depth sheltered sites (RD, NRD1 and NRD2) the least.

H' diversity is generally higher inside the reserve but ANOVA analysis show that differences are not significant, except for RD-NRD1 and RE-NRE, because of the sporadic occurrence of schooling species (e.g. *Chromis chromis, Boops boops, Sarpa salpa* or *Oblada melanura*) (Table 3).

Effects of protection on community structure

Cluster clearly separates most reserve from non-reserve samples (Fig. 2). Therefore, the protected area is characterized by a group of species restricted to the reserve. This agrees well with the differences described above on species richness between protected and non-protected areas.

The principal component analysis also confirms the strong effect of the reserve on the structure of fish populations. The first factor (21.6 % variance explained) separates the reserve samples (positive values) from the non reserve samples (negative values). The second factor (11.8 % variance explained) seems to separate shallow samples from deeper ones (Fig. 3).

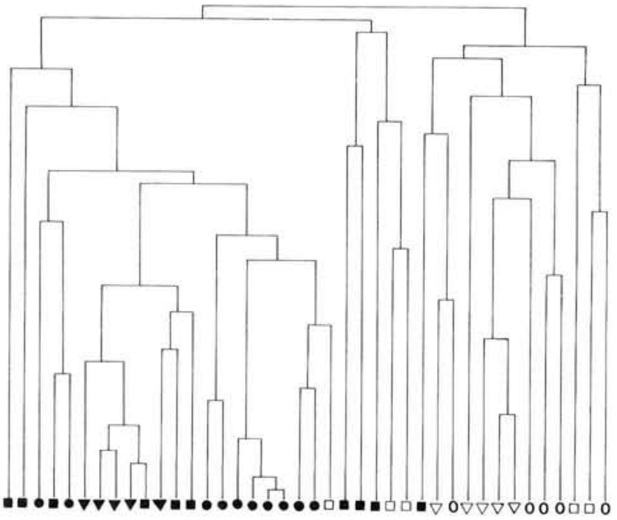

FIG. 2. — Dendrogram of similarities between all censuses sampled on the eight selected sampling stations (Open symbols: reserve sampling points; full symbols: non-reserve sampling points). Symbols as in Fig. 1.

Most species which positively correlate with the first factor are highly vulnerable speceis, whilst those that correlate negatively, except *Serranus cabrilla* and *Mullus surmuletus*, are mainly non-vulnerable species (Table 4).

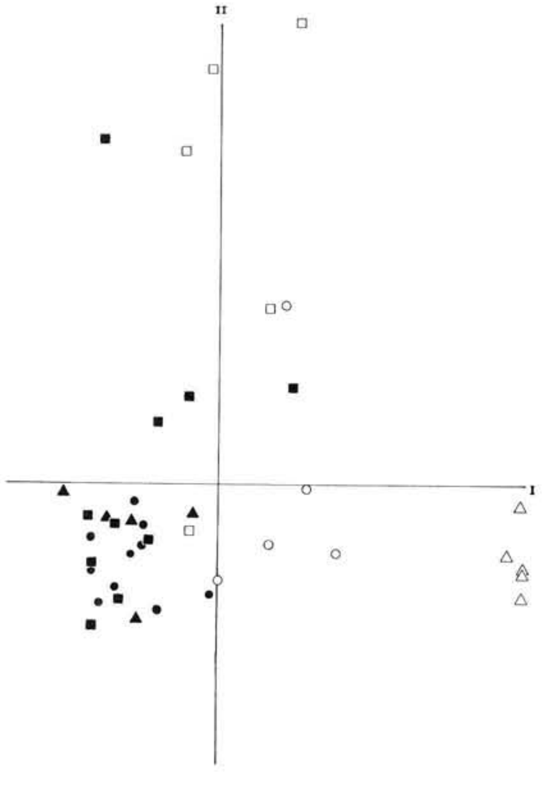

FIG. 3. — Principal Component Analysis of all samples. The first two PCA axes account for 33 % of variance. The first factor is interpreted as a reserve-nonreserve gradient; the second one represents the depth gradient (Open symbols: reserve sampling stations; full symbols: non-reserve sampling stations). Symbols as in Fig. 1.

TABLE 4. — List of species significantly correlated ($p < 0.05$) on the first two eigenvectors (I = Reserve; II = Depth) produced by ordination (* = vulnerable species; R = reserve; NR = non-reserve; D = deep; S = shallow).

