Journal of the Marine Biological Association of the United Kingdom, 2012, 92(7), 1525–1533.
doi:10.1017/S0025315412000136

Recreational fish feeding inside Brazilian MPAs: impacts on reef fish community structure

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Although the practice of recreational feeding of fish by tourists is widespread within marine protected areas (MPAs), the ecological consequences of this activity have received little attention. This research aimed to investigate the influence of artificial feeding on reef fish communities of two Brazilian MPAs. Visual censuses were performed in areas not visited by tourists, in order to characterize the natural community structure of each reef system. In the Maracajaú reefs, the effect of artificial feeding was assessed below a moored floating dock found in the area. Stationary visual censuses were carried out before, during and after the fish feeding activity. In the Maragogi reefs, areas with presence and absence of tourism visitation were established. Transect methodology was employed in each of these areas. On both MPAs, fish feeding was a formal activity and occurred on a daily basis during the course of this study. Within the MPAs, 88 species belonging to 40 families were recorded. In Maracajaú, fish, shrimps and squids were provided by the tourists on the floating dock, which favoured mobile invertebrate feeders, whereas in Maragogi, animal ration and human food were used, causing aggregations of omnivores. Differences were observed in terms of abundance between before and after feeding in Maracajaú and between the control and impacted areas of Maragogi. The data are consistent with fish feeding leading to attraction of determined species, causing an increase in their abundance, also indicating that both the type of food and the extension of activity area are important factors determining the effects on fish communities.

Keywords: reef tourism, artificial feeding, reef impacts, fish trophic categories

Submitted 19 January 2012; accepted 22 January 2012; first published online 3 April 2012

INTRODUCTION

Marine tourism is an increasing activity and comprises several branches of the economy, being considered as the major industry in the world (Wood, 2001). On the Brazilian coast, marine protected areas (MPAs) receive a large number of tourists every year (Ferreira & Maida, 2006). In Abrolhos Marine National Park, considered the most important coral reef formation of the south-western Atlantic, the number of tourists increased 400% in only five years during the late 1980s and early 1990s (Leão, 1994).

The current consensus is that when intensive human recreational activities occur without proper planning and regulation, changes in the ecosystems and organisms are often observed (Creed & Amado Filho, 1999; Eckrich & Holmquist, 2000). It has been shown that implementing protection measures makes marine areas even more attractive to tourists (Badalamenti *et al.*, 2000). Therefore, the purpose of primary importance for any protected area is to take the required management measures (Milazzo *et al.*, 2006). Choosing specific no-take zones for diverse uses should be considered to preserve environmental health and simultaneously educate visitors to ensure MPA sustainability (Herrera-Silveira *et al.*, 2010).

Studies on human recreational activities impacts inside MPAs have usually focused on the impact of diving (Medio *et al.*, 1997; Hawkins *et al.*, 1999; Barker & Roberts, 2004), boat anchorage (Creed & Amado Filho, 1999; Milazzo *et al.*, 2002), human trampling (Eckrich & Holmquist, 2000; Milazzo *et al.*, 2002) and artificial fish-feeding (Milazzo *et al.*, 2006). Concerning the impact of diving, there are some divergences among authors' opinion which vary between negative (Medio *et al.*, 1997) or no effects (Hawkins *et al.*, 1999). However, for the other human activities there is a consensus about their negative consequences. Artificial fish feeding can alter fish behaviour towards humans (Perrine, 1989; Cole, 1994; Sweatman, 1996) and influence the abundance of some species (Cole, 1994). Nevertheless, the ecological consequences caused by this ever-increasing activity have received little attention (Cole, 1994; Sweatman, 1996; Orams, 2002; Milazzo *et al.*, 2005; Ilarri *et al.*, 2008), especially in marine environments.

