THE EFFECT OF PROTECTION LEVEL ON A COASTAL FISH COMMUNITY AT SCANDOLA, CORSICA

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The Scandola Nature Reserve, set up in 1975, is situated in the centre of the marine part of the Corsican Regional Natural Park (*Parc Naturel Régional de la Corse*), which includes 80 km of coastline (Fig. 1). It is the oldest nature reserve in France to include both a land (920 ha) and marine (590 ha) reserve. There is a total protection area between Punta Palazzu and the island of Gargalu (72 ha) where fishing is strictly banned, both for amateur anglers and spearfishers and for professional fishermen. Professionnal fishing is allowed in the rest of the reserve under certain conditions (small boats, low-power engines, traditional fishing methods) (Antona *et al.*, 1981 ; Meinesz *et al.*, 1983).

Setting up a protected marine reserve involves providing legislation restricting or banning certain activities, including fishing, diving, and access and anchoring for boats. The purpose of these restrictions is to protect or restore the endangered marine fauna. Surprisingly however, as Bell (1983) pointed out, there have been very few studies to determine the effects of setting up a reserve on the existing fauna, in particular its fish component. The difficulties involved in carrying out a non-destructive, quantitative study of fish fauna is probably the main reason for the lack of investigations of this kind.

While the value of marine reserves, of whatever legal status, may not seriously be in doubt, the lack of proper assessments, backed up by relevant statistics, is often felt when attempting to justify the setting up or extension of a reserve.

I. MATERIAL AND METHODS

The role of the reserve and its effect on the fish assemblages was investigated in July 1988 by comparing, for the two main habitats, stations situated within the total protection area of the reserve, in the partial protection area of the reserve and outside the reserve.

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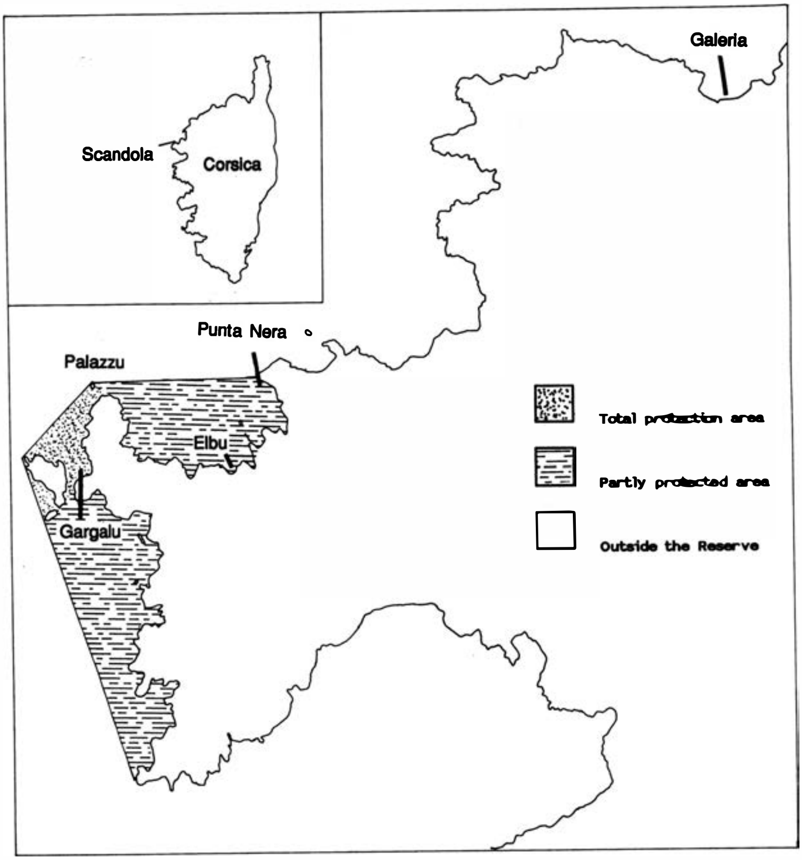

Figure 1. — Location of the stations studies in the Scandola reserve (Corsica, north-western Mediterranean) : Palazzu (rocky substrate) and Gargalu (meadow) in the total protection area, Punta Nera (rocky substrate) in the partly protected area, Galeria (meadow) outside the reserve.

Posidonia oceanica meadows and rocky shores are the two major coastal habitats of the sublittoral zone in the Scandola reserve (Boudouresque, 1980). The stations studied in the *P. oceanica* meadow were Gargalu in the total protection area, Elbu in the partly protected area of the reserve and Galeria outside the reserve. The stations investigated on rocky substrate were Palazzu in the total protection area and Punta Nera in the partly protected area of the reserve. These stations were chosen because of the similarity of certain environmental factors, in particular the rugosity of the seabed (in the sense given by Luckhurst and Luckhurst, 1978) and their exposure. In order to limit variations due to depth, the sea grass stations were subdivided into shallow zone (less than 10 m deep) and deep zone (10 to 25 m). On rocky substrate, only the depth range 0-10 m was studied. A detailed description of each station is given by Francour (1989).

