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SOME POPULATION PARAMETERS AS BIOINDICATORS TO ASSESS THE "RESERVE EFFECT" ON THE FISH ASSEMBLAGE

J. T. BAYLE-SEMPERE, A. A. RAMOS-ESPLA

Dept. de Ciències Ambientals & Recursos Naturals (Laboratori de Biologia Marina), Facultat de Ciències, Universitat d'Alacant, POB 99, E-03080 Alicante, Spain.

ABSTRACT

Marine fisheries reserves have been proposed as a useful tool to manage littoral fisheries. In this article, four population parameters are studied to use them as bioindicators to assess the effect of the protection on the fish assemblage. Abundance and diversity were poor correlated with protection. Richness and size were more correlated with it, being more suitables to assess more efficiently the "reserve effect" on the fish assemblage. Some targeted species have shown a strong correlation with protection, being usables as bioindicators to assess the "effect reserve".

RESUME

Les réserves marines apparaissent comme un outil utilisable dans la gestion des pêcheries littorales. Dans cette étude, quatre paramètres sont étudiés dans le but de les utiliser comme bioindicateurs destinés à évaluer les effets de la protection sur le peuplement ichtyologique. L'abondance et la diversité sont peu corrélées avec la protection. La richesse et la taille sont, quant à elles, plus liées à cette protection, et

permettent de mieux évaluer l'efficacité de "l'effet réserve" sur le peuplement ichtyologique. Certaines espèces cibles ont montré une forte corrélation avec la protection, elles pourraient donc être utilisées comme bioindicateurs pour évaluer "l'effet réserve".

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INTRODUCTION

During recent years, marine fishery reserves (MFR) have been proposed as a useful tool to manage littoral fisheries (Plan Development Team, 1990) and increased human pressure on marine littoral habitats (COGNETTI, 1986). With this objective, the Marine Reserve of Tabarca (MRT) (Alicante, SE Spain, W Mediterranean) was created in April 1986 to protect and manage the natural marine littoral environment (RAMOS-ESPLA, 1985*a*) and a sampling program was begun to scientifically evaluate the effect of protection on the main natural communities and species presents (RAMOS-ESPLA & BAYLE-SEMPERE, 1990).

A sampling program was initiated in October 1988 to evaluate and compare the changes of fish populations under different levels of protection in the MRT with fish populations outside the protected area. The socio-economic importance of the littoral fish community as an exploited resource by local fishing industry justifies the effort given to its study (ROBERTS & POLUNIN, 1991). For the same reason, a number of published studies have examined the effects of the protection on fish assemblages in Mediterranean protected areas (BELL, 1983; GARCIA-RUBIES & ZABALA, 1990; FRANCOUR, 1991*a*; BINCHE, 1992; HARMELIN & BACHET, 1992) and in other parts of the world (BUXTON & SMALE, 1989; RUSS & ALCALA, 1989; ALCALA & RUSS, 1990; COLE *et al.*, 1990; BENNET & ATTWOOD, 1991). However, few works have analyzed the relationships of some population parameters and some fish species with the degree of protection in order to use them as bioindicators for monitoring the "effect of reserve" on the fish assemblage.

Parameters as abundance, species richness, diversity, and size are expected to be positively correlated with the degree of protection due to a drop in mortality. Otherwise, changes in the distribution and abundance of some species are expected to be more influenced than other by the degree of protection. In this way, the fish species most correlated with the degree of protection might be used as bioindicators to monitor more efficiently the performance of the MFR's.

In this paper, data are presented about the correlations of four fish populations parameters and some fish species with a protection formed by different managed localities. Likewise, changes of these parameters over the time are analyzed to evaluate their usefulness as bioindicators among different time-periods. The ultimate purpose is to allow a more efficient monitoring of the " effect of reserve" on the fish assemblage.

METHODS

1 - Study Area

This work was done developed inside of the zone protected by the MRT and in the unprotected nearest coast during August 1990 and August 1992. The MRT is located 4 km off the cape of Santa Pola, and it encompasses a small archipielago comprised of a main island - Nueva Tabarca- and some islets and small emergent rocky reefs (RAMOS-ESPLA, 1985*b*). This marine reserve was created adapting the three basic functions of a "biosphere reserve" (MAB, 1987). According to these guidelines, the protected area was divided in three zones (Figure 1) with different protection levels and permited uses (RAMOS-ESPLA, 1985*a*; RAMOS-ESPLA & BAYLE-SEMPERE, 1990; RAMOS-ESPLA *et al.*, 1992). The *Posidonia oceanica* (L.) Del. seagrass bed predominates over the benthic bottoms of the MRT (RAMOS-ESPLA, 1985*a*; SANCHEZ LIZASO, 1992). Some species are of subtropical affinity. The seawater around the MRT are markedly oligotrophics (ZOFFMAN *et al.*, 1985; GRAS *et al.*, 1992; PRATS RICO & MARTIN, 1992), being free from the anthropic pressures typical of the near peninsular coast.