Learning the extent and causes of the impact inflicted by tourists is important for the viability of MPAs. Therefore, there is an urgent need for understanding the impacts of

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this practice, in order to stimulate improvements in management efforts. The main purpose of our study is to address the influence of artificial feeding on the reef fish community structure of two MPAs (MPA Recife de Corais and MPA Costa dos Corais), evaluating changes of community parameters (abundance, richness and trophic dominance) in the presence of tourists, using different approaches for impact assessment: (a) comparing 'before', 'during' and 'after' artificial feeding periods, where they occur on a specific area using baits; and (b) comparing impacted and control sites, within regular and no visitation areas, respectively, where food items offered consist of animal ration and human food (bread and crackers).

MATERIALS AND METHODS

Study area

The study areas are located inside two MPAs distant nearly 500 km from each other with different geographical and physical characteristics. The multiple use MPA Recife de Corais, on the northern coast of Rio Grande do Norte (Figure 1), covers an area with complex reef types, ranging from beach rocks to shallow and deep coral reefs (Feitosa *et al.*, 2002). Maracajaú reefs (09°02′46.64″S 35°11′49.94″W), comprise an area of approximately 13 km² of ellipsoid-shaped reefs, 7 km off the coast with depths ranging from 1 to 4 m. These reefs are formed by coral pinnacles supported by a shallow sandy base. The main reef builder in this region is the stony coral *Siderastrea stellata* (Verrill, 1868) (Laborel, 1969) with vermetid gastropods and crustose coralline algae providing a great contribution to the reef cover (Maida & Ferreira, 1997; Castro & Pires, 2001). The marine tourism in the Maracajaú reefs occurs on a daily basis. Tourists get to the reefs on motor boats. In those reefs a floating dock is found, where tourists receive information about the local reef environment and snorkelling and SCUBA activities are offered. In addition, tourists can interact with reef fish fauna providing fish baits (fish, shrimps and squids), previously acquired by tourist operator employees from a local fisherman at Maracajaú beach. Fish feeding occurs at the rear steps of the floating dock.

The multiple use MPA Costa dos Corais extends 135 km from the southern coast of Pernambuco to the northern coast of Alagoas State (Figure 1) and constitutes the first and the most extensive Federal Conservation Unit to include coastal reefs in the area of protection (Ferreira & Cava, 2001). The Maragogi reefs (5°23′10.22″S 35°15′32.51″W) are located approximately 3.5 km off the coast and comprise a sandstone bank with a thin framework formed by corals (mainly *Porites* species), calcareous algae

