Fish assemblages of an artificial reef in *Posidonia oceanica* (L.) Delile, 1813 meadow off the southern Balearic Islands (western Mediterranean)

O. Reñones[1], J. Moranta[2], J. Coll[2] and I. Moreno[2]

[1] Centro Oceanográfico de Baleares. Instituto Español de Oceanografía. Apdo. 291. Palma de Mallorca (Islas Baleares), Spain
[2] Departamento de Biología Marina. Universitat de les Illes Balears. Ctra. de Valldemossa, km 7,500. 07071 Palma de Mallorca (Islas Baleares), Spain

ABSTRACT

The fish assemblage associated with an artificial reef composed of small blocks (12 m³) with high structural complexity set in a Posidonia oceanica *(L.) Delile, 1813 meadow has been studied for 2 years by means of visual censuses. The fish assemblage was dominated qualitatively by species with medium home ranges living in the surrounding areas of the blocks (mainly Labridae species), and numerically by schooling mid water species. After 38 months of deployment the progressive colonisation of species living on the blocks and the surrounding areas was still ongoing. The colonisation process interacts with seasonal changes, and no clear variations in the fish community variables were observed. The type of block used and the situation of the reef seem inappropriate to the aims for which it was deployed.*

Key Words: Artificial reefs, fish assemblage, Balearic Islands, western Mediterranean.

RESUMEN

Comunidad íctica de un arrecife artifical sobre pradera de *Posidonia oceanica* (L.) Delile, 1813 en las islas Baleares (Mediterráneo occidental).

La evolución de la comunidad íctica de un arrecife artificial situado sobre pradera de Posidonia oceanica *(L.) Delile, 1813 y formado por pequeños bloques (12 m³) de gran complejidad estructural se ha estudiado mediante censos visuales durante dos años. Cualitativamente la comunidad íctica está dominada por especies con desplazamientos medios que viven en las proximidades de los módulos (principalmente lábridos) y cuantitativamente por especies gregarias que se distribuyen en la columna de agua. A los 38 meses del fondeo del arrecife aun se observa la colonización de los bloques por especies que viven en sus proximidades o sobre los mismos. El proceso de colonización interacciona con las variaciones estacionales, no observándose una tendencia clara en los parámetros poblacionales. El tipo de módulo utilizado y la localización del arrecife no parecen ser apropiados para la consecución de los objetivos perseguidos en su inmersión.*

Palabras clave: Arrecifes artificiales, comunidad íctica, islas Baleares, Mediterráneo occidental.

INTRODUCTION

Artificial reefs, as well as marine reserves, have been proposed as tools for managing the littoral areas of the Mediterranean. The deployment of artificial reefs began in the 1970s with the aim of protecting habitats having particularly high biodi-

versity (e.g. *Posidonia oceanica* (L.) Delile, 1813 meadows or maërl communities) from illegal trawling, and consequently, enhancing small-scale fisheries in the surrounding areas. They have also been proposed as a potential solution to overexploitation of nearshore fishery resources and to increase production in areas with limited habitat and/or food resources. A large diversity of block types have been deployed under different environmental conditions for the attainment of these goals (e.g. Relini and Moretti, 1986; Anon., 1989; Ody, 1990; Spanier *et al.*, 1990; Guillén *et al.*, 1994; Gómez-Buckley and Haroun, 1994; Falace and Bressan, 1995; Marinaro, 1995; Riggio, 1995; Santaella and Revenga, 1995).

In spite of the large number of artificial reefs created, information regarding the associated fish fauna in relation to oceanographic conditions of the area, block type, and their location, as well as the extent of their success, is relatively limited (Bregliano and Ody, 1985; Anon., 1989; Charbonel, 1990; Spanier *et al.*, 1990; D'Anna *et al.*, 1994; Bayle-Sempere, Ramos-Esplá and García-Charton, 1994; Bombace *et al.*, 1994; Fabi and Fiorentini, 1994; Moreno *et al.*, 1994a,b; Ody and Harmelin, 1994; Relini, Relini and Torchia, 1994).

In the Balearic Islands, four artificial reef areas were established in 1989, with the double goal of protecting the deeper edge of the *Posidonia oceanica* seagrass bed and increasing biomass in the area (Moreno *et al.*, 1994b). The present study reports on a study of the fish assemblage associated with one of these artificial reefs and its evolution during a two-year period. The reef is located in an oligotrophic area of the western Mediterranean (Formentera Island) and it is composed of small blocks with high structural complexity.

MATERIAL AND METHODS

Study site

The artificial reef is located at a depth of 30 m in a *Posidonia oceanica* meadow (38° 41' 45'' N, 1° 30' 00'' E) about 1.1 km off the north coast of Formentera Island (Balearic Islands, Western Mediterranean) (figure 1).