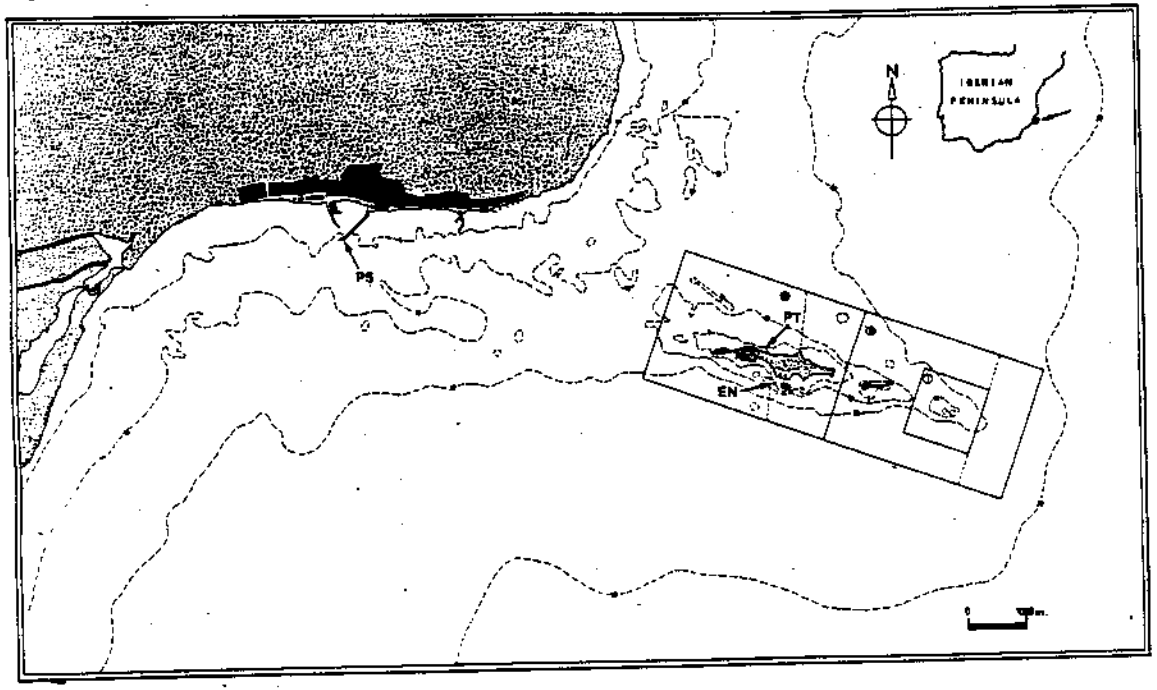

Figure 1. Situation of the localities studied (EN : fully protected locality; PT : partially protected locality; PS : unprotected locality).

Two sampling-localities were choosen inside the MRT : one located in the IIIa zone (EN : *Escull Negre* rocky reef) where fishing activities are not allowed. The other one is located in the IIIb zone (PT : breakwater Tabarca's port), which is subject to sport-angling fishing (10-15 angling-fishers/day, during the sampling periods). The breakwater at Santa Pola's port (PS) was choosen as a full-exploited sampling-locality (20-30 sport-angling/day during the sampling periods, spearfishing and artisanal fisheries). All the sample localities were rocky-bottom and with similar rugosity, benthic community and depth (8-10 m).

2 - Collection of Data

A visual census method with SCUBA along a 50 x 5 m strip transect (HARMELIN-VIVIEN & HARMELIN, 1975) was choosen to collect the field data, as applied in other Mediterranean localities (BELL, 1983; HARMELIN, 1987; GARCIA-RUBIES & ZABALA, 1990; HARMELIN, 1990; FRANCOUR, 1991*a*). The sampling was carried out by swimming slowly along the transect and recording the number and sizes of all fishes associated with the bottom and the water column. Abundance data were collected in a form with pre-established discrete classes of abundance which follow a roughly exponential progression with base 2, like that used by other authors (HARMELIN-VIVIEN & HARMELIN, 1975; HARMELIN, 1987; GBRMPA, 1978; GLADFELTER *et al.*, 1980; BELL, 1983; GARCIA-RUBIES & ZABALA, 1990; HARMELIN, 1990). The size of the individuals was estimated with a ruler attached to the end of a meter stick (BOHNSACK & BANNEROT, 1986). Eight transects per period at each sampling locality were undertaken, spending between 15 and 20 minutes per transect. All of data were collected between 10 and 14 hours (legal hour), under similar hydrological and meteorological conditions to minimize the effects due to these factors (HARMELIN-VIVIEN *et al.*, 1985).

3 - Analysis of Data

Mean abundance, mean species richness, mean diversity index

(MARGALEF, 1974) and standardized mean size were calculated for each locality in each sampling period, and considering both sampling period together. We examined both the whole fish assemblage and only the fish assemblage vulnerable to fishing (*sensu* GARCIA-RUBIES & ZABALA, 1990). The precision of the mean value of each parameter was estimated by the standard error (s.e.) and the coeficient of variation (c.v.) (ZAR, 1984).

The standardized size was obtained dividing the mean size of each species by its maximum size given in the literature (WHITEHEAD *et al.*, 1984). In this way, the mean sizes of the different species were comparable to each other so that a global analysis of this parameter in the fish assemblage could be carried out. The standardized mean size was the average value in each sample.

A Kruskal-Wallis' test (SOKAL & ROHLF, 1979; ZAR, 1984) was used to test the differences of each parameter among sampling localities, considering the sampling-periods separately and combined. The same test was applied to evaluate the existence of significant differences between the two sampling-periods, in each sampling-locality. Likewise, the product-moment correlation coefficient (SOKAL & ROHLF, 1979; ZAR, 1984) was calculated for the parameters studied and a discrete variable created to define the degree of protected (1 = unprotected; 2 = partially protected; 3 = fully protected).

In order to determine what species would best reflect protection, a principal component analysis (LEGENDRE & LEGENDRE, 1982; CUADRAS, 1991) was made on the transformed log(x+1) abundances of the vulnerable species. Moreover, the product-moment correlation coefficient was calculated for the abundances of the vulnerable species and the variable "protection" to contrast it with the principal component analysis results.