Species	*Correlation* *I*	*Coefficients* *II*
*Serranus cabrilla**	−0.797 NR	0.131
*Mullus surmuletus**	−0.747 NR	0.241
Gobius bucchichii	−0.627 NR	0.198
Symphodus roissali	−0.474 NR	0.572 S
*Sarpa salpa**	−0.427 NR	0.382 S
Symphodus rostratus	−0.286	0.093
Blennius rouxi	−0.278	−0.386 D
Boops boops	−0.278	0.429 S
Tripterygion spp.	−0.258	0.237
Blennius gattorugine	−0.248	0.159
*Labrus viridis**	−0.218	0.104
*Symphodus tinca**	−0.188	0.800 S
*Oblada melanura**	−0.094	0.297
Symphodus ocellatus	−0.054	0.008
Chromis chromis	−0.020	0.432 S
Spicara smaris	−0.013	−0.148
*Coris julis**	0.032	0.179
Ctenolabrus rupestris	0.037	−0.328 D
*Labrus merula**	0.046	−0.069
Symphodus melanocercus	0.096	−0.490 D
Symphodus doderleini	0.128	−0.539 D
*Scorpaena porcus**	0.164	0.210
Mugil spp.	0.212	0.490 S
*Diplodus vulgaris**	0.402 R	0.200
*Labrus bimaculatus**	0.450 R	−0.543 D
*Symphodus mediterraneus**	0.461 R	−0.183
*Diplodus annularis**	0.531 R	0.268
*Diplodus sargus**	0.613 R	0.437 S
*Sciaena umbra**	0.682 R	0.382 S
*Diplodus puntazzo**	0.695 R	0.204
*Sparus aurata**	0.785 R	0.424 S
*Spondyliosoma cantharus**	0.806 R	0.057
*Dicentrarchus labrax**	0.812 R	0.316
*Diplodus cervinus**	0.828 R	−0.027

Two way ANOVA (size × reserve) show that density is generally higher inside the reserve but the effect is not statistically significant, except between stations RE-NRE and RS-NRS1 (Table 5). Otherwise the analysis shows a significant effect of marine reserve on size class distribution. This is due to the higher densities of medium and large individuals at reserve sites. The size frequency distributions of the whole community of species from reserve and non-reserve sites are given in Fig. 4. Medium or large-sized individuals formed the modal size class at sites inside the reserve, whereas the modal class outside the protected area is always for small-sized individuals. Large-sized individuals are always more abundant than small ones inside the reserve (Fig. 4).

Total abundance and size frequency distributions of five species and a multispecific group (big Labridae, such as *Labrus merula, L. viridis* and *Symphodus tinca*) wich are common target fish (Figs. 5 to 10) are clearly affected by the reserve effect. The modal size class of these species always consisted of medium-sized individuals inside the reserve and of small individuals outside the protected area.

The abundance data also shows the same above described pattern (i.e. density is higher inside the reserve) except for two species, *Mullus surmuletus* and *Serranus cabrilla*, which are more abundant outside the reserve. In the first case, this is due to changes in the numbers of individuals forming schools, which are higher when the schools are formed by juvenile or small fish than when they are formed by medium-sized or large individuals.

The apparent contradiction of the *Serranus cabrilla* results has been found previously by BELL (1983). In this case, the strong territorial behaviour of this species and a relation between body size and area defended may be the explanation. Thus, large individuals defend more extensive territories than smaller ones which should result in lower densities when the main population is formed by large individuals (marine reserve) than when it is formed mainly by small fishes (outside the marine reserve).

TABLE 5. — Summary of two way ANOVA (size × reserve) on all vulnerable species between comparable samplig stations (RS = Reserve shallow; NRS1 = Non-reserve shallow 1; NRS2 = Non-reserve shallow 2; RD = Reserve deep; NRD1 = Non-reserve deep 1; NRD2 = Non-reserve deep 2; RE = Reserve exposed; NRE = Non-reserve exposed) (*p < 0.05; **p < 0.025; ***p < 0.005; NS=Not significant).

Source of variation	*d.f.*	*SS*	*MS*	*Fs*
Size	2	1.607	0.804	21.730 ***
RS-NRS1	1	0.248	0.248	6.703 ***
Size × RS-NRS1	2	4.171	2.086	56.378 ***
Error	24	0.881	0.037	
Total	29	6.907		
Size	2	0.491	0.246	11.182 ***
RD-NRD1	1	0.002	0.002	0.002 NS
Size × RD-NRD1	2	0.959	0.480	21.818 ***
Error	24	0.530	0.022	
Total	29	1.982		
Size	2	1.343	0.672	24 ***
RS-NRS2	1	0.116	0.116	4.143 NS
Size × RS-NRS2	2	3.272	1.636	58.429 ***
Error	24	0.675	0.028	
Total	29	5.406		
Size	2	1.111	0.556	25.273 ***
RD-NRD2	1	0.007	0.007	0.318 NS
Size × RD-NRD2	2	1.868	0.934	42.455 ***
Error	24	0.525	0.022	
Total	29	3.511		
Size	2	1.703	0.852	56.800 ***
RE-NRE	1	1.234	1.234	82.267 ***
Size × RE-NRE	2	4.151	2.076	138.400 ***
Error	24	0.357	0.015	
Total	29	7.445		