The sea floor in the area has a gentle slope with bare sand substrate from the coastline to a depth of approximately 15 m. From this depth to 35 m, there is a well conserved *Posidonia oceanica* seagrass bed.
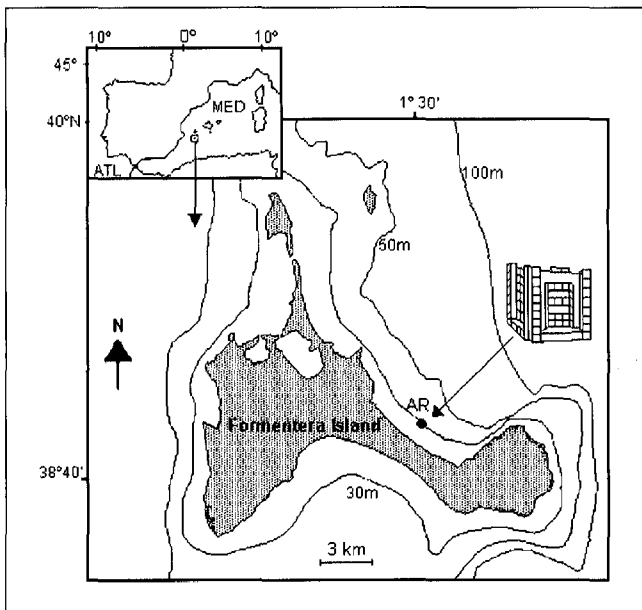

Figure 1. Localisation of the artificial reef (AR) off Formentera Island (Balearic Islands, western Mediterranean) and type of blocks used in thereef construction

Reef description

The artificial reef was deployed in July 1990. It is composed of 48 concrete blocks, 2 m high, with a base of 2.5×2.5 m², weighing 5.5 t (figure 1) and arranged in groups of 4 to 6. The distance between groups is variable, fluctuating between 30 and 70 m. The whole reef covers a rectangular area of 28 435 m². Each block face has numerous cavities, from 15×15 cm² to 100×20 cm², which are, in some instances, connected to the hollow central space defined by the block's four sides.

According to Moreno *et al.* (1994a), the benthic coverage of the blocks increased slowly during the first two years after deployment, remaining constant afterwards. The benthic community was basically formed of: algae, sponges, hydrozoans, polychaetes, bryozoans and tunicates. The most persistent group was the polychaetes, which appeared at a very early stage of colonisation; the tunicates appeared at the end of the first year, and molluscs and echinoderms appeared rather late, 2 years after deployment.

In spite of the 3-year fishing ban imposed by the European Union, the reef was fished during the period of the study by the small-scale fisheries. The main methods used were bottom long-line and trammel and gill nets. Therefore, all the results obtained in the present study must be considered as a product of fished artificial reefs.

Sampling techniques

The fish assemblages were surveyed by scuba-diving following standardised procedures (Harmelin-Vivien *et al.*, 1985) during February, May and September, from September 1991 to September 1993. The census was carried out in two steps. First, the fish wandering around and over the block within a radius of 2 m were sampled without disturbing them from a position as far from the block as possible. Then, the cavities and crevices of the block were closely examined

to detect small, cryptic and sedentary species. Fish abundance, by size class, was recorded using a pre-established abundance scale (following a geometric progression of base 2). Three size classes have been considered –small, medium and large, each encompassing one-third of the maximum size of the species according to Fisher, Bauchot and Schneider (1987).

Visual censuses were carried out between 10-14 h GMT, in days with underwater horizontal visibility greater than 20 m. During each sampling period, between 10-14 blocks without structural deformations and situated on a homogeneous substrate and benthic community (*P. oceanica*) were sampled.

Data analysis

Each block sampled was considered as a replica in each sampling event for data analysis.

Following Ody and Harmelin (1994), each fish species was assigned to one of four categories, taking into account its spatial distribution as well as its relation to the reef: category 1: cryptic and sedentary species, which take a stationary position inside the block or on the bottom around it; category 2: species with a medium home range, living in the proximity of the blocks; category 3: species with a relatively wide home range, moving throughout the reef area. These categories correspond to the spatial categories 6, 5 and 3 respectively, described by Harmelin (1987) for the rocky littoral bottoms of the Mediterranean. Here, also, a fourth category was considered for surface and midwater fishes that show a swarming response to the reef (category 4).

As proposed by Blondel (1979) cumulative species richness curves were constructed to test the reliability of the species richness estimates. The curve is obtained by calculating the mean values of this parameter for each possible combination of n blocks.

The mean species richness, mean abundance, and Shannon-Wiener diversity index were calculated for each sampling period. Linear regression analysis was used to study the effect of time since deployment on the species richness and abundance of spatial categories. The possible presence of seasonal variations, in each separate year, was examined using the non-parametric tests Kruskal-Wallis and Mann-Whitney, because the assumptions of parametric tests were not met (Zar, 1984). The size distribution of each species category was compared between different seasons using the χ^2 text. A significance level of $p < 0.05$ was used in all data analysis.