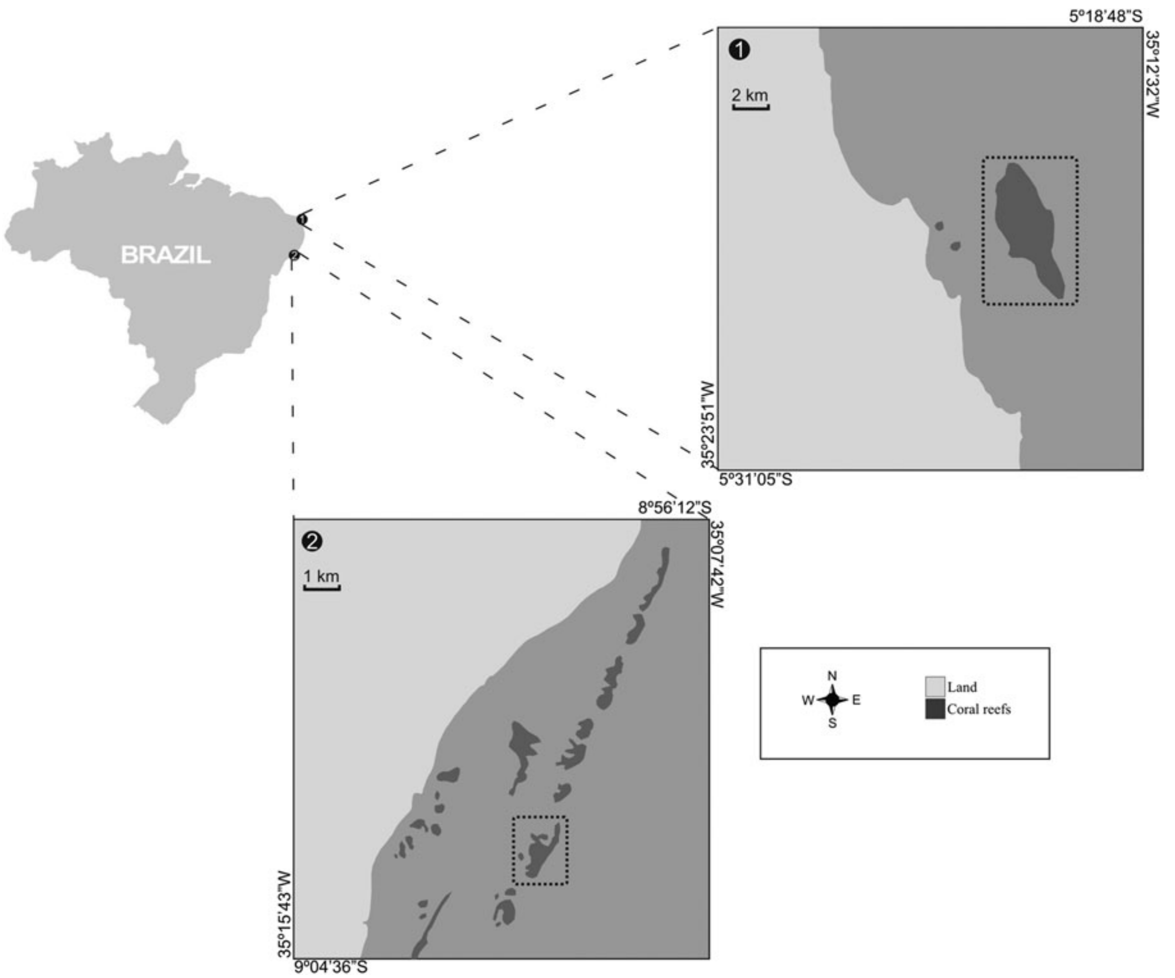

Fig. 1. Location of sampled areas.

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and vermetid molluscs (Laborel, 1969). The marine tourism in the Maragogi reefs also occurs on a daily basis. Through pontoon boats, tourists get to the reefs and receive information about the local reef environment during their journey to the area. Human visiting is concentrated in specific locations at low-tide, delimited with buoys where shallow sandy areas are formed. Fish feeding is random and widespread throughout the visiting area and animal ration or human food (bread and crackers) can be bought at the beach or from other boats at the visiting area.

SAMPLING PROCEDURES

The community structure of reef fish from Maracajaú (MPA Recifes de Corais) was previously assessed by Feitosa *et al.* (2002) and the data were used in this study. Additionally, visual censuses, adapted from Sale & Douglas (1981), were performed using transects of 50 × 4 m, in areas not visited by tourists in the Maragogi reefs. The purpose of these censuses was to characterize the community structure, where a total of 24 surveys were conducted from April 2003 to March 2004.

In Maracajaú, the effect of the artificial feeding was analysed below a floating dock. As it consisted of a small restricted area (nearly 160 m^2), stationary censuses were carried out, with a defined radius of 3 m (Bohnsack & Bannerot, 1986), using SCUBA. The censuses were performed before, during and after the feeding activity. 'Before' sections refer to the observations made at least one hour before the tourists arrived at the floating dock. 'During' sections were assessed while fish were fed. This activity lasted on average for 2.5 hours. Nearly 60 minutes after departure of tourists and consumption of all food by fish the censuses of 'after' sections were carried out. Eight censuses were performed for each treatment, totalling 24 censuses from April 2003 to March 2004. The surveys were made in the morning at low tides and lasted on average for 15 minutes.

As previously mentioned, human visiting in the Maragogi reefs is concentrated in specific locations at low-tide, where, very shallow sandy areas are formed. For the purposes of this research, two reef areas, 200 m apart from each other, being one treatment area (where the activity is common and delimited with buoys) and the other classified as the control area (where no visitation is allowed) were established to assess the effects of fish feeding. Reefs had very similar substratum and depth. Underwater visual census was employed along 50 × 4 m strip transects, modified from Sale & Douglas (1981). Four censuses (two for each area) were conducted per month between December 2003 and March 2004, totalling 16 surveys.