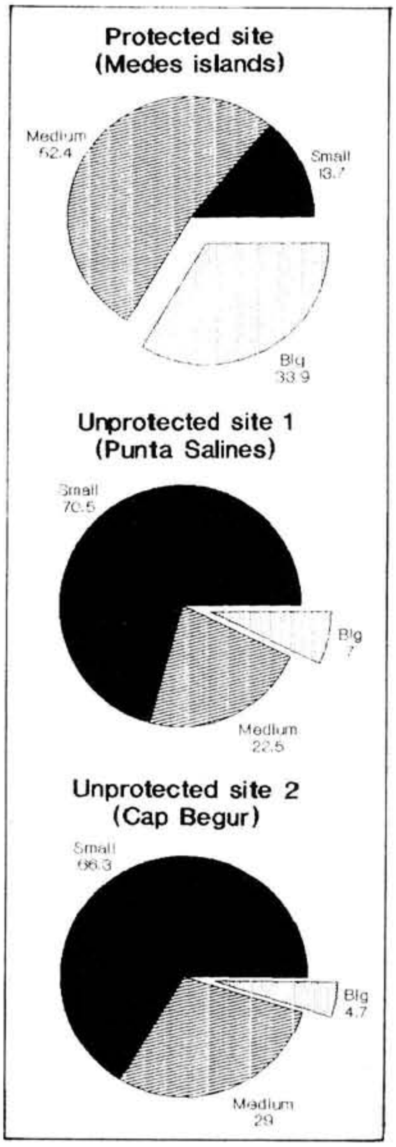

FIG. 4. — Size frequency distributions (in %) of all vulnerable species at the three selected sites.

Effects of depth on richness, diversity and structure

Depth is the second parameter used to explain the structure of fish assemblages. Depth appears to have an strong effect on species richness (Table 6), but the sense of the differences observed is inverse depending on the site: inside the reserve, richness is significantly higher in shallow waters ($p < 0.025$), whilst ouside it, richness increases significantly with depth ($p < 0.025$). Neverthless, one way-ANOVA shows that depth does not have a significant effect on H′ diversity values (Table 7).

Symphodus tinca, Mugil spp., *Symphodus roissali, Diplodus sargus, Sciaena umbra,* and, in general,

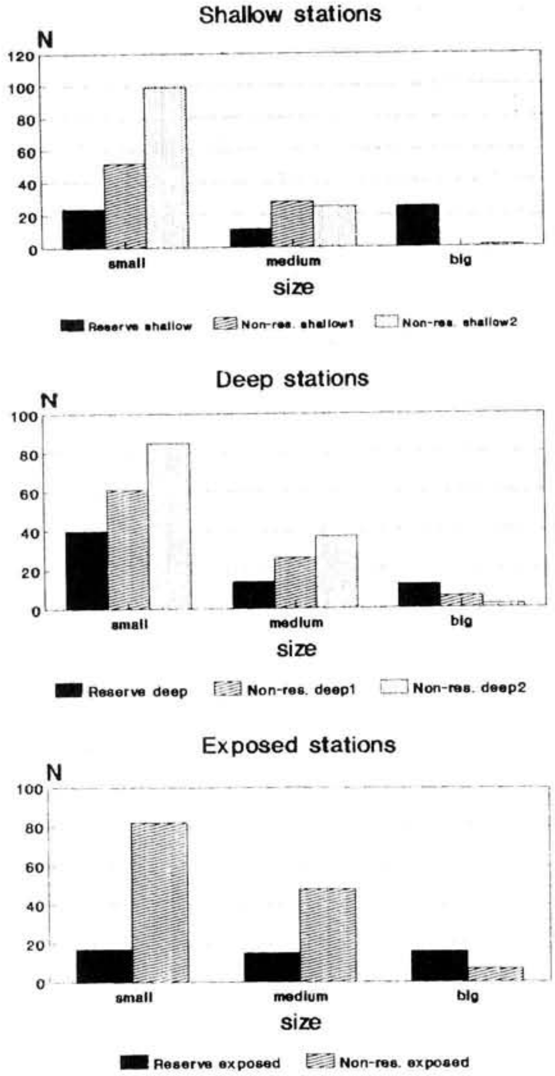

FIG. 5. — Size frequency distributions of *Serranus cabrilla* (N: accumulated number of individuals).

TABLE 6. — One-way ANOVA showing the effect of depth on mean number of species between comparable sampling stations (RS = Reserve shallow; NRS1 = Non-reserve shallow 1; NRS2 = Non-reserve shallow 2; RD = Reserve deep; NRD1 = Non-reserve deep 1; NRD2 = Non-reserve deep 2) (*p < 0.05; **p < 0.025; ***p < 0.005; NS = Non significant).

