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Effects of recreational fishing on three fish species from the *Posidonia oceanica* meadows off Minorca (Balearic archipelago, western Mediterranean)

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SUMMARY: Experimental fishing and visual censuses were conducted at nine *Posidonia oceanica* sites off Minorca exposed to different levels of fishing intensity to assess the effects of recreational fishing on the species that dominate the catch. Total catch per unit effort (CPUE) was highly seasonal and a statistically significant interaction term existed between the season and the level of fishing intensity. CPUE decreased everywhere at the end of the fishing season (autumn), but such a reduction was more intense at those sites exposed to the highest level of fishing. Visual censuses confirmed that there was a lower abundance of vulnerable fish in autumn. Differences vanished in spring probably because fish reshuffled between the considered sites throughout the winter, when the level of fishing intensity was extremely low. Although the average total lengths of *Serranus scriba* and *Diplodus annularis* were unaffected by the level of fishing intensity, the average total length of *Coris julis* was smaller at the most heavily fished sites. In conclusion, recreational fishing has a relevant impact on most of the exploited species and some of the seasonality reported for the *Posidonia oceanica* fish assemblages might be caused by the seasonality of the fishery.

Keywords: abundance, angling, *Coris julis*, *Diplodus annularis*, seagrass, *Serranus scriba*, size.

RESUMEN: EFECTOS DE LA PESCA RECREATIVA SOBRE TRES ESPECIES DE PECES DE LAS PRADERAS DE *POSIDONIA OCEANICA* DE MENORCA (ISLAS BALEARES, MEDITERRÁNEO OCCIDENTAL). – Se realizaron pescas experimentales y censos visuales en nueve localidades del litoral de Menorca con pradera de *Posidonia oceanica* y sometidas a diferentes niveles de presión pesquera con el fin de evaluar el efecto de la pesca recreativa sobre las principales especies capturadas. La captura total por unidad de esfuerzo fluctuó estacionalmente, existiendo una interacción estadísticamente significativa entre la estación y el nivel de intensidad de la pesca, ya que si bien la CPUE disminuyó en todas las estaciones al final de la temporada de pesca (otoño), la reducción fue más intensa allí donde mayor había sido la presión pesquera. Los censos visuales confirmaron que dicha reducción fue debida a un descenso en la abundancia de ejemplares vulnerables. No obstante, estas diferencias desaparecieron a la siguiente primavera, seguramente porque los peces se redistribuyeron durante el invierno entre las zonas de pesca. Aunque la intensidad de la pesca no afectó a la talla media de los ejemplares de *Serranus scriba* y *Diplodus annularis*, la talla media de los ejemplares de *Coris julis* disminuyó al aumentar la presión pesquera. Este estudio demuestra el impacto de la pesca recreativa sobre la mayoría de las especies explotadas y sugiere que la estacionalidad observada en las comunidades de peces de las praderas de *Posidonia oceanica* podría ser debida, parcialmente, a la estacionalidad del esfuerzo pesquero.

Palabras clave: abundancia, pesca con anzuelo, *Coris julis*, *Diplodus vulgaris*, fanerógamas marinas, *Serranus scriba*, talla.

INTRODUCTION

Sport fishing of marine fish has been practiced for a long time (Bickerdyke, 1887; Ferrer, 1914), but fishery biologists have long neglected it as a relevant source of exploitation. Pickett and Pawson (1994) assessed the relevance of recreational angling for a marine species in Europe for the first time and concluded that sport anglers generated half the total catch of sea bass (*Dicentrarchus labrax*) off the United Kingdom. More recently, Coll *et al.* (2004) and Chavoin and Boudouresque (2004) demonstrated the role of recreational spearfishing in the depletion of large fish from Mediterranean rocky reefs and Morales-Nin *et al.* (2005) pointed out that 31% of the annual fish production at trophic level 4 is removed from the coastal waters of Majorca Island (Balearic Archipelago, western Mediterranean) by sport fishing. However, information about the relevance of recreational fishing in the Mediterranean is still scarce and limited to rocky bottoms (Sánchez Lizaso *et al.*, 2000; Francour *et al.*, 2001 and references herein).

The seagrass *Posidonia oceanica* forms dense meadows off the Balearic Archipelago and other unpolluted regions of the Mediterranean (Procaccini *et al.*, 2003). The fish assemblages inhabiting *P. oceanica* meadows in the western Mediterranean are dominated by small species seldom exceeding 20 cm in total length (Massutí, 1965; Bell and Harmelin-Vivien, 1982; Seloudre and Chauvet, 1986; Bouchereau *et al.* 1989; Reñones *et al.*, 1995; Francour, 1997; Jiménez *et al.*, 1997; Francour, 2000; Garcia-Rubies and Corbera, 2002). Despite the low commercial value of these small species (Lloris and Meseguer, 2002), they have a major contribution to the global catch by the recreational fishery and it has been suggested that they are exploited intensely (Morales-Nin *et al.*, 2005). Previous studies have demonstrated that recreational angling on rocky areas may change the reproductive biology of at least one of these species (Harmelin *et al.*, 1995), but information about the impact of fishing on the meadow-dwelling populations is contradictory (Francour, 1994; Harmelin *et al.*, 1995; Francour, 2000).

This paper aims to assess how meadow-dwelling populations of *Coris julis*, *Diplodus annularis* and *Serranus scriba* respond to increasing levels of fishing intensity by recreational anglers off the Balearic Archipelago.