RESULTS

1 - Qualitative results

All the fishes censused comprised 41 species belonging to 14 families. Sparidae (12 species), labridae (11 species) and serranidae (5 species) were the most represented families, and included 68.3 % of the total observed species in this study (Appendix 1). The accumulated species richness in each locality was rather similar (32 species in EN, 30 in PT and 28 in PS). Otherwise, certain target species for spearfishing, such as groupers (*Epinephelus sp*) and brown meagre (*Sciaena umbra*) were quite more abundant in the fully protected locality (EN). These results agree well with those reported by other authors from neighbouring areas in the Mediterranean Sea (BELL, 1983; HARMELIN, 1987; GARCIA-RUBIES & ZABALA, 1990).

2 - Changes of the population parameters with protection

Significant differences were found among the sampling-localities for all the population parameters studied (Table I). However, all them of were not positively correlated with protection (Table II). In the case of the mean abundance, both for the whole and the vulnerable fish assemblage, the highest resulting values did not always correspond with the fully protected sampling locality. The correlation with protection was low for the whole assemblage, and not statistically significant for only the vulnerable fish assemblage. Otherwise, the abundance always shows a s.e. and c.v. quite high (Table III).

The mean species richness was correlated with protection (Table II). It shows higher values as much as greater is the protection, especially if only vulnerable species are considered. With regard to its precision as an indicator parameter, the c.v. ranged between 7.09 % and 15.66 %, showing lower values than the mean abundance.

The mean diversity calculated for the whole fish assemblage was always result greater in the unprotected locality (Table III), although significant differences existed between sampling-localities for both periods of study (Table I). Its correlation with protection (Table II) was negative and statistically not significant for the whole fish assemblage. Considering only the vul

Especie	PS-90	PS-92	PS-90/92	PT-90	PT-92	PT-90/92	EN-90	EN-92	EN-90/92
M. helena	0	0	0	0	0	0	0.3±0.245	0	0.1±0.128 (273.2 %)
E. alexandrinus	0	0	0	0	0.5±0.274	0.2±0.151 (214.9 %)	0.1±0.187	4.3±0.442	2.2 ± 0.58 (103.2 %)
E. guaza	0	0	0	1.6±0.597	0	0.8±0.361 (171.3 %)	4.8±1.012	11.5±2.244	8.1 ± 1.464 (71.5 %)
S. cabrilla	0	0	0	0	0.1±0.187	0.09±0.09 (400 %)	0.1±0.187	0	0.09 ± 0.09 (400 %)
S. scriba	1.3±0.525	0.7±0.4	1.0±0.327 (127 %)	6±0.896	4.8±1.088	5.4±0.696 (51.23 %)	8.2±1.445	11.5±1.943	9.8 ± 1.242 (50.3 %)
D. labrax	0.1±0.187	0.1±0.187	0.1±0.128 (273.2 %)	3.5±0.807	1.3±0.525	2.4±0.544 (90.4 %)	3± 1.06	1.5±0.633	2.2 ± 0.627 (111.5 %)
A. imberbis	0	0	0	0	0	0	13.56±3.2	32.1±3.258	22.8 ± 3.263 (57 %)
S. dumerili	0	0	0	0.7±0.40	0	0.3±0.216 (230.9 %)	0	0	0
P. humile	0	0.3±0.245	0.1±0.128 (273.2 %)	0	0	0	0	0	0
P. incisus	7.4±2.378	0	3.7±1.497 (161 %)	0	0	0	0	0	0
S. umbra	0	0	0	0	0.5±0.274	0.2±0.151 (214.9 %)	27.5±3.519	42.4±3.513	35 ± 3.075 (35.1 %)
M. surmuletus	2.8±0.525	29.4±3.404	16.1±3.818 (94.73 %)	5.3±1.223	7.4±2.718	6.4±1.464 (91.43 %)	2.8±1.039	0	1.4 ± 0.619 (176.2 %)
B. boops	0	0	0	26.2±11.75	10±4.27	18.1±6.395 (141.1 %)	174.3±59.8	90.6±60	132.5 ± 42.3 (127.8 %)
D. dentex	0.1±0.187	0	0.09±0.09 (400 %)	6.3±1.14	0.75±0.40	3.5±0.931 (104.6 %)	0.1±0.187	2.4±1.415	1.3 ± 0.748 (228 %)
D. annularis	1.3±0.597	5.9±1.524	3.6±0.991 (109.3 %)	2.25±0.40	0	1.1±0.349 (124.1 %)	7.2±1.302	9.1±1.936	8.2 ± 1.154 (56.1 %)
D. cervinus	0	0.1±0.187	0.09±0.09 (400 %)	0	0.1±0.187	0.09±0.09 (400 %)	1.8±0.789	4.5±1.44	3.1 ± 0.864 (108.5 %)
D. puntazzo	1.6±0.666	2.4±0.562	2.03±0.434 (85.4 %)	1.8±0.617	0.9±0.394	1.4±0.374 (106.4 %)	6.0±0.993	4.6±0.958	5.3 ± 0.689 (51.3 %)
D. sargus	8.1±1.187	17.7±2.535	12.9±1.831 (56.4 %)	19.3±3.055	6.1±1.469	12.7±2.356 (73.9 %)	41.9±12.11	61.8±4.529	51.9 ± 6.758 (52 %)
D. vulgaris	20.6±1.737	45.6±2.942	33.1±3.625 (43.6 %)	67±17.74	32.8±3.793	49.9±9.811 (78.5 %)	192.3±30.69	139.8±15.42	166 ± 17.92 (43.1 %)
L. mormyrus	0	3.5±3.5	1.7±1.7 (400 %)	0	0	0	0	0	0

Appendix 1: Densities expressed as mean number of individuals per 250 m² ± SE of all the species censused in the study (in brackets, coeficient of variation).