The parameters used in the comparison of assemblages are species richness, demographic structure, and density and biomass of fish, expressed respectively as number of individuals and grams wet weight (WW) per 10 m^2. Only the 25 most common and conspicuous species were sampled, including 11 Labridae and 7 Sparidae (Table I). As Minconi *et al.* (1990) listed 125 species in the Scandola reserve, the term 'fish fauna' as used hereafter refers therefore to the fauna sampled, not the total fauna (Harmelin-Vivien and Francour, 1990). Demographic structure is estimated on the basis of three size classes (S = small, M = medium and L = large) ; each class corresponds to one third of the maximum-minimum body length range. The maximum length used is that given by Bauchot and Pras (1980), whereas the minimum length is that observed *in situ* (Francour, 1990). Density is estimated by a system of visual censuses — consequently non-destructive — carried out by scuba diving (Harmelin-Vivien *et al.,* 1985). Biomass is then calculated by using an average weight for each size class, determined by the size-weight ratio previously established for these species (Francour, 1990). All the censuses were done between 8 and 10 am or between 2 and 4 pm (solar time). In all, twenty 40 m^2 transects were covered in the shallow meadow stations, twenty four 40 m^2 transects in the deep meadow stations, and 19 circles (counting from central point) measuring 1.250 m^2 each in the rocky substrate stations.

II. RESULTS

1. The species

1.1. Species richness

For an identical sampling effort, the number of species found, among those expected, was similar for all the sea grass stations : 13 species out of 17 in the three shallow zones (Tab. I). In deep zone, the slight difference only concerns three species that were poorly represented along the transects (*Sarpa salpa, Seriola dumerili* and *Symphodus cinereus*). It will be assumed therefore that the composition of the assemblage sampled, at a given depth, is identical. On the other hand on rocky substrate, almost twice as many species were found at Palazzu in the total protection area (11 species) as at Punta Nera (6), out of a total of 11 species expected.

1.2. Demographic structure

The relative abundance of each size class is shown in detail by species for each sea grass meadow and rocky substrate station in Table II. The percentage of each size class is compared between stations for the main species only (χ^2 test, Tab. III). The disparity observed between stations in the demographic structure of the Sparidae can be explained principally by the low proportion of *Diplodus annularis* in class S, and the greater numbers of class M at Elbu, in comparison with other meadow stations. For the other species, the demographic structure is very similar between stations. Only class L for *Coris julis* and class S for *Symphodus melanocercus* differ between stations : for the latter species, the sea grass meadow

TABLE I

Composition by species of the fish fauna sampled at each station : Elbu, Gargalu, Galeria, Palazzu and Punta Nera.

* = species present, — = expected but not found, no symbol = not sought. *Labrus spp.* = the two species, *L. merula* et *L. viridis,* are grouped together as the single item *Labrus spp.* ; all the Mugilidae are inclued as a single item.

		Shallow meadow			Deep meadow		Rocky	
Family	Species	Elbu	Gargalu	Galeria	Elbu	Gargalu	Palazzu	Nera
Carangidae								
	Seriola dumerili	—	—	—	*	—	*	—
Labridae								
	Coris julis	*	*	*	*	*		
	Labrus spp.	*	*	*	*	*	*	*
	Symphodus cinereus	*	—	*	*	—		
	S. doderleini	—	—	—	*	*		
	S. mediterraneus	—	*	—	*	*		
	S. melanocercus	*	*	*	*	*		
	S. ocellatus	*	*	*	*	*		
	S. roissali	*	*	*	*	*		
	S. rostratus	—	*	*	*	*		
	S. tinca	*	*	*	*	*		
Moronidae								
	Dicentrarchus labrax						*	—
Mugilidae							*	—
Mullidae								
	Mullus surmuletus	*	*	*	*	*		
Sciaenidae								
	Sciaena umbra						*	*
Serranidae								
	Serranus cabrilla	*	*	*	*	*		
	S. scriba	*	*	*	*	*		
Sparidae								
	Diplodus annularis	*	*	*	*	*		
	D. puntazzo						*	—
	D. sargus						*	*
	D. vulgaris						*	*
	Dentex dentex						*	*
	Sarpa salpa	*	—	—	*	—	*	*
	Spondyliosoma cantharus	*	*	*	*	*	*	—
Number of species expected		17	17	17	17	17	11	11
Number of species found		13	13	13	17	14	11	6

TABLE II

Demographic structure by species for different stations sampled, expressed as percentage of abundance of individuals.

Class S = small, M = medium, L = large.