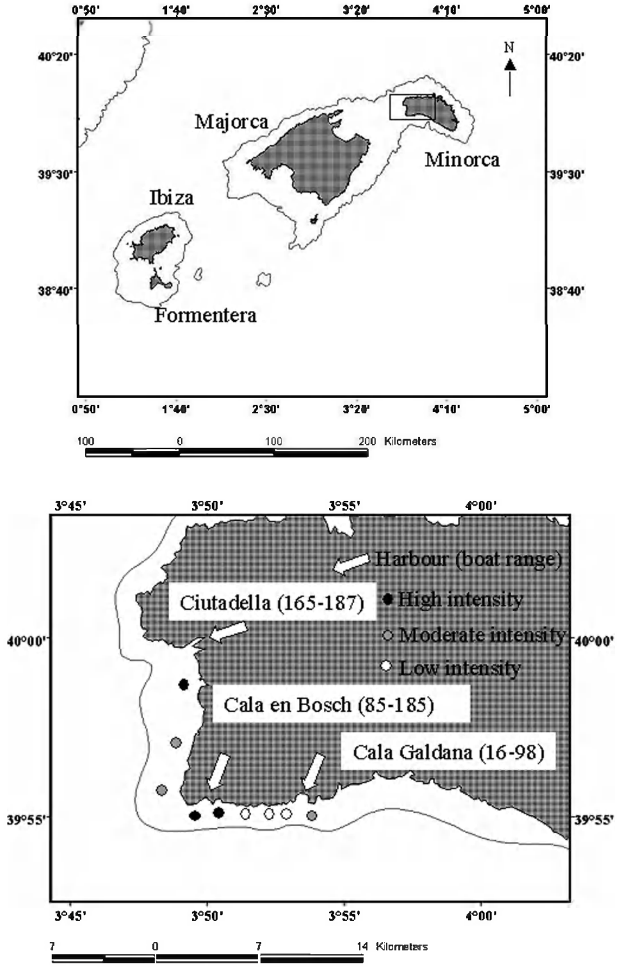

FIG. 1. – Location of the nine sampling sites. The light grey contour denotes the –50 m isobath. The annual range of moored boats in each harbour is shown in brackets.

MATERIAL AND METHODS

Experimental design

The study was conducted along the stretch of coastline running from Ciutadella to Cala Galdana (Fig. 1), in southwestern Minorca (Balearic Archipelago, western Mediterranean). Recreational fishing is the main fishing activity in the *Posidonia oceanica* meadows, as professional fishermen typically exploit deeper ecosystems. Only in autumn and winter do some fishermen use trammel nets along the lower limit of the meadows off Ciutadella to target red mullets (*Mullus surmuletus*) and cuttlefish (*Sepia officinalis*). The anglers operating in that area moor their boats at three ports (Ciutadella, Cala en Bosch and Cala Galdana), so fishing intensity is expected to decrease with increasing distance from them.

However, fishing intensity off Cala Galdana is lower than expected, because angling there is highly seasonal. Previous sampling revealed that the catch was dominated by *C. julis*, *D. annularis* and *S. scriba*, and information about them was collected systematically from October 2000 to July 2001 by means of experimental fishing and visual census at nine sites exposed to three different levels of fishing intensity. These sites were initially selected in agreement with the distance from the above-mentioned ports and previous information about the distribution of the fishing effort in the area, but the actual distribution of the fishing effort in the whole area during the study was monitored monthly from September 2000 to August 2001 to check that the selected sites differed in the actual level of fishing intensity.

The whole area, ranging in depth from 5 to 35 m, was divided into 20 sectors, each one equivalent to a 1 x 1 km UTM quadrate, and the distribution of fishing effort was assessed by recording from seven lookouts how many boats were fishing in each sector. The observers covered several UTM quadrates from each lookout and each UTM quadrate was checked only from one, previously assigned lookout. Sampling was stratified and each lookout was visited monthly on three working days and three weekend days. The dates for censing boats were selected in advance and fieldwork was conducted whatever the weather conditions were. On the assigned days, the observers visited the lookouts every three hours from dawn to dusk and counted the number of fishing boats operating in each sector. Once all the boats had been counted, the observers left the lookout and came back three hours later for a new census. Observed daily fishing intensity for any given sector was computed as the sum of the boats observed in all the visits of that day. The fishing intensity in the ith sector in the jth month (F_{ij}) was computed as follows:

$$F_{ij} = \Sigma\ (Fr * R) + \Sigma\ (Fe * E)$$

where Fr is the average number of boats observed fishing in the ith sector on the working days of the jth month, R is the number of working days in the jth month, Fe is the average number of boats observed fishing in the ith sector on the weekend days of the jth month and E is the number of weekend days in the jth month. The annual fishing intensity in the ith sector was just the sum of the monthly values for fishing intensity.

Experimental fishing

Experimental fishing, using hook and line like those used by recreational fishermen, was conducted at each experimental site in November 2000, February 2001, May 2001 and July 2001. The fishing gear consisted of a nylon monofilament line (diameter=0.3 mm) with a 40-60 g lead and four hooks scattered along the final 1.5 m of the line. Two lines were used in each fishing trip, one with 7 mm wide, 17 mm long Mustad™ J-hooks and the other with 4 mm wide, 11 mm long ones. The two persons conducting the experimental fishing used both lines on each trip for exactly the same time to avoid any bias due to fishing skills. Live polychaetes from a commercial supplier were used as bait. Polychaetes were cut into 5 mm pieces just before being used. The boat was not anchored while fishing and drifted with the current. The boat's position was corrected when it left the *Posidonia oceanica* meadow or when the water depth was outside the 20-30 m range. Total fishing time was recorded. Catch per unit effort (CPUE) was computed as the number of fish caught per hour by two persons operating two 4-hook lines like those described above.

In the laboratory, the catch was labelled and frozen at –20ºC. Once defrosted, the specimens of all the species were measured to the nearest millimetre (total length) and weighed to the nearest milligram.