Table I. Mean species abundance per block (± standard error) in each sampling. For each species the number of its category is given

Family	Species	Sep. 91	Feb. 92	May 92	Sep. 92	Feb. 93	May 93	Sep. 93
Muraenidae	1 *Muraena helena*		0.3 ± 0.19	0.2 ± 0.11	0.2 ± 0.10	0.1 ± 0.09	0.2 ± 0.15	0.1 ± 0.09
Serranidae	2 *Serranus cabrilla*	1.6 ± 0.22	1.6 ± 0.15	1.3 ± 0.14	1.0 ± 0.11	1.4 ± 0.32	0.8 ± 0.15	1.2 ± 0.26
	2 *Serranus scriba*	0.7 ± 0.16	1.0 ± 0.63	0.8 ± 0.32	0.4 ± 0.18	1.2 ± 0.50	2.1 ± 0.50	1.2 ± 0.35
	2 *Epinephelus costae*	0.2 ± 0.13			0.2 ± 0.10	0.2 ± 0.15		0.1 ± 0.09
	2 *Epinephelus caninus*				0.1 ± 0.07	0.2 ± 0.10		
	2 *Epinephelus marginatus*	0.2 ± 0.13			0.2 ± 0.10		0.4 ± 0.21	0.2 ± 0.12
Apogonidae	1 *Apogon imberbis*	0.5 ± 0.22	2.1 ± 0.61	2.1 ± 0.47	2.4 ± 0.46	2.5 ± 0.68	1.7 ± 0.43	5.2 ± 1.02
Carangidae	4 *Seriola dumerili*		17.3 ± 8.93			3.1 ± 3.04	26.9 ± 18.45	10.5 ± 7.40
Sciaenidae	2 *Sciaena umbra*		0.9 ± 0.81	0.3 ± 0.13	0.5 ± 0.31	0.1 ± 0.09	0.3 ± 0.13	1.3 ± 0.79
Mullidae	3 *Mullus surmuletus*	1.0 ± 0.79		0.1 ± 0.08	0.3 ± 0.17	0.2 ± 0.15		0.5 ± 0.37
Sparidae	3 *Diplodus annularis*	0.3 ± 0.15	0.1 ± 0.09	0.7 ± 0.22	0.7 ± 0.24	0.3 ± 0.12	0.2 ± 0.10	1.5 ± 0.78
	3 *Diplodus puntazzo*				0.2 ± 0.12	0.6 ± 0.33	0.2 ± 0.12	0.5 ± 0.37
	3 *Diplodus sargus*	0.4 ± 0.22	0.1 ± 0.09		0.3 ± 0.31	0.4 ± 0.22	0.7 ± 0.40	3.0 ± 1.47
	3 *Diplodus vulgaris*	2.8 ± 0.74	1.4 ± 0.62	2.1 ± 0.51	1.7 ± 0.43	4.5 ± 1.49	0.8 ± 0.37	2.5 ± 1.60
	3 *Spondyliosoma cantharus*	4.0 ± 4.00		0.1 ± 0.08	0.1 ± 0.08			0.4 ± 0.36
Centracanthidae	4 *Spicara maena*	8.0 ± 3.10				10.8 ± 10.35	0.1 ± 0.08	1.8 ± 1.82
	4 *Spicara smaris*	39.1 ± 34.65				5.3 ± 1.38	5.8 ± 5.77	3.6 ± 3.64
Pomacentridae	4 *Chromis chromis*	45.4 ± 7.04	80.5 ± 11.93	64.8 ± 12.95	101.5 ± 17.58	105.4 ± 11.32	94.9 ± 15.19	59.0 ± 10.54
Labridae	2 *Labrus bimaculatus*			0.1 ± 0.08				
	2 *Labrus merula*	0.3 ± 0.21	0.6 ± 0.20	0.4 ± 0.19	0.2 ± 0.12	0.1 ± 0.09	0.4 ± 0.14	0.2 ± 0.12
	2 *Labrus viridis*	0.3 ± 0.15	0.3 ± 0.19		0.2 ± 0.12	0.2 ± 0.15	0.6 ± 0.18	0.8 ± 0.18
	2 *Coris julis*	9.3 ± 1.67	14.6 ± 1.81	17.4 ± 2.17	20.0 ± 2.42	24.5 ± 2.33	16.4 ± 1.62	38.5 ± 5.06
	2 *Symphodus rostratus*	0.2 ± 0.13	0.3 ± 0.14	0.6 ± 0.19	0.3 ± 0.13	0.5 ± 0.13	1.0 ± 0.34	0.3 ± 0.19
	2 *Symphodus doderleini*	0.1 ± 0.10	0.3 ± 0.14	0.5 ± 0.19	0.7 ± 0.17	0.5 ± 0.17	0.5 ± 0.18	0.5 ± 0.28
	2 *Symphodus mediterraneus*	0.9 ± 0.38	1.1 ± 0.37	2.6 ± 0.38	2.1 ± 0.43	2.1 ± 0.45	2.5 ± 0.48	2.8 ± 0.54
	2 *Symphodus melanocercus*	0.9 ± 0.41	0.4 ± 0.15	0.6 ± 0.15	1.2 ± 0.36	0.9 ± 0.30	1.5 ± 0.18	1.1 ± 0.28
	2 *Symphodus ocellatus*			0.5 ± 0.19				3.9 ± 1.56
	2 *Symphodus tinca*	3.7 ± 1.02	5.7 ± 1.81	2.8 ± 0.61	1.5 ± 0.40	7.2 ± 1.62	3.4 ± 0.56	1.7 ± 0.59
	2 *Thalassoma pavo*							0.1 ± 0.09
Gobiidae	1 *Gobius auratus*				0.3 ± 0.21		0.1 ± 0.08	
	1 *Gobius cruentatus*			0.1 ± 0.08		0.1 ± 0.07	0.1 ± 0.08	
	1 *Gobius geniporus*				0.2 ± 0.10	1.5 ± 1.38	0.2 ± 0.10	
	1 *Gobius vittatus*			0.3 ± 0.31			0.1 ± 0.08	
	1 *Gobius* sp.		0.9 ± 0.72					0.1 ± 0.09
Blenniidae	1 *Parablennius rouxi*			0.1 ± 0.08	0.5 ± 0.22	0.5 ± 0.24	0.1 ± 0.08	2.2 ± 0.54
Tripterygiidae	1 *Tripterygion delaisi*			0.3 ± 0.19	0.9 ± 0.27	0.4 ± 0.17	1.5 ± 0.29	1.4 ± 0.49
Scorpaenidae	1 *Scorpaena porcus*					0.1 ± 0.07		
	1 *Scorpaena scrofa*		0.3 ± 0.14	0.1 ± 0.08	0.2 ± 0.10	1.0 ± 0.23	0.6 ± 0.27	