	Elbu shallow			Elbu deep			Gargalu shallow			Gargalu deep			Galeria			Palazzu			Punta Nera		
	% S	% M	% L	% S	% M	% L	% S	% M	% L	% S	% M	% L	% S	% M	% L	% S	% M	% L	% S	% M	% L
C. julis	63.2	34.2	2.6	50.6	34.2	15.2	69.6	22.8	7.6	64.7	28.4	6.9	67.9	30.8	1.3						
Labrus spp.	100	0	0	0	0	100	0	100	0	100	0	0	50.0	25.0	25.0	0	100	0	0	0	100
S. cinereus	0	100	0	0	50.0	0							0	100	0						
S. doderleini				0	100	0				0	100	0									
S. mediterraneus				0	0	100	0	33.3	66.7	0	75.0	25.0									
S. melanocercus	13.3	80.0	6.7	23.1	69.2	7.7	0	75.0	25.0	58.8	41.2	0	0	100	0						
S. ocellatus	0	88.2	11.8	0	73.3	26.7	0	85.7	14.3	0	80.0	20.0	10.0	70.0	20.0						
S. roissali	0	100	0	0	0	100	0	50.0	50.0	0	100	0	0	0	100						
S. rostratus				25.0	50.0	0	0	100	0	0	83.3	16.7	0	80.0	20.0						
S. tinca	66.7	16.7	16.6	57.1	42.9	0	40.0	53.3	6.7	0	100	0	30.0	70.0	0				0	0	100
D. annularis	29.7	54.1	16.2	30.9	64.3	4.8	63.2	31.6	5.2	68.0	32.0	0	41.7	52.8	5.5						
D. puntazzo																0	60.0	40.0			
D. sargus																0	100	0	0	100	0
D. vulgaris																0	100	0	0	100	0
D. dentex																2.3	0	97.7	0	0	100
S. salpa	100	0	0	0	100	0										0	31.8	68.2	0	0	100
S. cantharus	100	0	0	100	0	0	100	0	0	100	0	0	100	0	0	0	100	0			
S. cabrilla	100	0	0	100	0	0	94.4	5.6	0	100	0	0	100	0	0						
S. scriba	25.0	75.0	0	30.0	70.0	0	23.5	70.6	5.9	44.4	55.6	0	50.0	50.0	0						
D. labrax																0	0	100			
S. dumerili				100	0	0															
M. surmuletus	100	0	0	84.2	15.8	0	88.9	11.1	0	78.6	21.4	0	100	0	0						
Mugil sp.																0	67.7				
S. umbra																0	67.7	32.3	0	100	0

in the Gargalu channel shows a higher proportion of small specimens compared to the other stations. For *C. julis,* the high percentage of large specimens at Elbu in deep zone is probably in itself sufficient explanation for the differences noted.

TABLE III

Comparison of demographic structure of the main species between the five meadow stations.

χ^2 to 4 degree of freedom, theorical χ^2 = 9.49, ° rejection of null hypothesis at 0.05.

Species	S	M	L
C. julis	7.835	3.329	12.867°
S. tinca	5.692	8.169	3.045
S. ocellatus	5.686	2.068	1.384
S. melanocercus	14.397°	7.881	5.396
D. annularis	20.322°	12.799°	10.340°
S. cantharus	0	0	0
M. surmuletus	3.872	3.873	0
S. cabrilla	4.546	4.546	0
S. scriba	2.174	1.468	1.744

For the two rocky substrate stations, Palazzu and Punta Nera, we have not carried out a similar statistical comparison of the demographic structure : the census method used (circle counts) takes into account individual specimens of classes M and L only (in normal circumstances). It should be pointed out however that the demographic structure of the assemblage sampled at Punta Nera is not well-balanced : each species is only represented by a single size class (M or L), whereas at Palazzu the two classes are usually found.

1.3. Density

The fish fauna is dominated by a small number of species : *Coris julis, Diplodus annularis* and *Spondyliosoma cantharus* in the shallow zone ; *C. julis, D. annularis* and *Serranus cabrilla* in deep zone (Tab. IV). But differences between stations are fairly marked as concerns their relative abundance. At Elbu, in shallow zone, the first three species represent 75 % of total density, and the first seven 97 %. These values are of the same order at Galeria (71 and 99 %). On the other hand, in the Gargalu channel, the assemblage appears to be more evenly distributed, since the respective percentages are only 60 and 87 %. In deep zone, the situation is similar between the two stations : the percentages are 58 and 88 % at Elbu, and 67 and 88 % at Gargalu. The high degree of similarity of the assemblages between the two depth ranges at Gargalu should be noted.