Source of variation	*d.f.*	*SS*	*MS*	*Fs*
RS-RD	1	36.1	36.1	5.270 **
Error	8	54.8	6.85	
Total	9	90.9		
NRS1-NRD1	1	0.4	0.4	0.4 NS
Error	8	8	1	
Total	9	8.4		
NRS2-NRD2	1	32.4	32.4	4.208 **
Error	8	61.6	7.7	
Total	9	94		

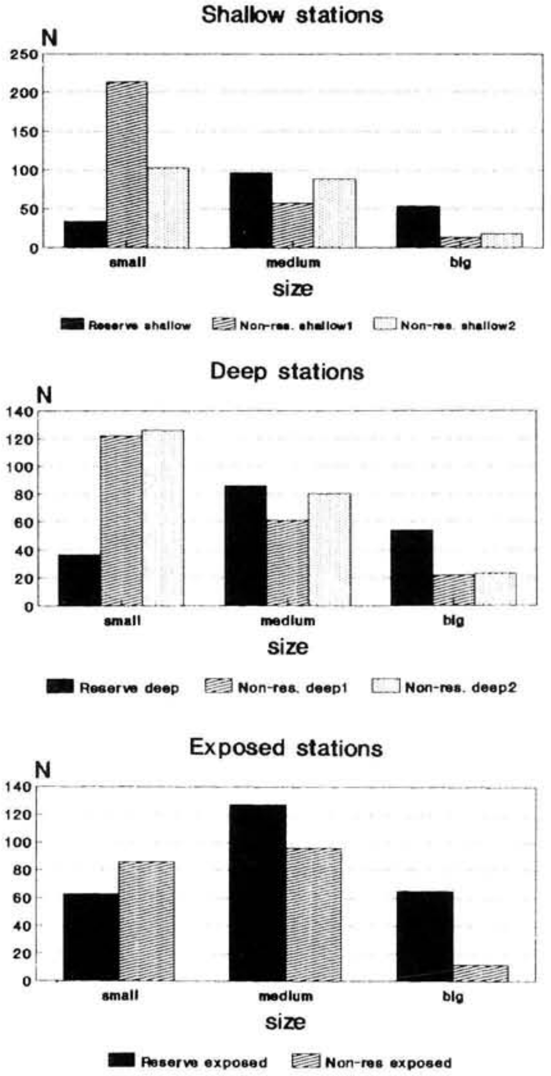

FIG. 6. — Size frequency distribution of *Coris julis* (N: accumulated number of individuals).

TABLE 7. — Summary of ANOVA showing the effect of depth on mean specific diversity (H′) between comparable sampling stations (RS = Reserve shallow; NRS1 = Non-reserve shallow 1; NRS2 = Non reserve shallow 2; RD = Reserve deep; NRD1 = Non-reserve deep 1; NRD2 = Non-reserve deep 2) (*p < 0.05; **p < 0.025; ***p < 0.005; NS = not significant).

Source of variation	*d.f.*	*SS*	*MS*	*Fs*
RS-RD	1	0.135	0.135	1.378 NS
Error	8	0.785	0.098	
Total	9	0.92		
NRS1-NRD1	1	0.859	0.859	2.055 NS
Error	8	3.345	0.418	
Total	9	4.204		
NRS2-NRD2	1	0.310	0.310	1.550 NS
Error	8	1.599	0.200	
Total	9	1.909		

mid-water species (categories 1 and 2 of HARMELIN, 1987) such as *Chromis chromis, Oblada melanura* and *Boops boops* that correlate positively with the second factor can be considered as "shallow species". *Labrus bimaculatus, Symphodus melanocercus, Ctenolabrus rupestris, Blennius rouxi* and *Symphodus mediterraneus* correlate negatively and can be considered as "deep species".

Depth also affects the size class distribution. Outside the reserve small sizes are more abundant in shallow sites than in deeper ones. Two way ANOVA shows that the effect is only significant at one station (NRS1-NRD1). Conversely, inside the reserve, medium and large classes are more abundant in the shallowest sites than in the deepest ones, but differences are not significant (Table 8).