RESULTS

The species composition of the fish assemblage and the mean abundance per block in each sampling time are given in table I. The values of the ecological variables calculated for each sampling occasion are given in table II. In all the samplings, we observed a high qualitative and quantitative variability in the fish assemblage, associated with the different blocks sampled (tables I and II).

Thirty-eight species belonging to 14 families were observed. Of these, 28.9 % belonged to category 1; 44.7 % to category 2; 15.8 % to category 3; and 10.5 % to category 4. While the surface and mid water species were the most species-poor, they quantitatively dominated the assemblage with 51-80 % of the total abundance (table II). More specifically, the planktophagous species, *Chromis chromis* (Linnaeus, 1758), was the most abundant in every sampling occasion. Category 2, formed by species living in proximity to the blocks, was the second most abundant category, representing between 14.5-40 % of the total (table II). *Coris julis* (Linnaeus, 1758) and *Symphodus tinca* (Linnaeus, 1758) accounted for a large proportion of this category.

The most abundant species in category 3 was *Diplodus vulgaris* (Goffrey Saint-Hilarie, 1817) and *Apogon imberbis* (Linnaeus, 1758) in category 1.

The number of samples in the various sampling periods was adequate to describe the different assemblages, as shown by the cumulative species richness curves (figure 2). The differences between these curves suggest an increase in the number of species per block as the age of reef increase. Similarly, species diversity shows a clear increase after the first three surveys.

The number of species per block increased significantly ($F = 34.94$; $p < 0.0005$) with time since deployment (figure 3a). This increase was due mainly to the colonisation of blocks by small cryptic species (table I). Abundance followed a different trend, depending on the category. Only the abundance of categories 1 and 2 increased significantly ($F = 30.50$; $p < 0.0005$ for the category 1; $F = 43.55$; $p < 0.0005$ for the category 2) with time (figure 3b,c), although the variability was high (determination coefficient: 27 % and 34.7 % for categories 1 and 2, respectively).

The comparison of category 1 abundance estimate revealed significant differences between September and the other two sampling seasons, each year being analysed separately ($p < 0.001$); however these seasonal differences could not be separated from those due to time since deployment. Significant seasonal differences were obtained in 1993 for categories 2 ($H_{14,13,11} = 13.49$; $p < 0.002$) and 3 ($H_{14,13,11} = 10.37$;

Table II. Mean values per block (± standard error) of species richness (S), total abundance, abundance of each category, Shannon-Wiener diversity index (H') and number of blocks sampled in each sampling (n)