Comparison of mean density of the main species between the meadow stations (Kruskal-Wallis test) shows few differences ; they concern essentially *C. julis* (classes S, L and T), *D. annularis* (classes S, M, L and T) and *S. cantharus*

TABLE IV

Mean density (in individuals/10 m^2) and biomass (in g WW/10 m^2), regardless of size class, at different Posidonia oceanica *meadow stations.*

ES = Elbu, shallow zone, ED = Elbu, deep zone, GS = Gargalu, shallow zone, GD = Gargalu, deep zone, Ga = Galeria.

	ES	ED	GS	GD	Ga
DENSITY					
C. julis	0.48	0.82	1.15	1.06	0.98
Labrus spp.	0.06	0.03	0.03	0.06	0.05
S. cinereus	0.03	0.06	0	0	0.03
S. doderleini	0	0.03	0	0.04	0
S. mediterraneus	0	0.03	0.09	0.07	0
S. melanocercus	0.18	0.14	0.10	0.18	0.04
S. ocellatus	0.21	0.16	0.17	0.10	0.13
S. roissali	0.03	0.03	0.06	0.03	0.04
S. rostratus	0	0.04	0.08	0.10	0.06
S. tinca	0.12	0.07	0.18	0.04	0.13
D. annularis	0.46	0.44	0.24	0.52	0.90
S. salpa	0.06	0.16	0	0	0
S. cantharus	1.41	0.25	0.42	0.16	0.39
S. cabrilla	0.14	0.30	0.23	0.24	0.23
S. scriba	0.08	0.10	0.21	0.09	0.08
S. dumerili	0	0.03	0	0	0
M. surmuletus	0.16	0.40	0.34	0.15	0.38
BIOMASS					
C. julis	4.0	17.1	13.5	12.5	6.4
Labrus spp.	1.8	34.2	9.4	1.8	18.2
S. cinereus	0.3	1.3	0	0	0.3
S. doderleini	0	0.1	0	0.1	0
S. mediterraneus	0	1.1	2.6	1.1	0
S. melanocercus	1.6	1.1	1.3	0.8	0.3
S. ocellatus	1.4	1.3	1.2	0.8	0.9
S. roissali	0.2	0.5	0.7	0.2	0.7
S. rostratus	0	0.2	0.2	0.4	0.3
S. tinca	9.1	2.4	11.9	3.0	6.5
D. annularis	7.4	4.5	1.8	2.2	8.6
S. salpa	0.9	24.2	0	0	0
S. cantharus	38.1	6.8	11.5	4.2	10.5
S. cabrilla	0.7	1.5	2.1	1.2	1.1
S. scriba	2.7	3.2	8.7	2.4	1.8
S. dumerili	0	12.5	0	0	0
M. surmuletus	1.7	13.3	9.1	6.1	4.1

(classes S and T). For *C. julis* and *S. cantharus,* the Elbu station in shallow zone differs significantly from the two Gargalu stations and the Galeria station, with a lower mean density than elsewhere for the first species, and higher mean density for the latter (Tukey test, $p < 0.05$). For *D. annularis,* it is the Galeria station that differs markedly from the four others, with a higher mean density.

TABLE V

Mean density (D, in individuals/10 m²) and biomass (B, in g WW/10 m²) at different stations of rocky substrate.

	Palazzu		Punta Nera	
	D	B	D	B
S. umbra	0.02	6.8	0.02	5.0
D. labrax	< 0.01	2.7	0	0
D. dentex	0.02	19.1	< 0.01	4.9
D. puntazzo	< 0.01	1.5	0	0
D. sargus	0.09	17.1	0.05	10.4
D. vulgaris	0.06	4.5	0.01	0.8
S. salpa	0.34	142.2	0.10	55.2
S. cantharus	0.10	3.4	0	0
Labrus spp.	< 0.01	0.3	< 0.01	1.1
Mugilidae	0.04	8.9	0	0

In the two rocky substrate stations, *Sarpa salpa* and *Diplodus sargus* are the dominant species, with a density 4 or 5 times higher for *S. salpa* than for *D. sargus*. The other species have much lower mean densities (Tab. V).

1.4. Biomass

The dominant species by weight are different : the large labrids *L. merula, L. viridis* (grouped together as *Labrus* in the tables) and *S. tinca* take on a certain importance despite their low density in the sea grass meadows. *Coris julis* is again among the first five species, but the contribution of *D. annularis* is often slight. The first seven species represent 90 % of the total biomass, whatever the station considered. What is more, there is no difference between the depth ranges, in contrast with what was observed for density. On the other hand, there is again a marked difference between stations for the relative contribution of the first three species : it is low at Gargalu (50 to 60 %, depending on depth) compared to the other three stations (70 %).

On rocky substrate, the high biomass of *Dentex dentex* at Palazzu is noteworthy ; it is the second best represented species at this station. At two stations, the salema, *Sarpa salpa,* represent 70 % of the total biomass.

