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Short communication

Observations on fish colonization and predation on two artificial reefs in the Canary Islands

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Fish populations on two different types of artificial reefs (oceanic and coastal) in the Canary Islands have been studied for several years by means of the Point Count visual census method. A total of 53 species were observed at both reefs. The isolated oceanic reef was associated with benthic rocky bottom species, as well as with a large seasonal influx of small pelagic fish. Also, several predator fish from the nearby sandy bottom biotope became associated with the modules. The increased abundance of predators such as *Synodus* spp. coincided with a dramatic reduction in recruits and juveniles of some commercially and recreationally important fish species.

Keywords: artificial reefs, Canary Islands, colonization, fish, predation.

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Introduction

Various studies have demonstrated the role of refuge size in enhancing the survival rate of prey species and shaping the structure of fish communities of artificial reefs (Alevizon and Gorham, 1989; Okubo and Kakimoto, 1991; Ody and Harmelin, 1994; Carr and Hixon,1995; Grossman *et al.*, 1997). The effects of predation on structure and density of fish communities have been studied in coral reefs by Hixon (1991) and Hixon and Carr (1997). Walsh (1985) demonstrated the importance of artificial reef design and degree of isolation for the survival of fish recruits.

Five artificial reefs have been constructed around the Canary Islands (Haroun and Herrera, 2000). One of these was deployed in March 1991 on a wide stretch of sandy bottom 3.5 km off the southern coast of Gran Canaria. This reef is considered to be oceanic in character. In the summer of 1993, another coastal artificial reef was deployed off the eastern coast of Lanzarote, 300–500 m from the coast and near natural rock. Since deployment, the flora and fauna associated with these reefs have been studied periodically, with special attention being given to the fish community. We present the results of our survey data aimed at gaining a better understanding of the differences in the structure of the fish communities in relation to the role of predators.

Materials and methods

There are three important biotopes in the neighbourhood of the oceanic artificial reef: (a) a rocky coast (0–6 m depth) at 3.5 km distance characterized by an intertidal zone rich in tide-pools; (b) a sandy bottom (6–40 m depth) in the immediate vicinity; and (c) an isolated natural reef (16–20 m depth) at 3 km distance, composed of a rocky platform that protrudes 2–3 m above the surrounding sand substrate. The reef is composed of 85 concrete modules of five different designs (1.2–5 t and 0.8–2 m high) and grouped in five separate sets.

The coastal artificial reef is composed of 35 modules (3.08 m high and 9.2 t) in two separate sets (CR-ZAN and CR-ZAS) at 20–27 m depth and 300–500 m away from other rocky bottoms, including the coast.

Prior to deployment, a study was conducted at the oceanic (Haroun *et al.*, 1994) and coastal sites to establish a baseline for future monitoring. This assessment included oceanographic and scuba surveys of the coastal rocky bottoms and, in the case of the oceanic site, of the nearby sublittoral natural reef.

The sublittoral communities of the two areas were surveyed with scuba equipment and included surveys of both benthic and demersal fishes. Before deployment, fish populations were estimated by Haroun *et al.* (1994) during the period November 1990 to March 1991 using a Visual Fast Count (VFC) method (Kimmel, 1985). After deployment, fish were surveyed using the Point Count method described by Bortone *et al.* (1989) and later modified by Bortone *et al.* (1991) and Falcón *et al.* (1993). We visually surveyed each module as well as the nearby sandy bottom within a radius of 5.6 m. The surveys were made approximately every 2 months at the oceanic artificial reef from December 1991 until February 1995 and annually at the coastal artificial reef.

Results

In the oceanic artificial reef area (including the natural reef and the coastal zone), a total of 58 species have been observed belonging to 32 families (Table 1). Prior to deployment, only 15 species had been observed in the sandy area, where the artificial reef was erected, 17 species in the coastal zone, and 20 species in the natural reef (Haroun *et al.*, 1994). Since deployment, 53 species have been observed on or close to the artificial reef. Only four species that had been observed over the sandy bottom at the site before deployment have not been observed in the area thereafter. All species originally present in the coastal zone were also observed in the artificial reef area, while, so far, observations of only one species have been restricted to the natural reef area.

The development of selected fish species near the oceanic reef modules is presented in Figure 1. Figure 1a shows time series for four species from nearby sandy bottom biotopes, three of which had been observed in the area before deployment (*Xyrichthys novacula*, *Bothus podas*, and *Stephanolopis hispidus*; Table 1). In 1992, one year after the reef had been constructed, these species were still present in relatively high densities of one per module, but they all decreased substantially by the end of 1992 to remain low thereafter. In contrast, the fourth species, *Taeniura grabata* (round stingray) became gradually more associated with the reef modules, especially adult specimens.

The modules functioned as aggregation points for several pelagic species. *Atherina presbyter* (a small pelagic species) was observed seasonally in dense schools (Figure 1b). The annual arrival of new prey fish cohorts seems to attract, with a 1–2 months' time-lag, piscivorous species from the sandy bottom biotope, such as *Trachinus draco* (greater weever), *Synodus saurus*

Table 1. Presence (×)/absence (—) data of fish species by habitat inspected before (CZ: coastal zone; NR: natural reef; SB: sandy bottom) according to Haroun *et al.* (1994) and after deployment of the oceanic reef (OR).