Species	PS-90	PS-92	PS-90/92	PT-90	PT-92	PT-90/92	EN-90	EN-92	EN-90/92
O. melanura	99.9±10.64	30.5±6.66	65.2±10.81 (66.3 %)	36.5±7.96	30.81±8.25	33.6±5.58 (66.4 %)	28.1±7.12	48.8±8.8	38.5 ± 6.08 (63.2 %)
S. salpa	42.1±7.58	65±9.73	53.59±6.64 (49.6 %)	51.4±11.46	10.5±4.59	30.9±7.97 (102.9 %)	62.2±13.36	25.1±7.08	43.7 ± 8.73 (79.9 %)
S. aurata	0	0	0	0	0.7±0.4	0.3±0.21 (230.9 %)	0.1±0.187	0	0.09 ± 0.09 (400 %)
S. cantharus	0	0	0	0	0	0	0	1.1±0.617	0.5 ± 0.331 (236 %)
Ch. chromis	90.25±11.4	57.1±8.06	73.6±7.98 (43.3 %)	32.9±9.8	31.43±4.82	32.1±5.28 (65.6 %)	548.6±62.25	432.3±48.91	490.5 ± 41.08 (33.5 %)
C. julis	0.1±0.187	0	0.09±0.09 (400 %)	0.3±0.245	5.6±1.77	3±1.098 (146.4 %)	13.56±2.54	20.3±3.532	16.9 ± 2.28 (53.7 %)
Ct. rupestris	0	0.1±0.187	0.09±0.09 (400 %)	0	0	0	0	0	0
L. merula	0	0.1±0.187	0.09±0.09 (400 %)	0.3±0.245	0	0.1±0.128 (273.2 %)	5.25±0.85	4.68±0.52	4.9 ± 0.488 (39.3 %)
S. cinereus	0	0.7±0.4	0.3±0.21 (230.9 %)	0	0	0	0	0	0
S. mediterraneus	0	0	0	0.3±0.245	0.5±0.274	0.4±0.179 (153.1 %)	0.9±0.394	0.5±0.274	0.7 ± 0.237 (126.4 %)
S. melanocercus	0	0	0	0.5±0.274	0	0.2±0.151 (214.9 %)	0	0	0
S. ocellatus	1.6±0.724	5±1.326	3.3±0.85 (102.6 %)	3.8±1.983	3.8±1.201	3.8±1.12 (115.6 %)	6.25±1.257	2.1±0.943	4.1 ± 0.927 (88.5 %)
S. roissali	4.3±0.661	6.25±0.958	5.2±0.615 (46.6 %)	0.9±0.394	0.1±0.187	0.5±0.232 (165.1 %)	3.3±0.375	2.06±0.629	2.7 ± 0.392 (57.7 %)
S. rostratus	0.3±0.375	0	0.1±0.187 (400 %)	0.9±0.394	0.9±0.394	0.9±0.269 (115 %)	2.6±0.548	0.5±0.394	1.5 ± 0.421 (105.7 %)
S. tinca	7.5±0.965	11.8±3.187	9.7±1.702 (70 %)	15.8±2.669	19.75±2.62	17.7±1.876 (42.2 %)	16.2±1.91	28.6±2.108	22.4 ± 2.107 (37.5 %)
Th. pavo	5.6±1.511	5.3±1.802	5.4±1.136 (83.1 %)	0.9±0.394	0	0.4±0.225 (192.6 %)	24.3±2.04	44.2±3.51	34.2 ± 3.23 (37.7 %)
P. gattorugine	2.4±0.74	0.5±0.562	1.5±0.51 (136.6 %)	0	0	0	0	0	0
P. rouxi	0.9±0.937	0	0.4±0.4 (400 %)	0	0	0	0.1±0.187	0	0.09 ± 0.09 (400 %)
T. tripteronotus	0	0	0	0	0	0	0.5±0.562	0	0.2 ± 0.281 (400 %)
Mugilidae	6.1±1.769	12.5±3.446	9.3±2.04 (87.8 %)	53.6±23.48	14.75±3.04	34.1±12.49 (146.1 %)	8.1±1.76	8.62±1.68	8.4 ± 1.17 (56.1 %)
A. hepsetus	5±5	63.1±17.852	34±11.68 (137.2%)	1237.5±269	321.2±37.3	779.3±176.6 (90.6%)	0	0	0

Appendix 1: Densities expressed as mean number of individuals per 250 m² ± SE of all the species censused in the study (in brackets, coeficient of variation).

nerable species, the correlation coefficient value was very low.

The standardized mean size was highly correlated with protection (Table II), for both the total and vulnerable fish assemblage. The greatest values were obtained for the most protected locality and were significantly different from the other localities. Their c.v. and s.e. were quite low and similar, especially for the vulnerable fish assemblage. These values show a greater precision with regard to the other parameters.

Table I : Differences among localities for each year studied and both together. Kruskall-Wallis' test results, their statistical significance and the relation among localities are showed (EN : fully protected lcality; PT : partially protected locality; PS : fuly exploited locality).

Parameter		1990	1992	1990-92
Mean abundance	(W)	12.08*** PT>EN>PS	18.12*** EN>PT>PS	26.71*** EN>PT>PS
	(V)	14.40*** PT>EN>PS	8.56* PT>EN>PS	23.47*** PT>EN>PS
Mean species richness	(W)	16.8*** EN>PT>PS	15.64*** EN>PT>PS	30.61*** EN>PT>PS
	(V)	16.24*** EN>PT>PS	17.70*** EN>PT>PS	34.75*** EN>PT>PS
Mean Diversity index	(W)	8.64* PS>EN>PT	15.31*** PS>EN>PT	20.79*** PS>EN>PT
	(V)	13.14*** EN>PT>PS	19.56*** EN>PS>PT	28.71*** EN>PS>PT
Mean standard. size	(W)	18.30*** EN>PT>PS	15.00*** EN>PT>PS	31.75*** EN>PT>PS
	(V)	18.48*** EN>PT>PS	19.86*** EN>PT>PS	36.17*** EN>PTPS

(***) P<0.005; (**) P<0.025; (*) P<0.05
(W)=Whole fish assemblage; (V)=Vulnerable fish assemblage.