1.5. Additional quantitative observations

A few counts were done using complementary methods, designed for highly mobile species or schooling fishes (Francour, 1990).

In surface zone at Elbu, the density of *Sarpa salpa,* assessed by the total count method, varied from 0.02 to 0.20 L/10 m², 0.02 M/10 m² and 0.08 S/10 m² ; or a mean biomass of 65 g WW/10 m^2. At Gargalu, in surface zone, the mean biomass estimated by this method was around 190 g WW/10 m^2 and 410 g WW/10 ^{2} at Galeria.

Dentex dentex was only observed in sea grass meadow at Gargalu. In isolated cases its biomass was estimated at 13 g WW/10 m^2. At Palazzu, as complete a census as possible of *Sciaena umbra* gave, taking all size classes together, around fifty individuals, or a density of around 0.06/10 m^2 (around 70 g WW/10 m^2). This value is slightly higher than that obtained using the circle count method (0.02/10 m^2).

1.6. Distribution in the environment

The degree of dispersion (Taylor's slope of the line, Elliott, 1977) at each sea grass station is estimated for the data for mean density and biomass calculated by species, for each size class (Tab. VI).

TABLE VI

Estimated dispersion (Taylor's slope of line) of fish fauna, in density and biomass, according to size class, in meadow stations.

Class S = small, M = medium, L = large, T = all classes.

	Shallow zone				Deep zone			
	S	M	L	T	S	M	L	T
Density								
Gargalu	0.52	0.85	1.15	0.59	0.78	1.00	0.82	0.87
Elbu	0.62	1.08	0.94	0.65	0.78	0.76	1.08	0.77
Galeria	0.76	0.94	1.09	0.80				
Biomass								
Gargalu	0.46	0.54	0.54	0.53	0.50	0.52	0.60	0.54
Elbu	0.54	0.62	0.55	0.52	0.56	0.53	0.58	0.52
Galeria	0.56	0.55	0.49	0.54				

For biomass, the results are very consistent between size classes and between stations. The mean value of the slope (0.54) reflects a wide degree of dispersion by weight in the assemblage. For density, dispersion varies with depth : the assemblage is numerically under-dispersed in shallow zone in the reserve (Elbu and Gargalu), whereas distribution shows random tendencies (slope close to 1) in deep zone or at Galeria.

2. Fish fauna and principal families

2.1. Demographic structure

The demographic structure of the fauna sampled (Tab. VII) is similar between the three sea grass stations, except for class S (χ^2 test, $p > 0.05$). This disparity is largely explained by the deep station at Elbu, where the number of small specimens sampled is significantly lower than elsewhere. On rocky substrate, the demographic structure is identical for all the stations.

The demographic structure of the three main families censused (Labridae, Sparidae and Serranidae), and of the genus *Symphodus*, which is the dominant genus of Labridae, is similar for all the sea grass stations except for the Labridae

TABLE VII

Demographic structure of the main families of fish, of the genus Symphodus, *and of the assemblage sampled at each station.*

Expressed as percentage of density of the three size classes. S = small, M = medium, L = large.

	Shallow			Deep		
	% S	% M	% L	% S	% M	% L
GARGALU						
Symphodus	13.0	69.6	17.4	21.7	69.6	8.7
Labridae	50.4	38.8	10.8	52.0	40.7	7.3
Sparidae	86.8	11.3	1.9	75.4	24.6	0
Serranidae	60.0	37.1	2.9	84.4	15.6	0
Assemblage	63.4	29.9	6.7	63.2	32.6	4.2
ELBU						
Symphodus	15.0	75.0	10.0	18.2	61.4	20.4
Labridae	39.3	54.4	6.3	38.7	43.6	17.7
Sparidae	82.9	13.1	4.0	52.1	45.1	2.8
Serranidae	80.0	20.0	0	82.1	17.9	0
Assemblage	69.3	26.3	4.4	55.0	36.3	8.7
GALERIA						
Symphodus	12.9	71.0	16.1			
Labridae	52.2	41.6	6.2			
Sparidae	59.2	36.9	3.9			
Serranidae	87.5	12.5	0			
Assemblage	60.7	34.9	4.4			
PALAZZU						
Assemblage	0.1	55.1	44.8			
NERA						
Assemblage	0	57.9	42.1			

(class L) and Sparidae (class S, χ^2 test, $p < 0.05$). In both of these cases, the deep station at Elbu differs significantly from the other sea grass stations : 17.7 % of large individuals of Labridae as against 7.7 % on average in the other four stations ; 52.1 % of small individuals of Sparidae against 76.0 %.

The fish assemblage in the sea grass meadow in the Gargalu channel presents a similar demographic structure in both shallow and deep zones. On the other hand at Elbu, demographic structure differs with depth, with fewer small individuals being observed in deep zone.