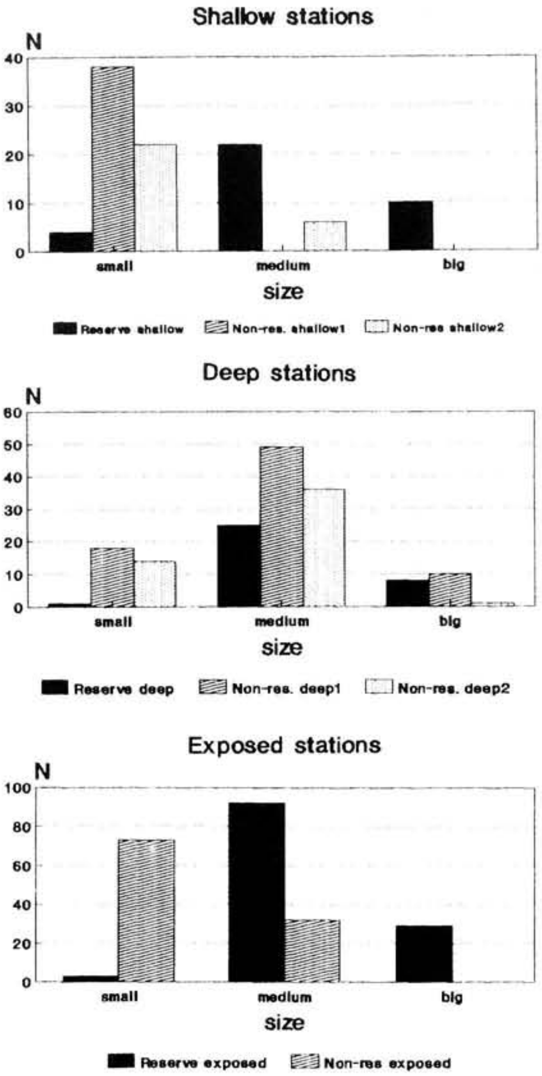

FIG. 7. — Size frequency distributions of *Diplodus vulgaris* (N: accumulated number of individuals).

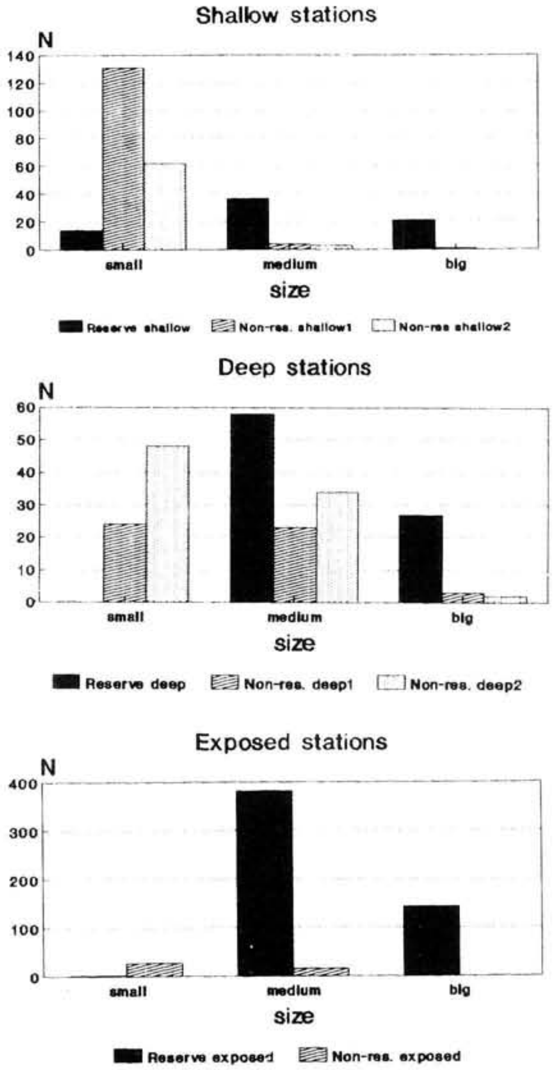

FIG. 8. — Size frequency distributions of *Diplodus sargus* (N: accumulated number of individuals).

TABLE 8. — Summary of two way ANOVA (sixe z depth) on all vulnerable species between comparable sampling stations (RS = Reserve shallow; NRS1 = Non-reserve shallow 1; NRS2 = Non-reserve shallow 2; RD = Reserve deep; NRD1 = Non-reserve deep 1; NRD2 = Non-reserve deep 2) (*p < 0.05; **p < 0.025; ***p < 0.005; NS = non significant).

Source of variation	*d.f.*	*SS*	*MS*	*Fs*
Size	2	0.758	0.374	15.160 ***
RS-RD	1	0.015	0.015	0.6 NS
Size × RS-RD	2	0.016	0.008	0.32 NS
Error	24	0.594	0.025	
Total	29	1.383		
Size	2	5.463	2.732	80.353 ***
NRS1-NRD1	1	0.199	0.199	5.853 **
Size × NRS1-NRD1	2	0.971	0.486	14.294 ***
Error	24	0.816	0.034	
Total	29	7.449		
Size	2	6.686	3.342	133.680 ***
NRS2-NRD2	1	0.092	0.092	3.680 NS
Size × NRS2-NRD2	2	0.128	0.064	2.560 NS
Error	24	0.605	0.025	
Total	29	7.511		