|	Sep. 91	Feb. 92	May 92	Sep. 92	Feb. 93	May 93	Sep. 93
Mean S	9.9 ± 0.60	9.5 ± 0.49	11.2 ± 0.51	11.6 ± 0.46	11.9 ± 0.57	12.9 ± 0.65	13.4 ± 0.73
Maximum S	12	12	14	14	15	17	17
Munimum S	7	7	8	9	8	10	9
Abundance	119.1 ± 33.89	129.7 ± 13.99	99.6 ± 12.60	138.2 ± 17.71	172.1 ± 18.07	163.9 ± 21.18	145.9 ± 12.45
Category 1	0.5 ± 0.22	3.6 ± 1.25	2.8 ± 0.64	4.9 ± 0.44	6.1 ± 1.53	4.4 ± 0.59	8.9 ± 0.94
Category 2	17.9 ± 1.99	26.8 ± 2.39	29.0 ± 2.61	28.5 ± 2.47	39.1 ± 2.84	30.0 ± 2.36	53.8 ± 5.28
Category 3	8.2 ± 4.75	1.6 ± 0.59	3.0 ± 0.66	3.3 ± 0.65	6.0 ± 1.50	1.9 ± 0.66	8.3 ± 3.08
Category 4	92.5 ± 34.50	97.8 ± 14.24	64.8 ± 13.44	101.5 ± 15.58	120.8 ± 17.56	127.6 ± 21.69	74.9 ± 13.91
H'	1.85 ± 0.18	1.65 ± 0.14	1.83 ± 0.16	1.60 ± 0.16	1.72 ± 0.12	1.64 ± 0.11	2.31 ± 0.11
n	10	11	12	13	14	13	12
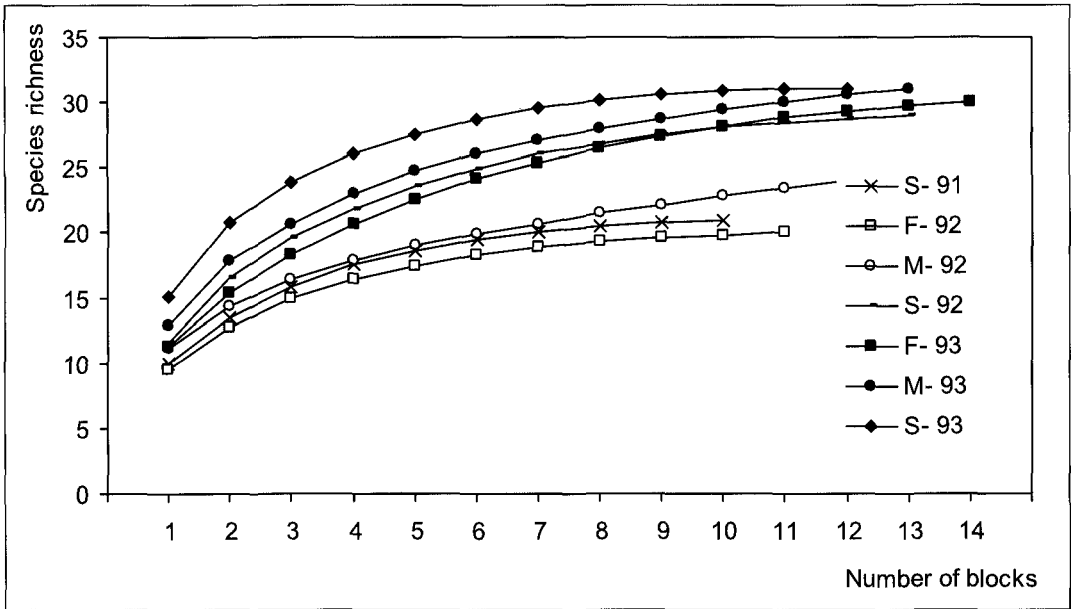
Figure 2. Cumulative species richness curves for each sampling

p < 0.05). Both categories were less abundant during May than on the other two sampling occasions. No significant differences were found for the abundance of category 4, or for total abundance.

Size distribution

Significant differences in the size distribution were obtained among seasons for the different categories (p < 0.05). The medium-size class was the most frequent modal class for all categories. In 1993 the size distributions in February for categories 1, 2 and 3, and in September for category 2, were dominated by the small class (figure 4). Also a difference in the size distribution was obtained in May for category 1, where the large size class was the most frequent (figure 4).

The small-size class for category 1 was composed by young individuals of *Gobius geniporus* Valenciennes, 1837 and, to a lesser degree, by recruits (less than 2 cm total length) of *Apogon imberbis* and *Tripterygion delaisi* Cadenat and Blanche, 1971. For category 2, this size class was composed by juveniles of *Coris julis, Symphodus ocellatus* Forsskal,1775, *Symphodus mediterraneus* (Linnaeus, 1758) and *Symphodus melanocercus* (Risso, 1810) (ordered in decreasing abundance). The small size class of category 3 was composed mainly by juveniles of *Diplodus vulgaris* and, in a lesser proportion, by *Diplodus puntazzo* (Cetti, 1777) and *Diplodus annularis* (Linnaeus, 1758).

DISCUSSION

The fish assemblage observed at the artificial reef was essentially the same as those previously described, for the same depth strata, from rocky littoral bottoms with photophilic algal communities in other areas of the Balearic Islands (García-Rubíes, 1993; Moranta, Reviriego and Coll, 1997; Reñones *et al.*, 1997). About 73.6 % of the species observed are also characteristic of the fish assemblages of *P. oceanica* meadows (Bell and Harmelin-Vivien, 1982; Harmelin-Vivien, 1984; Francour, 1991; Reñones *et al.*, 1995), over which the blocks were situated, whereas 23.7 % were more strictly associated with rocky areas.