The number of tourists in both MPAs was obtained through the Maracajaú Diver tourism operator and the Recifes Costeiros Project (http://www.recifescosteiros.org) on the same day the visual censuses were performed. In Maracajaú, the first author personally assessed with the local diving operator, which coordinated activities took place on the floating dock. As for Maragogi, data were gathered by the first author with agents of the Recifes Costeiros Project. This project had the main purpose of providing scientific support for the management plan of the MPA Costa dos Corais.

DATA ANALYSIS

Fish abundance data were recorded on plastic sheets and species were later classified in trophic categories according to Ferreira *et al.* (2004) as follows: planktivores, roving herbivores, territorial herbivores, mobile invertebrate feeders, sessile invertebrate feeders, carnivores, piscivores and omnivores.

To analyse the effects of artificial feeding, the most abundant species were compared among treatments. As changes on the fish community within the area of influence of artificial feeding (treatment area) are evident even without any quantification, the most representative species on treatment and control areas were compared. Significant differences of these species would be expected if fish are being attracted by the activity. Data were tested using the Friedman and the Mann–Whitney tests (BioEstat 5.0 software), for the Maracajaú and Maragogi treatments, respectively. A one-way analysis of similarity (ANOSIM) was used to test for significant differences of meaningful groups, considering the total abundance data of all replicates on treatments (Clarke, 1993). Prior to the analysis data were log-transformed (log x + 1). This analysis was conducted using PRIMER 6.0 software.

Spearman correlations were also employed to verify associations between richness and abundance with the number of tourists (BioEstat 5.0 software). Correlations were made between before/during treatments and during/after treatments to verify if there was any change on the community with human presence in situations of no food and the moment after an offer ceased. Both situations were tested separately as in the latter situation food remains were still detected, interfering with results.

RESULTS

Assessing the community structure of the Maracajaú reefs, 34 species belonging to 18 families were recorded. Of these, 22 species belonging to 13 families were recorded under the floating dock (Table 1). The fish community of the Maracajaú reefs was characterized by the high abundance of three species: *Haemulon aurolineatum* Cuvier, 1830 (19.08 ± 3.92), *Stegastes fuscus* (Cuvier, 1830) (6.79 ± 1.34) and *Sparisoma axillare* (Steindachner, 1878) (1.42 ± 0.28). The trophic categories most abundant were mobile invertebrate feeders (32.83 ± 3.75), followed by territorial herbivores (13.92 ± 2.24).

For feeding activity effects, the species *H. aurolineatum*, *Abudefduf saxatilis* (Linnaeus, 1758), *Lutjanus synagris* (Linnaeus, 1758), *S. axillari*, *Ocyurus chrysurus* (Bloch 1791) and *Acanthurus chirurgus* (Bloch, 1787) were considered, as they were abundant and their frequency of occurrence seemed affected by the activity (Table 2). Among species recorded within periods, *H. aurolineatum* was the most abundant, followed by *A. saxatilis* and *Ocyurus chrysurus* (Bloch, 1791) (Table 2). The most common trophic categories in all treatments were mobile invertebrate feeders and omnivores (Figure 2)

The mean abundance with standard error found for before, during and after treatments were 312 ± 62.74, 544.12 ± 51.47 and 582.25 ± 69.63, respectively. The richness with standard error recorded for before, during and after treatments were 8.25 ± 0.41, 12.87 ± 1.18 and 15.62 ± 1.18, respectively. Survey periods presented significant differences for mean abundance and richness (Friedman test; $P = 0.0131$ and $P = 0.0008$; respectively), both with differences

https://doi.org/10.1017/S0025315412000136 Published online by Cambridge University Press

Table 1. Species recorded for assessment of the community structure of the Maracajaú and Maragogi reefs, with respective mean abundance and trophic category.