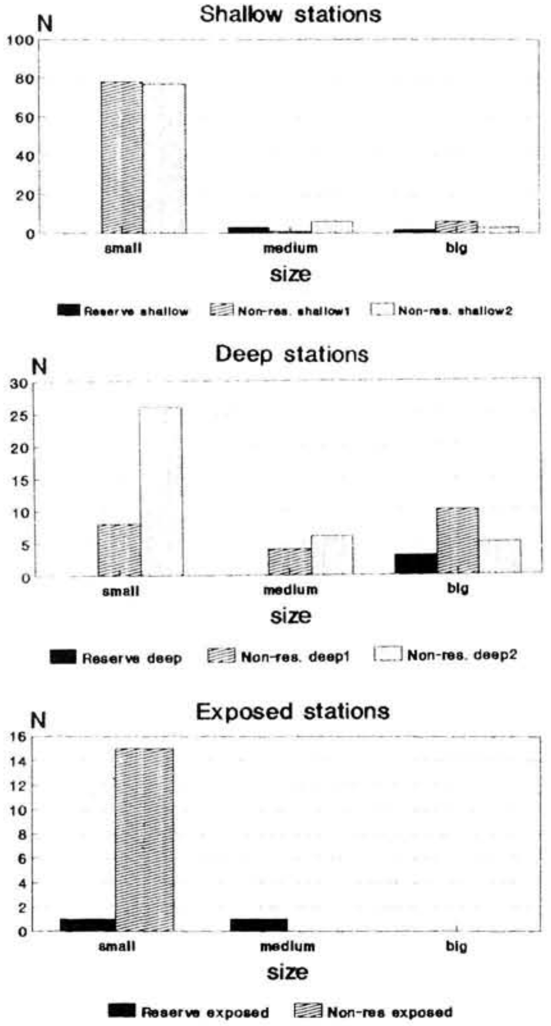

FIG. 9. — Size frequency distributions of big vulnerable labridae (N: accumulated number of individuals).

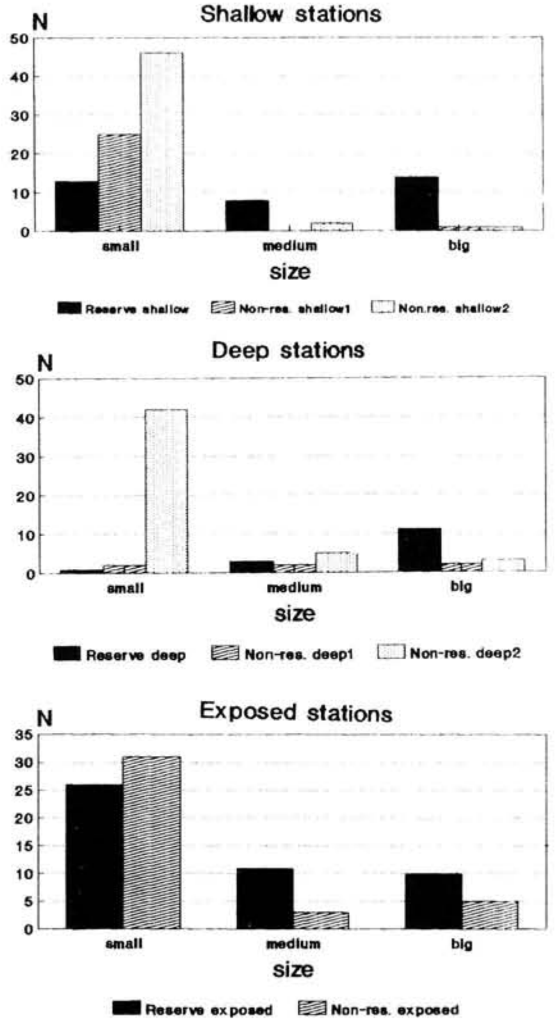

FIG. 10. — Size frequency distributions of *Mullus surmuletus* (N: accumulated number of individuals).

DISCUSSION

The taxonomic composition of fishes repertoried in the Medes region agrees well with other similar NW Mediterranean areas (BELL, 1983; HARMELIN, 1987). The Medes Islands ichthyofauna seems to be richer than that of Banyuls-sur-Mer (BELL, 1983). This difference may originate in the lower accuracy of Bell's method in accounting small sedentary species. Species richness is significantly higher inside the reserve sites than outside. Hovewer, H′ diversity shows no significant differences between the protected and unprotected area. This is because of the "noisy" effect introduced by the erratic presence or absence of large schools of mid-water species (*Boops boops, Chromis chromis, Oblada melanura*, etc.). The reserve effect is the first factor affecting both the qualitative and quantitative structure of fish assemblages, depth being the second one. BELL (1983) found the same structuring factors but in inverse order, perhaps because of the wider range of depths compared by this author.

Except for *Serranus cabrilla* and *Mullus surmuletus*, the abundance of vulnerable species correlates strongly with the reserve effect, and therefore shows that the reserve has been effective in providing protection for such species. Some highly spearfished species such as *Epinephelus guaza* or *Sciaena umbra* have been censused exclusively within the reserve. Others such as *Dicentrarchus labrax, Sparus aurata* and *Diplodus cervinus* are far more abundant inside the reserve (see Table 9). The demographic structures of the fish population can be considered the main difference between protected and unprotected areas. That does not mean marine reserves are merely overcrowded refuges for large individuals, but zones where natural, non-harvested and, as a consequence, adult fish populations, are maintained. From this point of view these protected populations can be considered as atypical, or "un-natural". But, what is

TABLE 9. — Densities expressed as mean number of individuals per 250 m² (± SE) of all the species censused in the study.