2.2. Density

In the sea grass stations, total density varies from 3.2 to 2.7 individuals/10 m^2 (Tab. VIII). Mean density is similar for the different stations (Kruskal-Wallis test, $p = 0.68$). More detailed comparison by size class reveals a difference in class L ($p < 0.001$). For this class, only the deep stations at Gargalu (0.11 individuals L/10 m^2) and at Elbu (0.25 ind./10 m^2) differ (Student-Newman-Keuls test, $p < 0.05$). On rocky substrate, density is 0.6 ind./10 m^2 ($s = 0.5$) at Palazzu, and 0.1 ind./10 m^2 ($s = 0.3$) at Nera. It is significantly lower at the Nera station than at Palazzu (Student's t-test, $p < 0.01$).

At each sea grass station, Labridae and Sparidae are the two dominant families ; they represent from 71 to 92 % of the total density of the fauna sampled. Among the Labridae, the genus *Symphodus* is numerically poorly represented despite a large number of species. On average, this genus represents 30 % of the Labridae, except at Elbu, in shallow zone (50 %). Mean density per family is similar between stations (two-way ANOVA, $F = 0.365$, $p = 0.55$). An identical comparison, for each of the size classes, rejects the null hypothesis for class L only ($F = 5.061$, $p = 0.001$). This is explained by the high density of Labridae of class L (0.23 ind./10 m^2) in the sea grass meadow at Elbu, in deep zone (Tukey test, $p = 0.05$).

2.3. Biomass

Mean biomass of the fauna varies from 34.9 to 76.0 g WW/10 m^2 for the different sea grass stations (Tab. VIII). The mean biomass differs significantly between the deep stations at Elbu and at Gargalu (SNK non-parametric test, $p < 0.05$). The high value recorded at Elbu, in deep zone, is in fact due to a single individual (*Labrus sp.*, class L). If this value is left out, the mean biomass at Elbu does not differ significantly from the value recorded at Gargalu at the same depth. The mean biomass for the different zones is then similar at the same depth (SNK non-parametric test, $p > 0.05$) : around 56 to 66 g WW/10 m^2 in shallow zone, and 35 g WW/10 m^2 at depth. On rocky substrate, the mean biomass at Palazzu (202 g WW/10 m^2) is significantly higher (t test, $p < 0.01$) than at Nera (42 g WW/10 m^2). It is difficult to compare the assemblages sampled on rocky substrate and in the sea grass meadow. Nevertheless, in the total protection area, there is a very marked difference between the very high mean biomass of the fish assemblage observed on rocky substrate, and the much lower biomass measured in the sea grass meadow.

TABLE VIII

Mean density (number of individuals/10 m²) and biomass (g WW/10 m²), regardless of size class, for the genus Symphodus, *the main families of fish and the assemblage sampled*

(in brackets = standard deviation).

	Shallow		Deep	
	Density	Biomass	Density	Biomass
GARGALU				
Symphodus	0.58 (0.46)	15.84 (27.99)	0.48 (0.39)	5.74 (8.61)
Labridae	1.74 (1.06)	33.10 (34.96)	1.56 (0.70)	18.85 (22.65)
Sparidae	0.66 (0.73)	13.20 (18.68)	0.68 (0.54)	6.41 (6.57)
Serranidae	0.44 (0.36)	10.72 (14.41)	0.33 (0.24)	3.55 (5.20)
Assemblage	3.18 (1.40)	66.10 (47.29)	2.72 (0.74)	34.89 (29.14)
ELBU				
Symphodus	0.50 (0.40)	8.64 (24.28)	0.46 (0.35)	5.99 (7.04)
Labridae	0.99 (0.65)	12.99 (23.83)	1.29 (0.69)	34.53 (61.90)
Sparidae	1.90 (2.03)	45.90 (53.11)	0.74 (0.43)	19.30 (38.40)
Serranidae	0.19 (0.19)	2.31 (4.09)	0.41 (0.28)	4.70 (5.17)
Assemblage	3.14 (2.26)	61.89 (58.04)	2.84 (0.96)	75.99 (94.71)
GALERIA				
Symphodus	0.39 (0.35)	8.49 (10.07)		
Labridae	1.41 (0.72)	33.09 (62.20)		
Sparidae	1.29 (0.72)	19.06 (21.78)		
Serranidae	0.30 (0.27)	2.85 (4.16)		
Assemblage	3.15 (0.99)	56.65 (63.74)		
PALAZZU				
Assemblage	0.55 (0.44)	202.19 (230.05)		
NERA				
Assemblage	0.11 (0.27)	41.74 (109.32)		

In terms of weight, the Labridae and Sparidae are again the two dominant families in the sea grass assemblages : 70 to 95 %, depending on the station. On the other hand, the contribution of *Symphodus* is different : it changes little in the Gargalu channel, regardless of depth, but was highly variable at Elbu, with a very marked drop in the shallow zone and an increase at depth. Mean biomass is significantly different between families and between stations (ANOVA, $p < 0.001$). There is generally a drop in biomass at depth for both families. The only exception, the Labridae at Elbu, is due to a single individual (L *Labrus* in deep zone), and may therefore be ignored.