A

$y = 7.10 + 0.167x$
$R = 0.55$
$n = 84$

Number of species per block

B

$y = -2.54 + 0.26x$
$R = 0.52$
$n = 84$

Abundance of Category 1

C

$y = 3.14 + 1.10x$
$R = 0.59$
$n = 84$

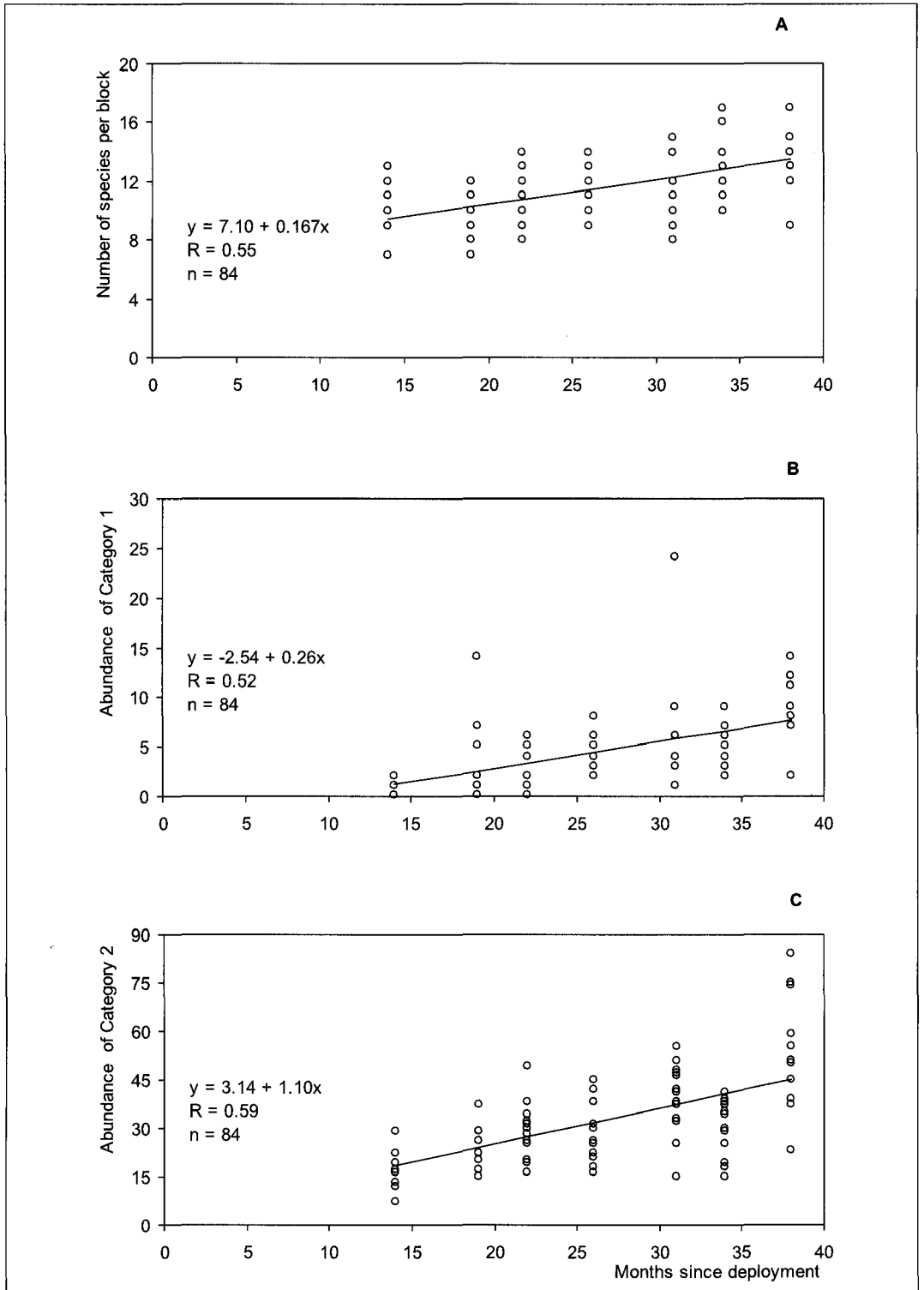Abundance of Category 2

Months since deployment

Figure 3. Linear regressions of time since deployment against: number of species per block (A); abundance of category 1 (B); and abundance of category 2 (C)
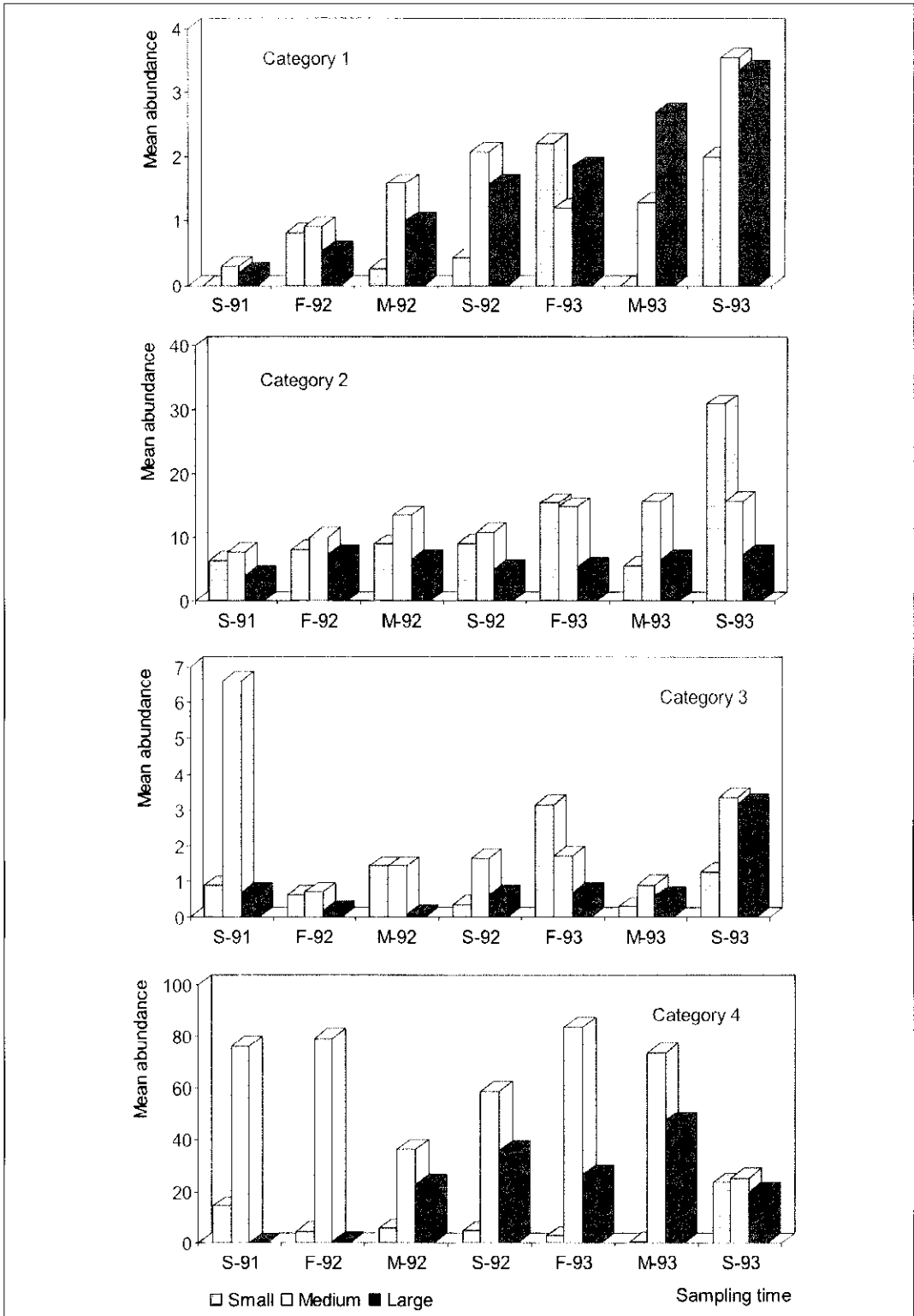
Figure 4. Size distribution of the species from categories 1, 2, 3 and 4 for each sampling

The assemblage was dominated by species that live in the proximity of the blocks (mainly Labridae) and by small, sedentary species living on the blocks. The planktophagous sedentary and the mesophagous species, *C. chromis* and *C. julis* respectively, were the most abundant during all of the sampling periods. Moreover, other pelagic species, such as the piscivorous *Seriola dumerili* (Risso, 1810) and the planktophagous *Spicara smaris* (Linnaeus, 1758) and *Spicara maena* (Linnaeus, 1758) were also abundant in some sampling periods, with a high variability in their abundance due to their migratory or erratic behaviour (Harmelin, 1987). The dominance, in number of individuals, of a few common species is a general pattern in the fish assemblages of artificial reefs (sampled with visual censuses) in the Mediterranean (Charbonel, 1990; Bayle-Sempere, Ramos-Esplá and García-Charton, 1994; Relini, Relini and Torchia, 1994). On the other hand, the species that were distributed throughout the reef area (mainly Sparidae species) were poorly represented qualitatively and quantitatively.