Species	*RS*	*RD*	*RE*	*NRS1*	*NRD1*	*NRS2*	*NRD2*	*NRE*
M. helena	0	0	0	0	0	0	0.2 ± 0.201	0
P. phycis	0.4 ± 0.246	0	0	0	0	0	0	0
S. scrofa	0	0.6 ± 0.246	0	0	0.4 ± 0.246	0	0	0
S. porcus	1.4 ± 0.680	0.6 ± 0.389	1.8 ± 0.917	0.4 ± 0.246	0.6 ± 0.398	0.2 ± 0.201	0.6 ± 0.398	2.6 ± 0.680
S. notata	0	0	0	0	0	0	0.2 ± 0.201	0
S. cabrilla	12.0 ± 1.306	13.2 ± 2.782	9.6 ± 0.510	17.4 ± 2.379	18.6 ± 2.133	25.0 ± 1.923	24.8 ± 3.260	27.4 ± 1.078
S. scriba	0.2 ± 0.201	0.2 ± 0.201	0	0.6 ± 0.398	0.2 ± 0.201	0.4 ± 0.246	0	0
E. guaza	0	0	1.0 ± 0.318	0	0	0	0	0
D. labrax	0.8 ± 0.581	0.4 ± 0.398	12.6 ± 4.566	0	0.2 ± 0.201	0	0	0
A. imberbis	0.2 ± 0.201	0	0	0	0	0.4 ± 0.398	0	0
S. dumerilii	0	0	6.0 ± 6.002	0	0	0	0	0
M. surmuletus	1.0 ± 0.774	0.6 ± 0.599	0.4 ± 0.246	17.0 ± 1.923	4.4 ± 1.503	17.2 ± 3.090	7.4 ± 0.814	3.0 ± 1.583
D. sargus	14.4 ± 3.587	17.0 ± 3.564	105.6 ± 13.630	27.2 ± 9.928	10.0 ± 5.264	13.0 ± 3.935	16.8 ± 8.470	9.0 ± 2.388
D. vulgaris	7.2 ± 1.319	6.8 ± 2.536	24.8 ± 2.352	7.6 ± 0.398	15.4 ± 4.490	5.6 ± 2.160	9.8 ± 3.412	21.5 ± 5.890
D. cervinus	0.8 ± 0.492	1.4 ± 0.510	2.8 ± 0.733	0	0.6 ± 0.599	0	0	0
D. annularis	1.0 ± 0.318	0.4 ± 0.398	1.4 ± 0.246	0.6 ± 0.246	0.2 ± 0.201	0.2 ± 0.201	0.2 ± 0.201	0
D. puntazzo	1.6 ± 0.398	1.0 ± 0.318	8.0 ± 4.405	0	0	0	0.8 ± 0.581	0.2 ± 0.201
S. cantharus	1.4 ± 0.926	1.8 ± 1.319	6.6 ± 1.288	0.8 ± 0.398	0	0	0.8 ± 0.581	0
S. aurata	1.2 ± 0.970	0	11.4 ± 1.364	0	0.4 ± 0.398	0	0.2 ± 0.201	0
P. pagrus	0	0	0	0	0	0	0.2 ± 0.201	0.2 ± 0.201
S. salpa	11.6 ± 4.749	24.0 ± 11.663	71.6 ± 41.434	169.0 ± 49.028	13.4 ± 8.461	41.6 ± 16.551	37.6 ± 11.355	113.8 ± 44.498
B. boops	91.2 ± 56.496	35.0 ± 21.793	279.2 ± 144.07	124.2 ± 63.406	83.2 ± 58.572	80.4 ± 39.959	174.6 ± 104.787	1647.8 ± 484.95
O. melanura	2.4 ± 1.471	44.0 ± 44.001	7.2 ± 2.178	4.0 ± 2.258	29.2 ± 8.349	77.2 ± 57.691	35.6 ± 13.483	245.2 ± 208.60
S. smaris	0	39.0 ± 24.919	20.0 ± 19.999	2.4 ± 1.417	0	0	51.0 ± 20.760	0
S. maena	4.0 ± 3.998	0.2 ± 0.201	0	0	0.4 ± 0.246	0	0	0
S. umbra	4.2 ± 1.319	0	12.0 ± 8.305	0	0	0	0	0
C. chromis	125.8 ± 16.994	37.0 ± 22.347	249.8 ± 66.72	113.4 ± 64.694	211.4 ± 63.576	151.2 ± 41.546	149.2 ± 39.668	690.6 ± 249.32
Mugil spp.	4.6 ± 1.775	3.0 ± 1.641	28.2 ± 1.771	0	0.4 ± 0.246	1.0 ± 0.447	0.2 ± 0.380	1.4 ± 0.246
Atherina spp.	15.0 ± 15.0	0	0	0	0	0	0	0
S. sphyraena	0	0	1.4 ± 0.872	0	0	0	0	0
S. doderleini	1.8 ± 0.917	4.6 ± 2.692	0.8 ± 0.376	0.6 ± 0.398	2.6 ± 1.436	0.2 ± 0.201	3.6 ± 0.678	0
S. mediterraneus	6.0 ± 1.140	6.0 ± 1.096	7.2 ± 1.020	5.2 ± 0.662	5.6 ± 1.601	1.8 ± 0.376	3.0 ± 0.707	6.2 ± 1.158
S. melanocercus	5.0 ± 2.410	14.8 ± 2.106	9.0 ± 1.547	3.0 ± 0.948	36.6 ± 19.123	8.0 ± 2.410	10.2 ± 1.910	7.2 ± 0.662
S. ocellatus	1.8 ± 1.069	4.0 ± 1.762	3.8 ± 1.318	3.0 ± 2.509	2.4 ± 0.926	3.8 ± 0.778	1.8 ± 0.376	5.4 ± 1.722
S. roissali	2.4 ± 0.926	1.8 ± 1.114	1.8 ± 0.662	5.2 ± 0.970	0	11.8 ± 3.090	3.0 ± 0.836	5.2 ± 0.582
S. rostratus	0.2 ± 0.201	0	0.6 ± 0.599	0.4 ± 0.246	1.2 ± 0.783	1.6 ± 0.510	1.4 ± 0.246	0