Visual censuses

Visual censuses (Harmelin-Vivien *et al*., 1985; Harmelin-Vivien and Francour, 1992; Francour, 1994, 1997; Garcia-Rubies and Corbera, 2002) were conducted at the selected sites in autumn (October and November 2000) and spring (April and May 2001). Two fixed 50 x 5 m transects were established at –7 and –19 m of depth at each site and fish were censused there five time in each season. Every individual fish was counted and classified as small (total length<1/3 of maximal length), medium (1/3 of maximal length<total length<2/3 of maximal length) or large (total length>2/3 of maximal length). Experimental fishing (see results) revealed that only eight benthic species were vulnerable to angling (*Coris julis*, *Diplodus annularis*, *Diplodus sargus*, *Diplodus vulgaris*, *Symphodus tinca*, *Serranus cabrilla*, *Serranus scriba*, and *Spondyliosoma cantharus*) and the smaller specimens of most species were seldom caught. As a consequence, a category of vulnerable fish, defined from the information derived from experimental fishing, was considered when the results of visual census were analysed. This category included all the specimens of *S. cabrilla* and *S. scriba* and the specimens of the two larger size classes of the remaining two species. This was also true for *C. julis*, independently of the coloration phase. *P. oceanica* cover, sand cover, rock cover and the density of *P. oceanica* were measured within each transect. Shoot density was measured at three points along the transect using a 50 x 50 cm PVC quadrat and cover was evaluated with the aid of a tape measure (Boudouresque *et al.*, 1986).

Data analysis

The existence of statistically significant differences in the environmental features (*P. oceanica* density, *P. oceanica* cover, sand cover and rock cover) of the sampling stations was tested by means of one-way ANOVA when the Levene test revealed homoscedasticity. Student-Newman-Keuls test was used as a *post hoc* test for ANOVA. The analysis was conducted independently for samples collected at -7 m (shallow) and -19 m (deep). Prior to analysis, shoot density was transformed as $X' = \log(x+1)$ to ensure a normal sample distribution. In the same way, cover data were transformed as $X' = \arcsin \sqrt{x}$.

Two-way analysis of variance (ANOVA) was used to assess the relevance of fishing intensity and season on catch per unit effort (CPUE of the number of fish caught per hour by two anglers). Two-way analysis of variance (ANOVA) was also used to assess the relevance of fishing intensity and depth on the density of vulnerable species. Prior to analysis, CPUE and fish density were transformed as $X' = \log(x+1)$ to ensure a normal sample distribution. One-way ANOVA was used to compare the average length of specimens from the sites exposed to the three levels of fishing intensity.

RESULTS

Distribution of the fishing effort

As expected, ANOVA ($F_{2,6} = 22.016$, $p = 0.02$) and a post hoc Student-Newman-Keuls test confirmed that the sectors originally assigned to low, moderate and high fishing intensity actually differed from each other in the annual level of fishing intensity, reported as the number of fishing boats per year (low = 60.0 ± 52.0, moderate = 200.0 ± 69.3, high = 406.7 ± 70.2). Recreational fishing was highly seasonal in the whole area, with a marked peak in August (Fig. 2). From November to May, most of the fishing activity was concentrated around Ciutadella port, with negligible levels of activity between Cala en Bosch and Cala Galdana.

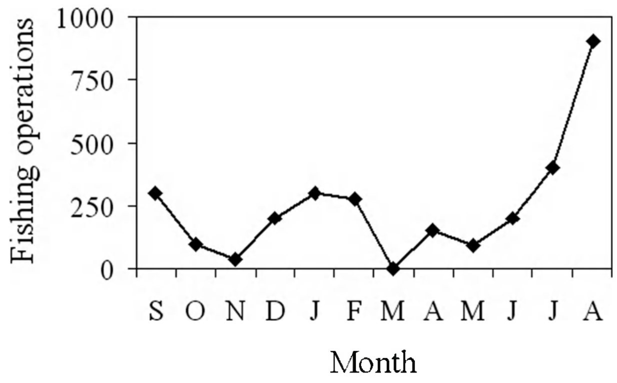

FIG. 2. – Seasonal profile of fishing intensity in the whole study area, reported as number of boats fishing monthly in the 20 1 x 1 km UTM quadrats from Ciutadella to Cala Galdana.

Experimental fishing

Stormy weather hindered experimental fishing in February, when only four experimental sites were sampled. Conversely, all the experimental sites were sampled successfully in November, May and July. Although the composition of the catch fluctuated seasonally (Fig. 3), most of the 1944 fish caught belonged to three species: 1453 to *C. julis*, 215 to *D. annularis* and to 115 *S. scriba*. The remaining 161

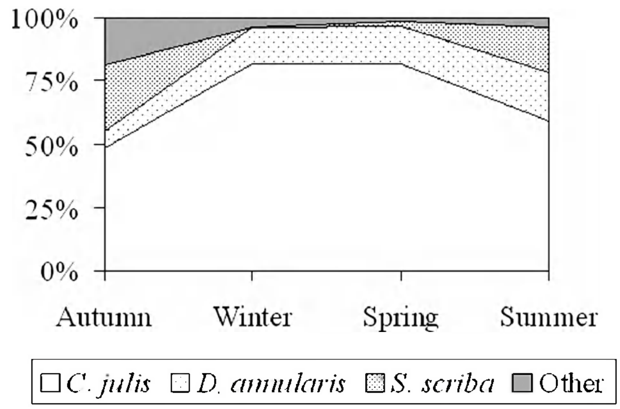

FIG. 3. – Seasonal changes in the composition of catch as revealed by experimental fishing.