Table II : Summary of the product-moment correlation coefficients values (C.C.) among the variable "protection degree" and the population parameters analyzed, indicating their significant level (s.l.).

Parameter		C.C.	s.l
Mean abundance	(W)	0.527	***
	(V)	0.146	n.s.
Mean species richness	(W)	0.813	***
	(V)	0.858	***
Mean diversity index	(W)	-0.068	n.s.
	(V)	0.293	*
Mean standardized size	(W)	0.813	***
	(V)	0.893	***

(***) P<0.005; (**) P<0.025; (*) P<0.05; n.s.: not significant.
(W)=Whole fish assemblage; (V)=Vulnerable fish assemblage.

3 - Changes of the population parameters over the time

The parameters did not follow the expected pattern among sampling periods (Table IV). Mean abundance for both the whole and vulnerable fish assemblage for EN and PT did not increase over the time and were not significantly different. Changes in the unprotected sampling-locality (PS) were not significant. The mean species richness also did not show significant increases in the protected localities. The mean diversity was always greater over the time, although in some cases (PT) the differences were not significant. Likewise, the standardized mean size had higher values in the second sampling period of study for both the whole and the vulnerable fish assemblage. However, the differences were not always significant.

4 - Community structure with regard to protection

The principal components analysis (Figure 2) show the effect of the protection on the structure of the fish community and the existence of a group of species that characterize protec

Table III : Mean values, standard error and coefficients of variation of the parameters studied, considering each year studied and both together.

Parameter		PS-90	PS-92	PS-90/92	PT-90	PT-92	PT-90/92	EN-90	EN-92	EN-90/92
Mean abundance	(W) m	310.313	364.688	337.5	1576.63	506.313	1041.47	1205.69	1035.94	1120.81
	se	±16.831	±32.811	±19.146	±279.24	±34.992	±199.985	±143.008	±113.349	±90.829
	cv	15.34%	25.44%	22.69%	53.32%	19.54%	76.8%	33.54%	30.94%	32.41%
	(V) m	191.188	276.625	233.9	1456	444.563	950.281	422.625	422.625	422.625
	se	±16.774	±34.256	±21.47	±281.803	±38.289	±189.53	±46.678	±28.657	±26.458
	cv	24.81%	35.02%	36.72%	54.74%	24.36%	79.77%	31.23%	19.17%	25.04%
Mean species richness	(W) m	14.5	15	14.75	17.875	14.875	16.37	23	21	22.43
	se	±0.59	±0.56	±0.40	±0.98	±0.54	±0.67	±0.59	±0.54	±0.41
	cv	11.65%	10.69%	10.93%	15.66%	10.43%	16.36%	7.34%	7.09%	7.45%
	(V) m	8.125	9.5	8.81	12.875	10.625	11.75	14.5	15.25	14.87
	se	±0.51	±0.32	±0.34	±0.69	±0.32	±0.46	±0.46	±0.41	±0.31
	cv	17.94%	9.74%	15.62%	15.21%	8.62%	15.99%	9.02%	7.63%	8.45%
Mean diversity index	(W) m	2.64	3.13	2.88	1.63	2.10	1.86	2.62	2.93	2.78
	se	±0.06	±0.07	0.08	±0.27	±0.15	±0.16	±0.02	±0.11	±0.06
	cv	7.03%	7.14%	11.18%	47.42%	20.76%	35.03%	2.48%	10.71%	9.79%
	(V) m	1.96	2.63	2.30	1.25	1.59	1.42	2.61	3.03	2.82
	se	±0.07	±0.06	±0.09	±0.28	±0.13	±0.15	±0.08	±0.05	±0.07
	cv	10.87%	7.43%	17.19%	6.33%	23.23%	43.79%	9.19%	4.99%	10.31%
Mean standard. size	(W) m	0.26	0.29	0.28	0.33	0.37	0.35	0.38	0.39	0.39
	se	±0.008	±0.01	±0.007	±0.01	±0.01	±0.01	±0.007	±0.008	±0.005
	cv	8.98%	9.78%	10.71%	11.19%	8.43%	11.72%	5.72%	6.01%	5.85%
	(V) m	0.23	0.25	0.24	0.30	0.33	0.32	0.34	0.37	0.36
	se	±0.003	±0.004	±0.003	±0.007	±0.005	±0.006	±0.009	±0.005	±0.006
	cv	4.03%	5.45%	5.52%	6.59%	4.8%	8.15%	7.71%	4.41%	7.7%

(m):meam value. (se): standard error. (cv): coefficientof variation.
(W)=Whole fish assemblage; (V)=Vulnerable fish assemblage.