The results obtained in the present study show that almost all the species from the surrounding seagrass bed had colonised the blocks within 14 months after its deployment. The rocky species showed different colonisation speeds, wich could be related to the utilization of the blocks (e.g. feeding habitat, shelter) as well as to the home range of the species. Predator species, such as *Muraena helena* Linnaeus, 1758 and the genus *Epinephelus* target species of the small-scale and sport fisheries, were present from the beginning of the study, although in low abundance. However *A. imberbis, T. delaisi, Parablennius rouxi* (Cocco, 1833) and the species of the genus *Gobius*, small criptic mesophagous species belonging to category 1, arrived later to the blocks and markedly increased in abundance during the sampling period. The association of these species with hard substrates has been attributed to their sheltering behaviour, considered as an adaptation to avoid predation (Wilkins and Myers,

1992, 1993). Their feeding habits (Zander, 1982; Zander and Berg, 1984) and small home range suggest that their presence and increase in abundance may be a result of the higher availability of food due to the progressive development of the algal cover and sessile fauna that occurs on the blocks (Moreno *et al.*, 1994a), which therefore provide suitable habitats for their preys and protection for themselves.

The colonisation process was still ongoing at the end of the study, not only for the rocky species but also for species that came from the surrounding seagrass bed, which increased in abundance over the last year of the study. This overall increase was partially due to the higher abundance of young-of-the-year individuals of some species. This increase can not be attributed to a decrease in piscivorous species, which were never abundant on the blocks. As for category 1 species, the development of the benthic community and food resources were the main factors that enhanced the establishment of juveniles on the blocks. The importance of algal cover in the structure of fish assemblages, and more especially for small size species and juveniles, has been documented in natural and artificial habitats in the Mediterranean Sea (Spanier *et al.*, 1990; D'Anna *et al.*, 1994, Relini, Relini and Torchia, 1994; García-Rubíes and Macpherson, 1995) and in other temperate and tropical areas (Shulman, 1984, 1985; Bodkin, 1986; Carr, 1989; Danner, Wilson and Schlotterbeck, 1994).

The colonisation process interacts with seasonal variability in assemblage structure. This may be the reason why no clear seasonal variations of the assemblage descriptive variables were observed. The most striking feature was a change in the abundance of some species related to their reproductive behaviour, recruitment event and the arrival of youngs-of-the-year. One of the species that showed a clear seasonal variation in its abundance was *S. tinca*, wich gathered at the blocks in February to spawn.

The results of the specific composition and relative abundance of species of categories 1, 2 and 3 differs from those record-

ed for other artificial reefs located in nearby protected areas of the Western Mediterranean, at similar depths (Charbonel, 1990; Bayle-Sempere, Ramos-Esplá and García-Charton, 1994; Ody and Harmelin, 1994; Relini, Relini and Torchia, 1994). The lower abundance of these species, in particular those of category 1, at observed at reefs with protected status could be due to the higher abundance of predators normally found in protected areas. However, it is also probable that these differences are due to some extent to the type of reef structure, which determines the relative abundance of larger or smaller fish. Hixon and Beets (1989) provided evidence that small-hole reefs (such as the blocks deployed at Formentera Island) maintain a higher number of small fish than the large-hole reefs (the type of blocks used at the other artificial reefs cited). This was attributed to the specific shelter selection of small-size species (Anderson, De Martini and Roberts, 1989; Wilkins and Myers, 1993) and negative interaction between larger shelters and small fish, due to the increase in predation (Randal, 1963; Shulman, 1984, 1985, Hixon and Beets, 1989). Therefore, this type of block seems to enhance the increase in biomass of small species, juveniles and recruits.

However the presence of recruits in the artificial reef was limited by depth because the majority of the species observed recruit in shallower areas (García-Rubíes and Macpherson, 1995; Harmelin-Vivien, Harmelin and Leboulleux, 1995). Only recruits of species with a wider and deeper distribution (García-Rubíes and Macpherson, 1995) such as *C. julis, S. mediterraneus, S. melanocercus, C. chromis* and *A. imberbis*, were observed in the blocks or the surrounding area.

Nevertheless, the majority of the species arrived at the reefs as subadults or adults. Our observations of recruits (less than 2 cm total length) at a deeper depth than previously reported for these species in other Mediterranean areas could be due to the deeper distribution of photophilic benthic communities in the Balearic Islands (Ballesteros *et al.*, 1993).

Underwater observations carried out during the 2 years of the study have shown that the design and situation of the reef were inappropriate to the aims for which it was deployed. It could not prevent illegal trawling in the area, and in fact, parts of the blocks were broken by the impact of the trawlers' otter boards. In addition, the small surface occupied by the reef, compared with the area to be protected, as well as the lack of rocky areas between the coastline and the reef, makes trawling in shallow depths possible. The results of the present study, and more specific studies addressing the evaluation of the influence of block design on the structure of fish assemblages (Shulman 1984; Anderson, De Martini and Roberts, 1989; Hixon and Beets, 1989), show that small-hole blocks enhance the presence of small individuals, but the depth at which the reef is deployed is a limiting factor for the production of biomass based on an increase in recruit survival. As in other Mediterranean areas, the availability of rocky littoral habitats in the Balearic Islands is not a limiting factor for fish production. The main factor to be considered is overexploitation, a problem that has not been resolved by artificial reefs.

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