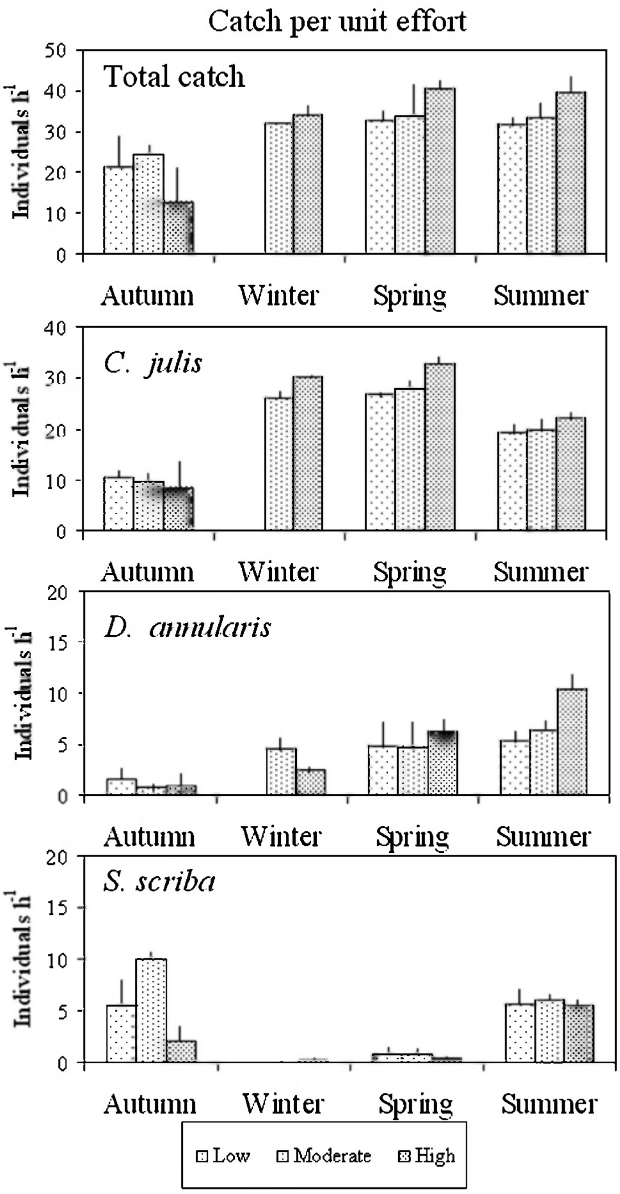

FIG. 4. – CPUE in four different seasons at the three considered levels of fishing intensity. Vertical bars show standard deviation.

TABLE 1. – Effects of the level of fishing intensity and season on the CPUE. Summary of the two-way ANOVAs. Mean and standard deviations values are shown in Figure 4. Bold type denote significance levels <0.05. SS: Sum of Squares; df: degrees of freedom; MS: Mean Square.

Source of variation	SS	df	MS	F	p	r^2
Total catch						
Model	0.7130	10	0.0731	5.098	**0.001**	0.718
Intensity	0.0156	2	0.0079	0.543	0.589	
Season	0.5250	3	0.1750	12.210	**<0.001**	
Intensity x season	0.1970	5	0.0394	2.747	**0.048**	
Error	0.2870	20	0.0143			
Total	67.884	31				
C. julis catch						
Model	1.2750	10	0.1280	10.1750	**<0.001**	0.836
Intensity	0.0013	2	0.0006	0.0520	0.9490	
Season	1.2170	3	0.4060	32.3780	**<0.001**	
Intensity x season	0.0500	5	0.0100	0.798	0.5640	
Error	0.2510	20	0.0125			
Total	53.264	31				
D. annularis catch						
Model	2.3490	10	0.2350	4.5410	**0.002**	0.694
Intensity	0.0347	2	0.0174	0.3350	0.719	
Season	2.1170	3	0.7060	13.6450	**<0.001**	
Intensity x season	0.1920	5	0.0385	0.7430	0.600	
Error	1.0340	20	0.0517			
Total	15.660	31				
S. scriba catch						
Model	3.8230	10	0.3820	20.1790	**<0.001**	0.910
Intensity	0.2430	2	0.1220	6.4190	**0.007**	
Season	2.9790	3	0.9930	52.4150	**<0.001**	
Intensity x season	0.3260	5	0.0652	3.4440	**0.021**	
Error	0.379	20	0.0189			
Total	12.359	31				

specimens (Fig. 3) belonged to nine other species (*Boops boops*, *Chromis chromis*, *Diplodus vulgaris*, *Oblada melanura*, *Pagrus pagrus*, *Seriola dumerili*, *Serranus cabrilla*, *Spondyliosoma cantharus* and *Symphodus tinca*).

Two-way ANOVA, followed by a post hoc Student-Newman-Keuls test, revealed a strong seasonality for the total CPUE, with a statistically significant interaction term between the season and the level of fishing intensity (Table 1). This is because the total CPUE decreased everywhere in autumn, but such a reduction was more intense at those sites exposed to the highest level of fishing intensity (Fig. 4). The CPUE of *C. julis* and that of *D. annularis* also exhibited a strong seasonal pattern, but without any significant role for the level of fishing intensity (Table 1). A post hoc Student-Newman-Keuls test revealed that the CPUE of both species was lower in autumn than in any other season. Conversely, the CPUE of *S. scriba* was significantly affected by both the season and the level of fishing intensity, with a significant interaction term (Table 1). This is because the CPUE of *S. scriba* peaked in summer and autumn, but in autumn the CPUE of *S. scriba* was lower at the sites exposed to the highest fishing intensity than at the other sites (Fig. 4). Differences between treatments were not statistically significant in the other three seasons, as revealed by a post hoc Student-Newman-Keuls test.