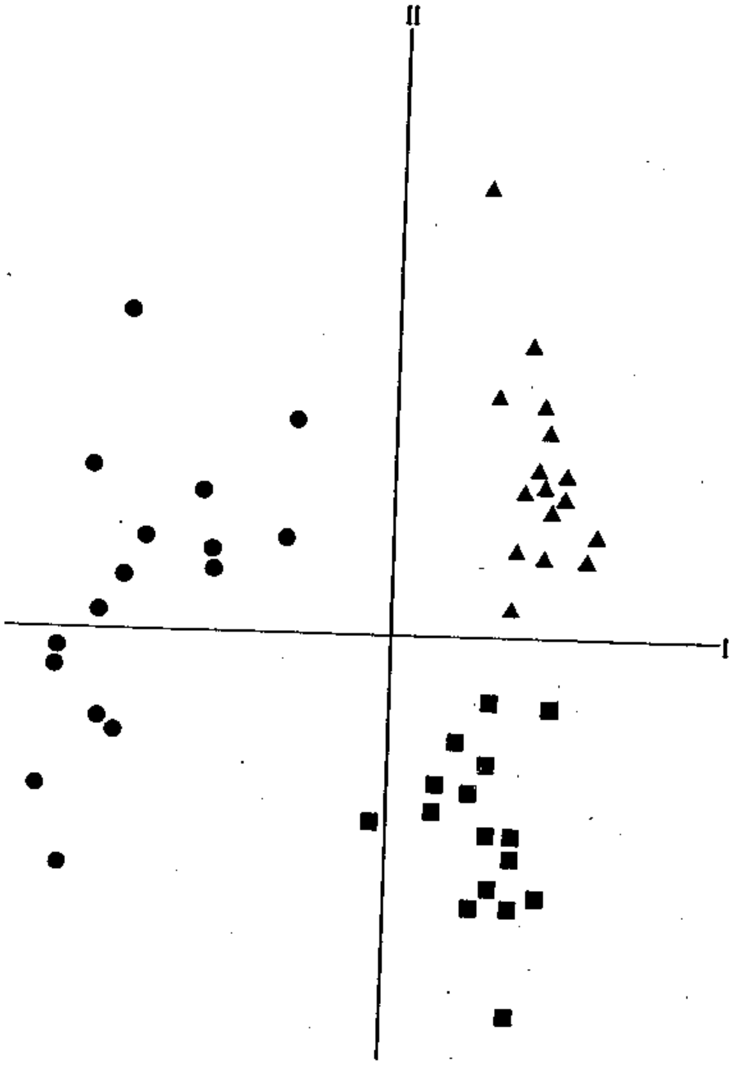

Figure 2. Principal component analysis of all samples. ● : fully protected locality; ■ : partially protected locality; ▲ : unprotected locality.

Table IV : Differences among sampling-periods in each locality studied, indicating the Kruskall-Wallis'test results, their statistical significance and the relationships among the sampling-periods studied (EN: fully protected locality; PT: partially protected locality; PS: fully exploited locality).

Parameter		EN	PT	PS
Mean abundance	(W)	$0.89^{n.s.}$	6.35^{**}	$2.16^{n.s.}$
		90>92	90>92	92>90
	(V)	$0.27^{n.s.}$	6.35^{**}	$3.57^{n.s.}$
		90=92	90>92	92>90
Mean species richness	(W)	$1.33^{n.s.}$	5.53^{**}	$0.35^{n.s.}$
		90>92	90>92	92>90
	(V)	$1.40^{n.s.}$	6.10^{**}	4.20^{*}
		92>90	90>92	92>90
Mean diversity index	(W)	6.35^{**}	$3.18^{n.s.}$	9.27^{***}
		92>90	92>90	92>90
	(V)	9.27^{***}	$3.18^{n.s.}$	10.59^{***}
		92>90	92>90	92>90
Mean standard. size	(W)	$0.70^{n.s.}$	7.45^{***}	3.98^{*}
		92>90	92>90	92>90
	(V)	5.33^{**}	8.04^{***}	$3.57^{n.s.}$
		92>90	92>90	92>90

(***) $P<0.005$; (**) $P<0.025$; (*) $P<0.05$; n.s.: not significant
(W)=Whole fish assemblage; (V)=Vulnerable fish assemblage.

tion. The first factor (34.13 % variance explained) separates the unexploited samples (negative values) from the exploited samples (positive values). The second factor (10.18 % variance explained) seems to respond to the greater or lower dominance of certain species, though its interpretation cannot be made with precision due to the low explained variance.

The species that show a greater negative correlation with the factor I (Table V) are, at the same time, those more significantly correlated with protection. This result confirms the effect of protection and the

Table V : Correlations of the vulnerable species with the axes I and II resulting from the principal components analysis, and the product-moment correlation ceofficient (C.C.) among the vulnerable species and the protection degree.

Especie	Eje I	Eje II	C.C.
S. umbra	-0.332	0.043	0.802***
L. merula	-0.332	0.077	0.780***
E. guaza	-0.315	-0.068	0.669***
D. vulgaris	-0.299	0.073	0.722***
C. julis	-0.286	-0.101	0.751***
D. cervinus	-0.283	0.064	0.517***
D. sargus	-0.266	0.116	0.642***
E. alexandrinus	-0.235	-0.141	0.548***
S. scriba	-0.228	-0.309	0.741***
D. annularis	-0.219	0.326	0.411***
S. tinca	-0.204	-0.204	0.573***
D. puntazzo	-0.191	0.212	0.513***
S. cantharus	-0.156	-0.141	0.291*
D. labrax	-0.103	-0.255	0.394**
M. helena	-0.103	0.132	0.255n.s.
S. cabrilla	-0.034	0.056	0.127n.s.
D. dentex	-0.028	-0.383	0.163n.s.
S. salpa	0.012	0.373	-0.127*
L. mormyrus	0.025	0.223	-0.178n.s.
S. dumerili	0.036	-0.187	0.000n.s.
O. melanura	0.037	0.103	-0.326*
S. aurata	0.043	-0.163	0.069n.s.
A. hepsetus	0.182	-0.305	-0.026n.s.
M. surmuletus	0.203	0.187	-0.542***

(***) P<0.005; (**) P<0.025; (*) P<0.05; n.s.: not significant

existence of a group of species more that directly benefit from the protection.