Family	Species	CZ	NR	SB	OR
Triakidae	*M. mustelus*	—	—	×	—
Squatinidae	*S. squatina*	—	—	×	×
Torpedinidae	*T. marmorata*	—	—	—	×
Rajidae	*Raja* sp.	—	—	×	—
Dasyatidae	*D. pastinaca*	—	—	—	×
	T. grabata	—	×	—	×
Myliobatidae	*M. aquila*	—	—	×	—
Synodontidae	*S. saurus*	×	—	×	×
	S. synodus	—	×	—	×
Muraenidae	*G. unicolor*	—	×	—	—
	M. augusti	—	×	—	×
Congridae	*H. longissimus*	—	—	×	×
Serranidae	*M. fusca*	—	—	—	×
	S. atricauda	×	×	×	×
	S. cabrilla	—	—	—	×
Priacanthidae	*H. cruentatus*	—	—	—	×
Apogonidae	*A. imberbis*	×	×	—	×
Carangidae	*P. dentex*	—	—	—	×
	S. dumerili	—	—	—	×
	S. fasciata	—	—	—	×
	S. rivoliana	—	—	—	×
Haemulidae	*P. incisus*	—	—	—	×
Mullidae	*M. surmuletus*	—	—	—	×
Sparidae	*B. boops*	×	×	×	×
	D. cervinus	×	—	—	×
	D. sargus	×	×	—	×
	D. vulgaris	×	×	—	×
	L. mormyrus	×	—	—	×
	P. acarne	—	—	—	×
	P. erythrinus	—	—	—	×
	P. pagrus	—	—	—	×
	S. salpa	—	—	—	×
	S. cantharus	—	×	×	×
Pomacentridae	*A. luridus*	×	×	—	×
	C. limbatus	×	×	—	×
Labridae	*C. trutta*	×	—	—	×
	C. julis	—	—	—	×
	S. mediterraneus	—	—	—	×
	T. pavo	×	×	—	×
	X. novacula	—	—	×	×
Scaridae	*S. cretense*	×	×	—	×
Trachinidae	*T. draco*	—	—	×	×
Scombridae	*S. sarda*	—	—	—	×
Gobiidae	*G. niger*	—	—	—	×
Blenniidae	*P. pilicornis*	—	—	—	×
	O. atlanticus	×	—	—	×
Tripterygiidae	*T. delaisi*	—	—	—	×
Sphyraenidae	*S. viridensis*	—	×	—	×
Atherinidae	*A. presbyter*	—	—	—	×
Scorpaenidae	*S. maderensis*	×	×	—	×
	S. porcus	—	—	—	×
	S. scrofa	—	×	—	×
Bothidae	*B. podas*	—	—	×	×
Soleidae	*S. vulgaris*	—	—	×	—
Balistidae	*B. carolinensis*	—	—	—	×
Monacanthidae	*S. hispidus*	—	×	×	×
Tetraodontidae	*C. rostrata*	×	×	—	×
	S. marmoratus	×	×	×	×
Total	58 spp.	17	20	15	53

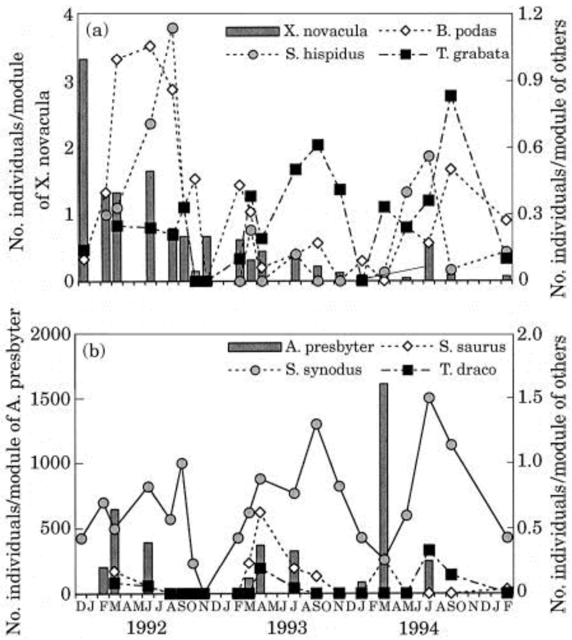

Figure 1. Time series of density of selected species at the oceanic artificial reef: (a) four sandy bottom species; (b) one pelagic (*A. presbyter*) and three benthic piscivorous species.

Table 2. Percentage composition of fish species number by habitat classification for the different artificial reefs (OR: oceanic reef; CR-ZAN, CR-ZAS: subsets of the coastal reef).

	Pelagic	Benthic	Epibenthic
OR	19.7	67.2	13.1
CR-ZAN	11.3	75.5	13.2
CR-ZAS	10.4	79.2	10.4

(green lizardfish), and *Synodus synodus* (brown lizardfish), which broadly follow a similar seasonal pattern.