III. DISCUSSION

For the three factors investigated (demographic structure, density and biomass), the results are relatively consistent, and where there are differences between sea grass stations, these are less marked than on rocky substrate. We nonetheless observed in several cases (demographic structure, mean density) a high degree of similarity between the two stations, shallow and deep zone, in the Gargalu channel. On the other hand, the two depth zones in the sea grass meadow at Elbu generally differ significantly. While no significant difference is observed in the composition of the assemblage (i.e. the species sampled), the relative abundance of the dominant species varies between the different stations. The fauna at Elbu and Gargalu is very clearly dominated by a small number of species, whereas at Gargalu, the dominant species are more numerous and the difference between the species is less pronounced. This brings us back to the idea of the consistent relative abundance observed in the fish assemblages in the total protection area of the reserve, which in our view constitutes the main difference between the main part of the reserve (Elbu) and the total protection area, as far as the *P. oceanica* meadow is concerned. Although similar in terms of numbers and weight, the structure of the fish assemblage of the sea grass meadow outside the total protection area is « unbalanced ». A few species are strongly dominant, and the large predators that are the species most vulnerable to fishing pressure (*Sparus aurata, Dentex dentex, Dicentrarchus labrax*) are rare. However, it may be that the particular position of the Gargalu station, close to a transit area for fish, partly explains the difference.

On the other hand, on rocky substrates the differences are very marked between the fish assemblages within the total protection zone (Palazzu) and outside it (Punta Nera). Biomass and mean density for the 11 species included in the study are five times higher at Palazzu than at Punta Nera. Demographic structure also shows quite distinctive patterns : all the size classes are represented at Palazzu, whereas at Punta Nera the size structure for all the species is unimodal. The possible significance of this difference requires careful examination. We tried to choose two stations that were as similar to each other as possible, but there may nonetheless be differences which cannot be explained simply by possible physical dissimilarities between the stations. The presence of large numbers of brown meager, *Sciaena umbra,* and of several groupers (*Epinephelus guaza*) at Palazzu is also significant. The presence of groupers, and in particular of young individuals, is especially noteworthy, given the increasing rarity of the species (Chauvet and Francour, 1990).

To our knowledge, only Bell (1983) has investigated the impact of a marine reserve on the fish fauna on the French coast. Bell worked exclusively on rocky substrate in the Banyuls-Cerbère reserve, and for comparison on similar substrates at Cap Béar, which is nearby but outside the reserve. His study included a larger number of species than ours, but his conclusions in fact only concern a few of them, notably those that are most vulnerable to fishing pressure (mainly Sparidae, Serranidae, Moronidae and Sciaenidae). His conclusions are very similar to ours. Density (there are no estimmates of biomass) was higher within the reserve than outside : 0.48 ind./m^2 outside the reserve, versus 1.03 ind./m^2 in the reserve, in shallow zone. In deep zone, these values were 0.58 and 1.16 ind./m^2. Demographic structure also differed widely between the protected and non-protected areas, particularly as concerns the proportion of large individuals. Finally, he points out the overall similarity of the fish fauna, in terms of number of species and relative abundance.

For the *P. oceanica* meadow, it is more difficult to assess the effect of a protection. There are data for the Port-Cros National Park (see review by Francour, 1990), but paradoxically both amateur and professional fishing are allowed there, and their impact is by no means negligible (Francour, 1988). It should however be pointed out that the data of Bell and Harmelin-Vivien (1982) obtained by trawling at Marseilles (unprotected area), and those of Harmelin-Vivien (1982) obtained at Port-Cros (geographically close) using the same method, do not show any marked differences for the fish assemblages in the sea grass meadow.