The specimens with the terminal phase coloration (TPC) represented 84% of the overall catch of *C. julis* and those exhibiting the initial phase coloration (IPC) the remaining 16%. The total length of the IPC *C. julis* ranged from 8.9 to 14.8 cm and that of the TPC *C. julis* ranged from 11.0 to 18.7 cm. The

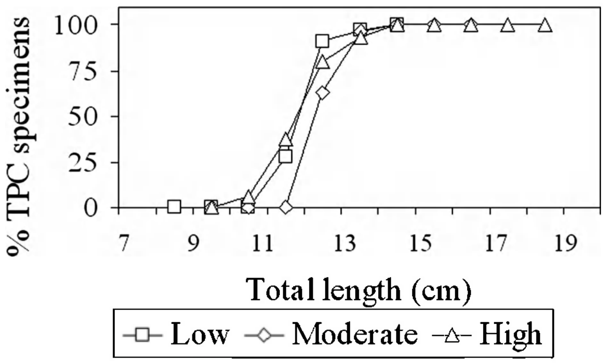

FIG. 5. – Relationship between total length and the percentage of specimens of *C. julis* with the TPC coloration at three different levels of fishing intensity.

relationship between total length and coloration was not affected by the level of fishing intensity, as no evidence of earlier shifting from the IPC to the TPC was observed at the most heavily fished sites (Fig. 5). However, the average total length of both type of specimens was smaller in the most heavily fished sites (IPC: 10.7 ± 1.2 cm; TPC: 13.0 ± 0.7 cm) than in those exposed to moderate (IPC: 11.3 ± 0.9 cm; TPC: 13.8 ± 1.0 cm) or low (IPC: 11.2 ± 1.1 cm; TCP: 13.7 ± 1.1 cm) levels of fishing intensity (ANOVA for IPC specimens; $F_{2,290}$ = 8.361; p <0.001; ANOVA for TPC specimens $F_{2,1157}$ = 62.558; p <0.001).

The total length of *S. scriba* ranged from 9.2 to 19.0 cm and the average was slightly smaller in the most heavily fished sites (12.9 ± 2.4 cm) than in those exposed to moderate (13.9 ± 1.9 cm) or low (13.9 ± 2.5 cm) levels of fishing intensity, although differences were not significant statistically (ANOVA; $F_{2,112}$ = 1.969; p = 0.144).

The total length of *D. annularis* ranged from 8.3 to 16.5 cm and the average (12.3 ± 1.5 cm) was unaffected by the level of fishing intensity (ANOVA; $F_{2,212}$ = 0.128; p = 0.880).

Visual censuses

Figure 6 shows average rock cover, sand cover, *P. oceanica* cover and *P. oceanica* density at the experimental sites. The sites exposed to the three

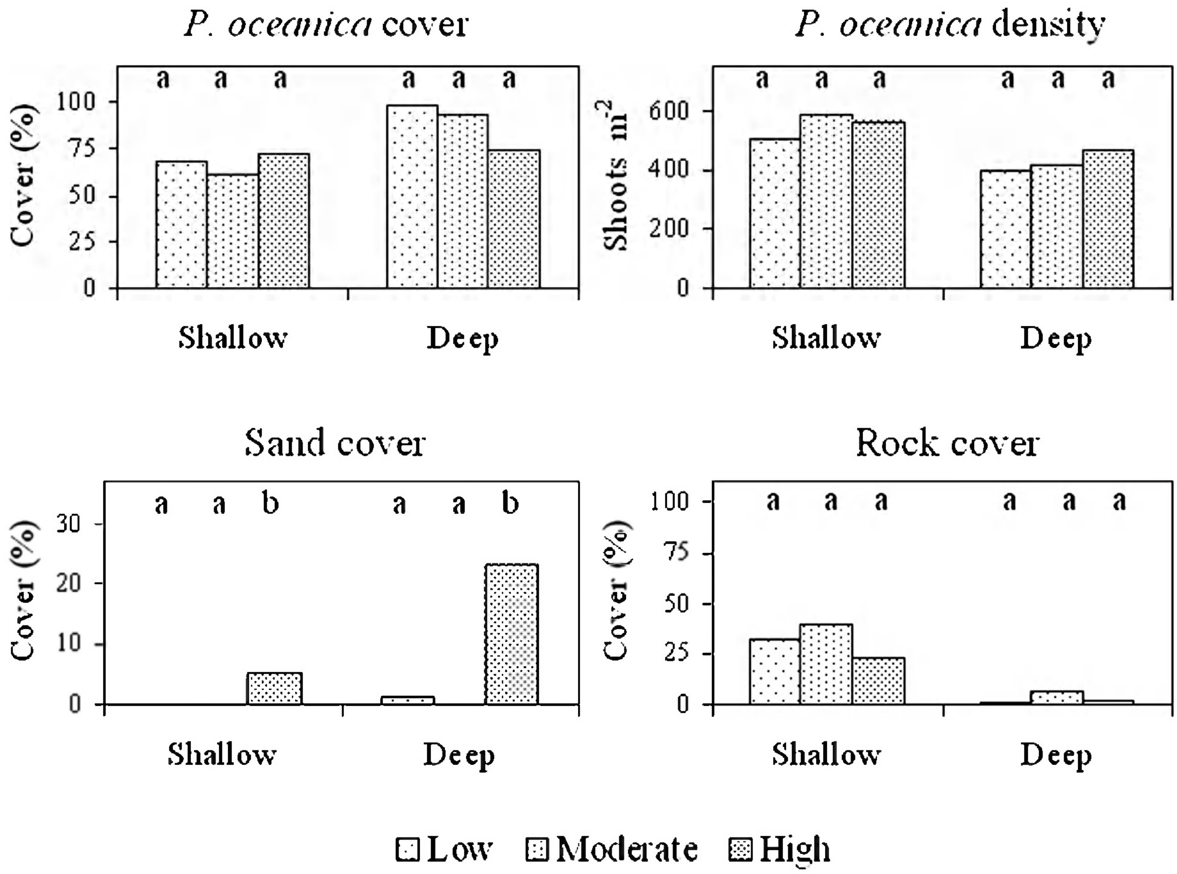

FIG. 6. – Environmental features of the transects from sites differing in the level of fishing intensity. Statistically significant differences exist between values in the same panel and depth with different superscript. Average depth of shallow sites: -7 m. Average depth of deep sites: -19 m.