DISCUSION

The taxonomic composition reported in this study under-represent the entire fish assemblage present in the MRT (RAMOS-ESPLA *et al.*, 1992). This is because individuals belonging to the family Mugilidae were not identified at the species level and some small cryptic and sedentary species (e.g., Scorpaenidae, Gobiidae, Bleniidae) were underestimated due to the methodology used (HARMELIN-VIVIEN *et al.*, 1985). Thus, the fish assemblage presented in this paper is the *sampled assemblage* (*sensu* HARMELIN-VIVIEN & FRANCOUR, 1991).

The qualitative results obtained in this study agree with those presented by other authors in similar studies (BELL, 1983; HARMELIN, 1987; GARCIA-RUBIES & ZABALA, 1990; FRANCOUR, 1991*a*, 1991*b*, 1992). Some species very vulnerable to harvest, like *Epinephelus sp* and *Sciaena umbra*, have been found only in the protected localities. The low values of the coefficient of variation shows the greatest population stability of these species with increases protection. Therefore, the effect of the management is to allow a smaller mortality rate on these vulnerable species in the protected zones (ROBERTS & POLUNIN, 1991; BOHNSACK, 1982).

1 - Changes of the population parameters with the level protection

All the considered population parameters don't show the expected pattern as the degree of protection increases. The mean abundance, even though it always presented significant differences between localities, was not always greater in the most protected locality. Furthermore, it always showed high values of s.e. and c.v. In fact, the presence of planktophagous and gregarious species (*Atherina hepsetus*, *Chromis chromis*, *Oblada melanura*, *Boops boops*) nullified the effect of the protection on abundance, for the whole asemblage and the vulnerable assemblage. The space-time distribution of these planktophagous and gregarious species is determined, mainly, by the zooplankton distribution (HAMNER *et al.*, 1988), which explain the results obtained for this parameter. In some studies, the mean abundance appears as a distinctive parameter that distinguishes between protected and unprotected zones (BUXTON & SMALE, 1989; RUSS & ALCALA, 1989; ALCALA &

RUSS, 1990; COLE *et al.*, 1990; BENNETT & ATTWOOD, 1991; BINCHE, 1990). However, some works where the mean abundance was greater in the protected zone (FRANCOUR, 1991*a*) did not report gregarious and pelagic species, probably due to the use of the stationary visual census technique as sampling methodology. In other cases, the differences between protected and unprotected localities were not significant (GARCIA-RUBIES & ZABALA, 1990; JOUVENEL, 1992) due to the presence of these pelagic and gregarious species. Therefore, the results from these studies show that total abundance is a poor parameter for predicting effects of protection.

The mean species richness responded positively with protection, especially when considering only the vulnerable species. The differences are due to the smaller presence in the exploited localities of some species, such as groupers and brown meagre, that were very attractive for fishing activities. A similar pattern has been described by other authors (KOSLOW *et al.*, 1988; RUSS & ALCALA, 1989; GARCIA-RUBIES & ZABALA, 1990; FRANCOUR, 1991*b*, 1992; HARMELIN & BACHET, 1992). However, in some cases (BELL, 1983; JOUVENEL, 1992), the mean species richness between protected and unprotected localities was not significantly different, especially if the whole assemblage was considered (HARMELIN & BACHET, 1992). Likewise, the physical and biological heterogenity of the bottom must be considered: differences in these factors may result in some differences in species richness (LUCKHURST & LUCKHURST, 1977; RUSS, 1985). In the present work, the greatest presence of the *Posidonia oceanica* seagrass bed was in the fully protected locality (EN). This factor may have favoured the increased mean richness because of overlaping assemblages from both kinds of bottom. Moreover, the abundance and distribution of fishes among localities may be affected by small differences of the environmental (WILLIAMS, 1991) or stochastic factors (Mc ARTHUR & WILSON, 1967). Thus, although the mean richness always appears strongly correlated with protection, it must be interpreted by considering the similarity of the fish assemblages among the localities studied and the characteristics of each species (vulnerable or not vulnerable).

The mean diversity of both whole and vulnerable fish assemblage digress from the initial expected pattern. Although the diversity index has been used frequently in the environmental management and conservation (MAGURRAN, 1989), they are mesures which loose information (such as species identity) and depend extremely much on the sample-size (NOSS, 1990) and on the relative proportions of each species present (MARGALEF, 1974). As in the case of mean abundance, this parameter is largely influenced by erraticly occurring pelagic species, present in large schools (i.e., *Boops boops, Chromis chromis, Oblada melanura, Atherina hepsetus*). As a consequence, the results are rather vagues given the great range of the c.v. in this parameter and its unpredictable behavior with the level of protection. These results agree with those obtained by other authors in similar studies (BELL, 1983; GARCIA-RUBIES & ZABALA, 1990; JOUVENEL, 1992).

The standardized mean size shows the greatest correlation and the greatest precision with protection. These results agree with those obtained by other authors (BELL, 1983; RUSS, 1985; GARCIA-RUBIES & ZABALA, 1990; BENNETT & ATTWOOD, 1991; FRANCOUR, 1991*a*, 1991*b*, 1992; JOUVENEL, 1992) who found a greater mean size and/or modal size in the protected localities, especially for the vulnerable fish assemblage. This increased size is one of the main effects derived from protection and the subsequent decrease of the mortality (BOHNSACK, 1982; Plan Development Team, 1990). It is reflected mainly by the large-sized piscivorous species. It may be used as a more accurate bioindicator parameter than the mean species richness because it is less qualitatively modified by the environmental and stochastic factors. Size, however, may be affected by the intraspecific competition among large and small sized individuals (ROBERTS & POLUNIN, 1991) and by the recruitment processes, both of them can mask the real effects of the protection.