IV. CONCLUSIONS

The protection offered by a restricted marine area should in theory have the effect on the fish fauna of increasing original stocks (a qualitative and quantitative gain) and allowing a return to more natural behaviour patterns (Harmelin, 1984). Assessment of these beneficial effects requires the use of non-destructive census methods (Bell, 1983 ; Harmelin, 1984) and long-term monitoring of the fauna. Long-term monitoring is a means of eliminating random variations of short duration that might conceal the major trend : the possible enrichment of the fauna. One of the aims of this preliminary study was to assess the role of the total protection area within the Scandola reserve, and thus determine its value. The censuses of the main species in the two main habitats will provide the basis for future comparison of the fauna. They should therefore be seen as the starting point for a long-term monitoring project. Certain findings seem to us to be clearly established, but at this stage our conclusions must nonetheless be considered as working hypotheses that will need to be validated later on. The choice of site for the total protection area of the reserve, between Palazzu and Gargalu, probably contributes to the richness of the fish fauna. Its exposure and structural complexity make it a particularly appropriate environment. The absence or relative insignificance of outside interference has favoured the continued existence of a stable, numerically-rich, diverse and well-balanced assemblage on rocky substrate. It is difficult to determine the respective contribution of physical factors and legislation (i.e. the total prohibition of fishing). However, the constant presence in the total protection area of species that are vulnerable to fishing pressure, such as *Dicentrarchus labrax, Dentex dentex, Spondyliosoma cantharus* and *Seriola dumerili,* and a well-balanced demographic structure, are in our view evidence of the importance of protection.

The role played by the total protection area is less clearly defined as far as the *P. oceanica* meadow is concerned, at least with regard to the fish fauna. We suggest several possible hypotheses to explain the apparent contrast with the rocky environment :

(i) The presence of a large number of predators, on rocky substrates, in the total protection area might result in an apparent decrease in mean density in the sea grass meadow. The species found there represent an important part of the predator's usual diet (Tortonese, 1975 ; Barnabé, 1976 ; Ktari *et al.,* 1978 ; Bell and Harmelin-Vivien, 1983), and although these predators do not live in the sea grass meadow, they might forage there.

(ii) The *P. oceanica* meadow is a particularly favourable environment for reproduction for many coastal species (Quignard, 1966 ; Lejeune, 1984), and this takes place essentially in spring and summer. The high density of class S individuals, in all the stations, is then temporary, and might mask a real difference between stations which would only be apparent in winter.

(iii) Fishing pressure within the sea grass meadows is relatively slight in this region (drag nets banned, relatively few fishermen, more or less seasonal fishing), and has little impact on the structure of the fish assemblage. This can be radically altered in areas where fishing pressure is high (Harmelin-Vivien and Francour, 1990).

The value of the total protection reserve on rocky substrate seems clear, but on the basis of the findings obtained at Scandola in the two areas of the reserve and at Port-Cros and Marseilles, it must for the present remain a supposition as concerns the meadow. Nevertheless, a recent study carried out at Ischia (Italy), where fishing pressure is very high, has shown a clear decline of species richness, biomass and density in comparison with previously studied sea grass meadows (Harmelin-Vivien and Francour, 1990, and in preparation).

SUMMARY

The fish fauna of a sublittoral zone of the Scandola nature reserve (Corsica) was studied in July 1988 using a non-destructive visual census method, on rocky substrate and *Posidonia oceanica* meadow. By comparing stations inside and outside the total protection area of the reserve (where all fishing is prohibited) it was possible to assess the ecological effects of protection. Mean density and biomass were similar for the different meadow stations : 3 ind./10 m^2 (0 to 25 m), 56-66 g WW/10 m^2 (0 to 10 m) and 35 g WW/10 m^2 (10 to 25 m). But demographic structure and relative importance of dominant species differed between the total protection area and partly protected areas of the reserve. On rocky substrate, density and biomass differed significantly : 0.6 versus 0.1 ind./10 m^2 and 202 versus 42 g WW/10 m^2 for totally and partly protected areas respectively. Thus the effect of a total protection of the fish fauna is more obvious on rocky substrate, whereas in the *P. oceanica* meadow, this is reflected in a better equilibrium in the specific structure of the fish fauna, rather than in any modification of density or biomass.

RÉSUMÉ

Le peuplement ichtyologique de la zone infralittorale de la Réserve naturelle de Scandola (Corse) a été étudié en juillet 1988 par une méthode non destructive de relevés visuels en plongée, sur milieu rocheux et dans l'herbier à *Posidonia oceanica.* La comparaison des stations dans et hors de la réserve intégrale (toutes formes de pêche y sont inderdites) permet d'évaluer le rôle de la protection

résultant de la mise en réserve. La densité et la biomasse moyennes sont comparables entre stations d'herbier : 3 ind./10 m^2 (0 à 25 m), 56-66 g PH/m^2 (0 à 10 m) et 35 g PH/10 m^2 (10 à 25 m). Par contre, la structure démographique et l'importance relative des espèces dominantes varient entre la réserve intégrale et non intégrale. Sur milieu rocheux, les différences sont plus tranchées : 0.6 contre 0.1 ind/10 m^2 et 202 contre 42 g PH/10 m^2 entre la réserve intégrale et non intégrale. L'importance d'une réserve intégrale est donc plus évidente en milieu rocheux. Dans l'herbier, elle se traduit plus par une structure spécifique du peuplement de poissons mieux équilibrée que par une modification de sa densité ou de sa biomasse.

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