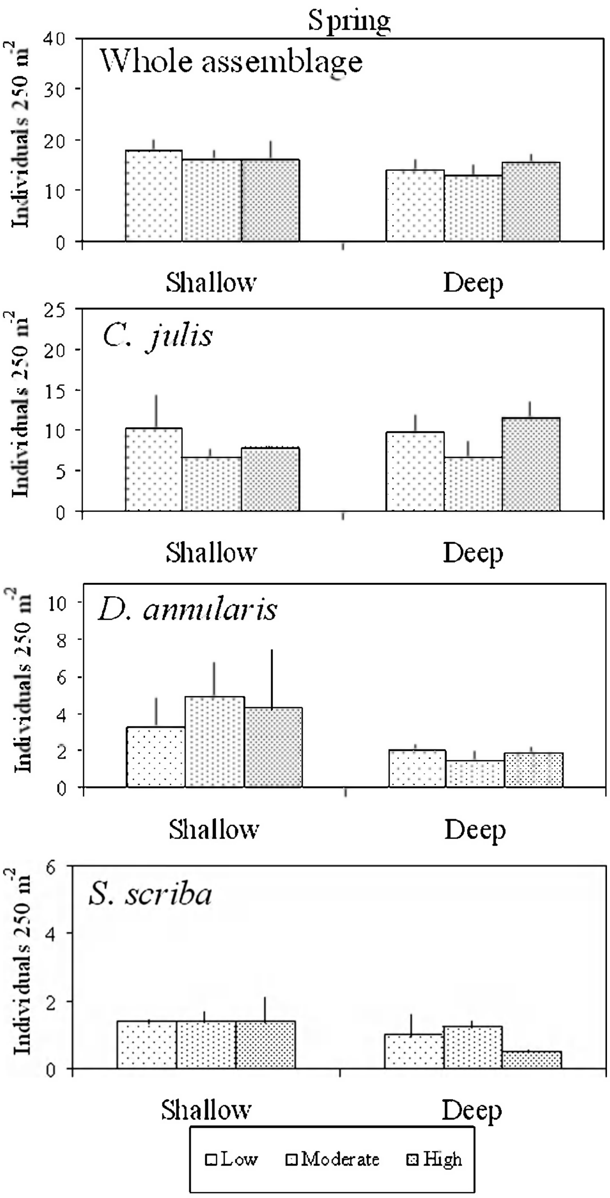

FIG. 7. – Density of vulnerable fish in spring. Vertical bars show standard deviation.

levels of fishing intensity did not differ at any depth in the density of *P. oceanica* (ANOVA –7 m; $F_{2,6}$ = 0.334; p = 0.729; ANOVA –19 m; $F_{2,6}$ = 2.612; p = 0.153), rock cover (ANOVA –7 m; $F_{2,6}$ = 1.233; p = 0.359; ANOVA –19 m; $F_{2,6}$ = 3.867; p = 0.083) or *P. oceanica* cover (ANOVA –7 m; $F_{2,6}$ = 0.674; p = 0.544; ANOVA –19 m; $F_{2,6}$ = 2.612; p = 0.153). However, sand cover was higher at both depths at the most heavily fished sites, as revealed by one-way ANOVA and a post hoc Student-Newman-Keuls test (ANOVA –7 m; $F_{2,6}$ = 27.835; p = 0.001; ANOVA –19 m; $F_{2,6}$ = 8.620; p = 0.017).

TABLE 2. – Effect of depth and the level of fishing intensity on the density of vulnerable fish in spring. Summary of the two-way ANOVAs. Mean and standard deviations values are shown in Figure 7. Bold type denote significance levels <0.05.

Source of variation	SS	df	MS	F	p	r^2
Total density						
Model	0.030	5	0.006	0.705	0.631	0.095
Intensity	0.004	2	0.002	0.211	0.813	
Depth	0.018	1	0.018	2.175	0.166	
Intensity x depth	0.008	2	0.004	0.465	0.639	
Error	0.102	12	0.008			
Total	26.330	18				
C. julis density						
Model	0.081	5	0.016	1.107	0.406	0.030
Intensity	0.032	2	0.016	1.084	0.369	
Depth	0.035	1	0.035	2.376	0.149	
Intensity x depth	0.015	2	0.007	0.495	0.621	
Error	0.176	12	0.015			
Total	17.872	18				
D. annularis density						
Model	0.281	5	0.056	1.115	0.403	0.033
Intensity	0.001	2	0.001	0.015	0.985	
Depth	0.235	1	0.235	4.666	0.052	
Intensity x depth	0.044	2	0.022	0.440	0.645	
Error	0.604	12	0.050			
Total	6.078	18				
S. scriba density						
Model	0.098	5	0.020	1.436	0.280	0.114
Intensity	0.027	2	0.014	0.993	0.399	
Depth	0.052	1	0.052	3.835	0.074	
Intensity x depth	0.019	2	0.009	0.680	0.525	
Error	0.164	12	0.014			
Total	2.071	18				