S. tinca	3.6 ± 1.941	0.8 ± 0.581	8.2 ± 1.592	3.6 ± 0.599	0.4 ± 0.398	6.0 ± 0.707	8.8 ± 2.267	6.4 ± 0.599
C. rupestris	7.2 ± 1.655	15.4 ± 2.317	10.6 ± 1.288	5.6 ± 0.510	16.6 ± 2.442	9.6 ± 1.207	13.4 ± 1.364	12.0 ± 0.707
L. merula	3.0 ± 0.836	2.0 ± 0.631	0.8 ± 0.201	1.4 ± 0.246	0.4 ± 0.246	0.6 ± 0.246	0.8 ± 0.376	1.8 ± 0.662
L. bimaculatus	0.8 ± 0.376	1.8 ± 0.720	0.6 ± 0.346	0	0.8 ± 0.376	0	0	0
L. viridis	0.4 ± 0.246	0.2 ± 0.201	0.4 ± 0.246	0.2 ± 0.201	0.4 ± 0.246	1.0 ± 0.318	2.8 ± 0.801	0
C. julis	36.8 ± 7.383	35.4 ± 6.574	51.2 ± 5.121	56.6 ± 18.112	41.0 ± 5.358	41.8 ± 1.932	45.6 ± 4.378	38.8 ± 3.484
T. pavo	0	0	0	0	0	0	0	0.4 ± 0.246
B. gattorugine	0.4 ± 0.398	0.2 ± 0.201	0.2 ± 0.201	0	0.4 ± 0.246	1.0 ± 0.447	0.2 ± 0.385	1.4 ± 0.246
B. incognitus	0	0	0.2 ± 0.201	0	0	0	0	0
B. rouxi	4.8 ± 1.114	6.2 ± 1.682	1.2 ± 0.376	3.8 ± 0.662	1.4 ± 0.498	7.0 ± 2.169	3.2 ± 1.335	6.6 ± 0.814
Tripterygion spp.	5.6 ± 1.167	2.4 ± 0.634	1.6 ± 0.872	3.8 ± 0.733	0.6 ± 0.398	2.8 ± 0.957	0.6 ± 0.398	2.6 ± 0.398
G. cruentatus	0	0	0	0	0.2 ± 0.201	0	0.2 ± 0.201	0
G. bucchichii	0	0	0	0.6 ± 0.599	0.4 ± 0.246	1.4 ± 0.570	2.8 ± 0.492	1.2 ± 0.492
G. auratus	0	0	0	0.6 ± 0.398	0.6 ± 0.398	0	0	0
S. sarda	0	0	0	0	0	0	0	1.2 ± 1.199

the reason for the lower density of small fishes inside the reserve? We can assume the biomass of fish to be limited by food, space or other limiting environmental resources that presumably become saturated inside the reserve due to the adult fish populations. Then, strong competition or predation pressures could either limit recruitment or displace the smallest individuals to peripheral habitats in the reserve, or even outside it. If this second case were true, a marine reserve would act not as a nursery but as an spawning center. The strongly significant interactions between site and depth on the size-class structure of fish populations, and, especially, the differences between censuses inside and outside the reserve, is interpreted as evidence of competition for space and food. As the rugosity was similar for transects at different depths, it appears that depth preferences may be due to food requirements (BELL, 1983). Presumably there is more food available on shallow bottoms and then shallow sites would be preferred by dominant (largest) individuals inside the reserve. The preference for deeper bottoms observed in large individuals outside the reserve has been interpreted as a refuge-behaviour against direct fishing pressure (spearfishing). In the same way, the change from daytime feeding in the reserve to evening feeding outside observed in large and medium sized individuals of Sparidae (pers. obs.) may also be a consequence of direct fishing pressure.

This study will provide the basis for comparisons with subsequent censuses to assess the future evolution of fish assemblages in the Medes Islands Marine Reserve.

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