2 - Changes of the population parameters over the time

The mean abundance did not increase over time due to the high variability introduced by the pelagic and gregarious species. JOUVENEL (1992) noted the same results. Mean species richness showed a similar pattern, although several reasons may explain it. Firstly, the fully protected locality (EN) did not have some rare species, such as *Sparus aurata* and *Serranus cabrilla*, in the second sampling-period. Also, some high sedentary species with cryptic habits (i.e., *Muraena helena*) were not recorded, either due to the limitations of the methodology used (HARMELIN-VIVIEN *et al.*, 1985), or because of its disappearance caused by competition for space with other species of similar habits (i.e., *Epinephelus sp*, *Sciaena umbra*). In the partially protected locality (PT), the mean species richness diminished over time due to the disappearance of some vulnerable species (*Diplodus annularis*, *Labrus merula*, *Epinephelus guaza*) and some erratically occurring (*Seriola dumerilii*) or infrequently observed (*Symphodus melanocercus*) species. In the unprotected locality (PS), there were only a significant increase in the mean species richness of the vulnerable fish assemblage. It is due to the presence of some erratically occuring and infrequent species (*Diplodus cervinus*, *Lithognathus mormyrus*). So, this parameter is very influenced by the turnover of species and individuals tyipcal of the fish assemblage, mainly attributable to the movements of big individuals and infrequent species.

The mean diversity increased over time, in both fully protected (EN) and unprotected (PS) localities. This pattern was due to a more equitable distribution of the number of individuals in each species (MARGALEF, 1974) than the effect of protection, in accordance with the results of other authors (GARCIA-RUBIES & ZABALA, 1990). It was influenced, mainly, by the fall-variation of the mean abundance of some gregarious species like *Atherina hepsetus*, *Chromis chromis*, *Boops boops*, and *Oblada melanura*.

The standardized mean size of

both whole and vulnerable fish assemblage showed the expected pattern. This agrees with results obtained by other authors from neighbouring areas (BINCHE, 1992; FRANCOUR, 1992; JOUVENEL, 1992). It is mainly due to the decrease of the fishing mortality with increased protection (BELL, 1983; Plan Development Team, 1990; ROBERTS & POLUNIN, 1991). In the fully protected locality (EN), the differences are only significant for the vulnerable fish assemblage due to the greater presence of large-sized species (*Epinephelus sp*, *Sciaena umbra*, *Labrus merula*), which are very sensitive to the harvest. The differences were not significant for the whole fish assemblage due to the recruitment of small individuals of some non-targeted species (*Chromis chromis*, *Boops boops*, *Thalassoma pavo*). These were more impacted by the recruitment variations (RUSS & ALCALA, 1989) than by protection. In the partially protected locality (PT), the increase of the standardized mean size is due to the decrease of the number of individuals of *Atherina hepsetus*. In the unprotected locality (PS), the increased size was only significant considering the whole assemblage. This was due to the increased presence of individuals of the family Mugilidae and some species of the genus *Symphodus*, all of which were species not-vulnerable to fishing.

3 - Fish community structure with regard to protection.

The principal components analysis shows the existence of a group of species which characterize the fish assemblage of the protected zone in accordance with the results of other authors (BELL, 1983; GARCIA-RUBIES & ZABALA, 1990; JOUVENEL, 1992). This agrees well with the difference in presence and abundance of some species among the different localities studied. Generally, these were the favorite targeted species (*Epinephelus sp*, *Diplodus sp*, *Sciaena umbra*, *Labrus merula*) and were very sensitive to the harvest pressure. These observations are consistent with those made by other authors (BOHNSACK, 1982; MUNRO *et al.*, 1987; KOSLOW *et al.*, 1988; ALCALA & RUSS, 1990) and indicates a general regularity with regard to the effect of the protection on the fish assemblage, and a greater incidence on the large-sized predator species. In this way, a MFR works as a refuge for these species, allowing the establishment of a reproductive population of large-sized individuals (Plan Development Team, 1990). Therfore, species such as *Sciaena umbra*, *Epinephelus guaza*, *Epinephelus alexandrinus*, *Labrus merula*, *Diplodus sp*, and *Coris julis* may be used as indicator species to assess the "reserve effect" in the Mediterranean sea, given their high correlation with the level of protection. Otherwise, *Sciaena umbra* and *Diplodus sp* (*Diplodus vulgaris*, *Diplodus sargus*, *Diplodus puntazzo*, which form multispecies schools) will be the more useful species for a more accurately quantitative assessment because they are more accesible to the sampling method. They have a more stable population and with wider geographical distribution, and are more suitable to be analyzed statisticaly.

CONCLUSION

The mean species richness and the standardized mean size of the vulnerable fish assemblage are the most suitable population parameters to assess the "reserve effect"of the MFR's. Their correlation with the degree of protection and their precision, are higher than in the other parameters analyzed. The mean species richness is appropiate to compare localities with different levels of protection (in a spatial dimension) because it is qualitatively affected by ecological and stochastical factors over time. The standardized mean size may be applied to the assessment of the fish assemblage among localities with different degrees of protection and over time (in a spatial and temporal dimension) because it is less affected by the qualitative changes of the fish assemblages between different sampling-periods. However, it may be masked by some biological processes (competition between large and small sized individuals, and recruitment). Some targeted species have shown a strong correlation with protection, being favoured by the establishment of the MFR as refuge free of harvest pressure. Thus, these species may be used as bioindicators to assess more efficiently the "reserve effect" on the fish assemblage.

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