Two-way ANOVA revealed that the density of vulnerable fish in spring (Fig. 7) was not affected by depth or the level of fishing intensity (Table 2). However, in autumn (Fig. 8), the vulnerable fish were scarcer at the deepest sites, regardless of the level of fishing intensity (Table 3). A similar pattern was observed for the density of vulnerable *C. julis* (Figs. 7 and 8), although a significant interaction term between depth and level of fishing intensity occurred in autumn (Tables 2 and 3). This is because at shallow sites the density of vulnerable *C. julis* decreased with increasing fishing intensity, whereas at deep sites the lowest density was recorded at intermediate levels of fishing intensity. The density of vulnerable *D. annularis* (Fig. 7 and Fig. 8) was unrelated to the depth or the level of fishing intensity in any season (Tables 2 and 3). Finally, the depth and the level of fishing intensity affected the density of vulnerable *S. scriba* in autumn (Fig. 8 and Table 3), but not in spring (Fig. 7 and Table 2). A significant interaction term was found in autumn because the relationship between the density of vulnerable *S. scriba* and fishing intensity was opposite at shallow and deep sites.

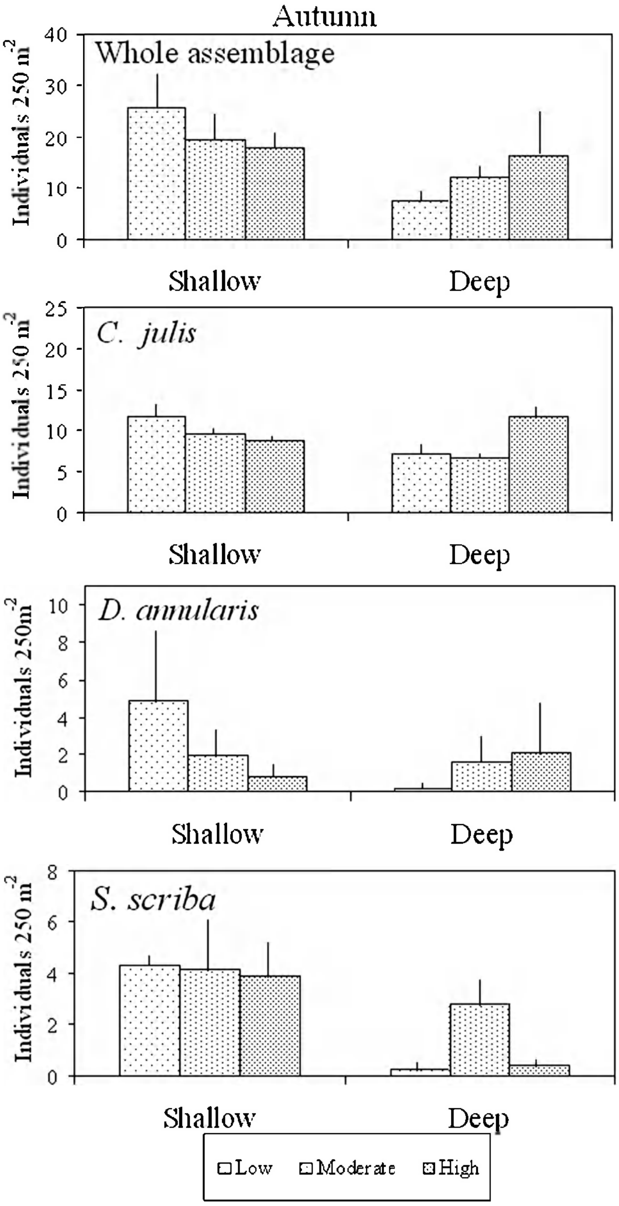

FIG. 8. – Density of vulnerable fish in autumn. Vertical bars show standard deviation.

TABLE 3. – Effect of depth and the level of fishing intensity on the density of vulnerable fish in autumn. Summary of the two-way ANOVAs. Mean and standard deviations values are shown in Figure 8. Bold type denotes significance levels <0.05.

Source of variation	SS	df	MS	F	p	r^2
Total density						
Model	0.442	5	0.088	4.473	**0.016**	0.505
Fishing intensity	0.017	2	0.009	0.434	0.658	
Depth	0.283	1	0.283	14.292	**0.003**	
Intensity x depth	0.142	2	0.071	3.602	0.060	
Error	0.237	12	0.020			
Total	26.529	18				
C. julis density						
Model	0.140	5	0.028	3.303	**0.042**	0.404
Fishing intensity	0.027	2	0.013	1.583	0.245	
Depth	0.027	1	0.027	3.217	0.098	
Intensity x depth	0.086	2	0.043	5.065	**0.025**	
Error	0.102	12	0.008			
Total	18.056	18				
D. annularis density						
Model	0.489	5	0.098	1.108	0.406	0.031
Fishing intensity	0.026	2	0.013	0.147	0.865	
Depth	0.150	1	0.150	1.705	0.216	
Intensity x depth	0.313	2	0.156	1.771	0.212	
Error	1.059	12	0.088			
Total	3.733	18				
S. scriba density						
Model	1.255	5	0.251	14.471	**<0.001**	0.798
Fishing intensity	0.191	2	0.095	5.498	**0.020**	
Depth	0.809	1	0.809	46.661	**<0.001**	
Intensity x depth	0.255	2	0.127	7.348	**0.008**	
Error	0.208	12	0.017			
Total	5.545	18				