Table 2 offers a comparison of fish community structure among the three artificial reefs investigated according to the habitat classification of Brito (1991). These data indicate that the oceanic reef attracts a larger proportion of pelagic species.

The total number of species observed at the coastal and oceanic artificial reefs after 2 years was the same (53). Although the average diversity (Shannon index) was higher in the coastal reef set (CR-ZAN and CR-ZAS; Table 3), the maximum diversity observed during a single survey was highest at the oceanic reef (OR). However, the high standard deviations indicate that the differences are not significant. At the CR, the maximum number of species observed during a single survey was 25, whereas up to 35 species were observed at the OR. The shorter distance between the CR and other rocky biotopes perhaps facilitated colonization. At these reefs, the initial population included fingerlings and juveniles from the ichthyoplankton, as well as adult fish that presumably had recruited from the nearby rocky biotope (Table 4).

Table 3. Mean Shannon diversity index, standard deviation (s.d.), and maximum value obtained for a single survey for each artificial reef (for codes, see Table 2) and the natural reef (NR).

	Mean	s.d.	Maximum
OR	2.23	0.86	3.94
CR-ZAN	2.80	0.50	3.32
CR-ZAS	2.77	0.40	3.28
NR	2.26	0.52	2.99

Discussion

Shulman and Ogden (1987) proposed that fish recruitment is largely limited by the availability and survival of larval stages. Another important factor controlling community structure is mortality caused by predation pressure (Williams and Sale 1981; Doherty and Sale, 1985; Sweatman, 1985). Carr and Hixon (1995) indicated that the distribution of coral reef fishes is related to the availability of refuges in the habitat. Also Hixon and Beets (1989), Hixon (1991), and Grossman *et al*. (1997) argued that diversity of refuge size enhanced survival rate of recruits and, therefore, fish productivity. These studies showed that the presence of predators affected the size distribution within populations and the dynamics of colonization. Predation pressure is less evident when predators are non-residents. Our results suggest that the influence of predation on juvenile fish at the isolated artificial reefs was low. The observations at the oceanic artificial reef indicated that piscivorous species such as *Synodus* spp., *Scorpaena maderensis*, and especially *Serranus atricauda* (blacktail comber) with a density of 0.6 individuals per module, are chiefly responsible for reduced survival and, thus, for controlling fish productivity. Migration does not seem to be an important factor. The coastal artificial reef modules did not provide a large number of refuges and these were all of similar size. Mortality at these coastal reefs is presumably high.

A preliminary evaluation of the oceanic artificial reef revealed 34 fish species (Haroun *et al*., 1994). Subsequently, the number of species observed at the reef has increased to 53. Compared to the original fish assemblage of the sandy habitat, the demersal fish community has obviously diversified.

The observations at the oceanic artificial reef offer two main conclusions: (a) some piscivorous species from the nearby sandy biotope aggregate near the modules and (b) other species typical of sandy bottoms decrease in

Table 4. Months elapsed since deployment of the artificial reefs before the first record of fish species from selected families.

Family	Species	Oceanic AR	Coastal (ZAN)	Coastal (ZAS)
Pomacentridae	*A. luridus*	10	18	6
Labridae	*C. julis*	12	6	6
	S. mediterraneus	20	18	18
Tripterygiidae	*T. delaisi*	15	17	6

abundance. Posey and Ambrose (1994) demonstrated that rock-associated predators located at the periphery of artificial reefs may have a strong impact on fish and invertebrate prey inhabiting sandy biotopes in the proximity. This interaction may explain the decline in smaller sand-associated demersal fishes observed here. Moreover, at sites with strong bottom currents, the turbulence caused by the presence of reef modules affects the loosely compacted substrate (e.g. grain-size distribution, organic matter content) and may modify the availability of invertebrate prey. Especially in the coastal artificial reefs, a halo of several metres of coarse sediment was observed around each module. Thus, the decline of sand-associated demersal fish species may be explained by the combined effect of the lack of appropriate prey organisms and of predatory pressure from piscivorous fish species attracted by the modules.

Some authors have noted a relationship between artificial reef communities and those from nearby rocky biotopes. Thus, species richness and fish abundance associated with a reef may be related to the degree of isolation (Gascon and Miller, 1981; Bohnsack *et al.*, 1991; Ody and Harmelin, 1994). Walsh (1985) indicated that more isolated reefs are characterized by higher fish density and species richness. The coastal artificial reefs in the Canary Islands are near rocky biotopes that may serve as donor areas and facilitate colonization. However, the proximity of natural reefs may also facilitate adult emigration, particularly because the simple design of the modules, with only one type of refuge, did not provide a broad range of refuge sizes. Nevertheless, species richness at the isolated oceanic reef appears to reflect a long residence time of fish and a low dispersion rate of adults to distant habitats.

Our results stress the importance of reef site selection in determining future exchange between artificial reef biota and nearby habitats and, thus, its fish production. Besides, module design strongly affects colonization patterns and predation pressure by providing suitable refuges, and thus also determines ultimate community structure.

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