DISCUSSION

A fish assemblage including about 40 species inhabits the meadows of *P. oceanica* off the Balearic Archipelago (Massutí, 1965; Grau *et al.*, 1993; Reñones *et al.*, 1995), but only three species (*C. julis*, *D. annularis* and *S. scriba*) represent the bulk of the catch of the recreational fishery (Morales-Nin *et al.*, 2005; this study). This is because most of these species (Gobidae, Gobiesocidae, Syngnathidae and most Labridae) have mouth gapes that are too small to be caught with the hooks regularly used in the fishery. Large labrids, like *Labrus viridis* and *Labrus merula*, have larger mouth gapes and were caught regularly at the beginning of the 20th century (Ferrer, 1914), but are currently too scarce to make any relevant contribution to the fishery. Nocturnal (Scorpaenidae), herbivorous (*Sarpa sarpa*) and pelagic (*Boops boops*, *Chromis chromis*, *Oblada melanura*, *Spicara maena,* and *Spicara smaris*) species are seldom caught, despite their abundance and large mouth gape, because recreational fishing is a diurnal activity off the Balearic Archipelago. Polychaetes are usually used as bait and the hooks are deployed across the meadow canopy and not in the water column (Cardona, unpublished data). Finally, Sparidae other than *D. annularis* and *S. sarpa* and Serranidae other than *S. scriba* are caught in low numbers, despite being diurnal carnivores with large mouth gapes, just because they are too scarce in the meadows (Reñones *et al.*, 1995; this study) to represent a high contribution to the fishery.

Reduced density and reduced average length are two typical signals of intense exploitation in fish populations (Jennings *et al.*, 2001) and both were encountered in the *P. oceanica* meadows off Minorca, thus demonstrating the capacity of a recreational fishery targeting abundant species to impact them. However, the response of each species to increasing fishing pressure depended on its life history and other species-specific traits.

Underwater census and experimental fishing revealed that *S. scriba* is the species exhibiting the sharpest decline with increasing fishing intensity, although pattern is significant only in autumn. Furthermore, this reduction is stronger at the deepest sites, where most fishing operations are concentrated, as boats avoid areas shallower than 10 m because they are too close to the rocky seashore. The seasonality of the response to increasing levels of fishing intensity may be because of the limited dispersal capacity of *S. scriba* (Harmelin, 1987) and the extremely high fishing intensity in summer, when the mortality rate at the most heavily fished sites is probably much higher than the possible new incomings by immigration. Fishing mortality decreases throughout the winter and the spring, due to the low level of activity of the fishery and the low catch rate of *S. scriba*. The absence of significant differences in the total length of *S. scriba* from sites exposed to different levels of fishing intensity is in contrast with the results reported by Harmelin *et al.* (1995) for the closely related *Serranus cabrilla*. This suggests that adult fish are not so sedentary as commonly thought and also reshuffle throughout the winter and the spring. As a consequence, the differences in density generated throughout the previous summer probably vanish due to the arrival of new recruits and new immigrants from less heavily exploited areas.

C. julis is also a sedentary species (Harmelin, 1987) and a response similar to that of *S. scriba* might be expected. However, evidence for an autumn reduction in CPUE or density, as the level of fishing increases, is weak and restricted to the shallow sites. Conversely, the level of fishing intensity dramatically affects the average length of *C. julis*, as both IPC and TPC specimens are shorter at the most heavily fished sites. The sensitivity of the average size of TPC specimens to the level of fishing intensity had already been reported (Harmelin *et al.*, 1995), but not that of the IPC ones. Such size differences indicate that the consequences of fishery mortality are not compensated for by immigration from adjoining sites. The absence of significant differences in the density of vulnerable *C. julis* is probably an artifact caused by the difficulty of censing this species visually in seagrass meadows, as diet analysis indicates that most of the population remains under the canopy while foraging (De Pirro *et al.*, 1999 but see Harmelin-Vivien and Francour, 1992). *C. julis* CPUE does not reflect the actual variations in density within the range here considered, as several fish cluster around the bait immediately after deployment (Cardona, personal observation) and the line is hauled once one of them is hooked. This was not true for *S. scriba*, which is much more solitary than *C. julis* and is hooked as the bait moves across the canopy towed by the drifting boat.

The experimental design failed to identify any effect of fishing on *D. annularis*, as size, density and CPUE did not change with fishing intensity. Interestingly, *D. annularis* is the only one of the three species by-caught by professional fishermen when operating in the *P. oceanica* meadows off Ciutadella in autumn and winter. However, previous studies had reported a much higher density of several *Diplodus* species inside marine reserves than in adjoining areas open to fishing (Sánchez Lizaso *et al.*, 2000 and references herein; Cardona *et al.*, 2007). All the species in the genus *Diplodus* are highly mobile (Harmelin, 1987) and hence constant reshuffling of specimens between experimental sites is expected unless they are separated by a distance larger than the fish home range or by unsuitable habitats. Most of the marine reserves where the abundance of *Diplodus* species increased after the prohibition of fishing satisfied at least one of those two requirements (Francour *et al.*, 2001 and references herein; Cardona *et al.*, 2007), but this was not true in the present study, because the *P. oceanica* meadow is continuous from Ciutadella to Cala Galdana and experimental sites differing in the level of fishing intensity are only a few kilometres apart. As a consequence, the absence of differences between sites differing in the level of fishing intensity cannot be considered to demonstrate the absence of any effect of the fishery and further studies at a larger scale are needed. Previous studies on the structure of fish assemblages in *P. oceanica* meadows have not considered the seasonality of the recreational fishery as a factor for explaining the seasonal changes in the structure of the assemblage. Francour (2000), for instance, attributed the smaller seasonal variations in the abundance of fish in meadows inside marine protected areas to a higher density of *Serranus* species, as they prey mainly on young fish and hence buffer the effects of variable seasonal recruitment events. However, the possible role of fishing seasonality outside marine reserves was ignored.

In conclusion, recreational fishing in the *P. oceanica* meadows has a relevant impact at least on the most sedentary species, although changes are obvious only at the end of the fishing season and vanish quickly in winter and spring. That seasonal pattern should be kept in mind by researchers studying the fish assemblages inhabiting *P. oceanica* meadows, particularly those attempting to document any reserve effect.

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