Family	Scientific name	Trophic category	Maracajaú reefs Abundance ± SE	Maragogi reefs Abundance ± SE
Muraenidae	*Gymnothorax miliaris* (Kaup 1856)	CAR	0.04 ± 0.04	
Synodontidade	*Synodus foetens* (Linnaeus, 1766)	PIS		0.25 ± 0.18
Holocentridae	*Holocentrus ascensionis* (Osbeck, 1771)	MIF	0.33 ± 0.11	0.83 ± 0.30
	Myripristis jacobus (Cuvier in Cuvier and Valenciennes, 1829)	MIF	0.46 ± 0.23	0.92 ± 0.36
Epinephelinae	*Cephalopholis fulva* (Linnaeus, 1758)	CAR	1.42 ± 0.42	3.25 ± 0.80
	Epinephelus ascensionis (Osbeck, 1771)	CAR	0.17 ± 0.07	0.33 ± 0.19
Grammistinae	*Rypticus saponaceus* (Bloch & Schneider, 1801)	CAR	0.04 ± 0.04	
Carangidae	*Carangoides bartholomaei* (Cuvier and Valenciennes, 1833)	CAR	0.04 ± 0.04	
Lutjanidae	*Lutjanus synagris* (Linnaeus, 1758)	MIF	0.04 ± 0.04	
	Ocyurus chrysurus (Bloch, 1791)	MIF	0.29 ± 0.13	
Gerreidae	*Eucinostomus lefroyi* (Goode, 1874)	MIF		0.08 ± 0.08
	Eucinostomus melanopterus (Bleeker, 1863)	MIF	0.13 ± 0.09	0.25 ± 0.18
Haemulidae	*Anisotremus moricandi* (Ranzani, 1840)	MIF		0.33 ± 0.22
	Anisotremus surinamensis (Bloch, 1791)	MIF		0.17 ± 0.11
	Anisotremus virginicus (Linnaeus, 1758)	MIF	2.29 ± 0.38	0.17 ± 0.17
	Haemulon aurolineatum (Cuvier in Cuvier and Valenciennes, 1830)	MIF	19.08 ± 3.92	9.25 ± 5.34
	Haemulon parra (Dasmarest, 1823)	MIF	2.50 ± 0.87	1.17 ± 0.49
	Haemulon plumieri (Lacépède, 1802)	MIF	2.04 ± 0.34	
	Haemulon squamipinna (Rocha and Rosa, 1999)	MIF	4.29 ± 1.13	0.17 ± 0.11
Sciaenidae	*Odontoscion dentex* (Cuvier in Cuvier & Valenciennes, 1830)	MIF	5.96 ± 3.23	0.17 ± 0.17
Mullidae	*Pseudupeneus maculatus* (Bloch, 1793)	MIF	0.46 ± 0.23	0.58 ± 0.43
Chaetodontidae	*Chaetodon striatus* (Linnaeus, 1758)	SIF	0.13 ± 0.07	0.42 ± 0.23
Pomacentridae	*Abudefduf saxatilis* (Linnaeus, 1758)	OMN	3.04 ± 0.89	2.92 ± 0.87
	Microspathodon chrysurus (Cuvier, 1830)	TERH	0.17 ± 0.13	0.08 ± 0.08
	Stegastes fuscus (Cuvier in Cuvier and Valenciennes, 1830)	TERH	6.79 ± 1.34	45.42 ± 8.85
	Stegastes variabilis (Castelnau, 1855)	TERH	0.46 ± 0.28	0.25 ± 0.13
Labridae	*Bodianus rufus* (Linnaeus, 1758)	MIF		1.17 ± 0.44
	Halichoeres brasiliensis (Bloch, 1791)	MIF	0.54 ± 0.20	2.17 ± 0.56
	Halichoeres penrosei (Starks, 1913)	MIF	0.21 ± 0.15	0.08 ± 0.08
	Halichoeres poeyi (Steindachner, 1867)	MIF	0.29 ± 0.15	1 ± 0.46
Scaridae	*Scarus trispinosus* (Valenciennes 1840)	ROVH	2.46 ± 1.02	
	Scarus zelindae (Moura, Figueiredo & Sazima, 2001)	ROVH	0.63 ± 0.24	0.58 ± 0.43
	Sparisoma amplum (Ranzani, 1842)	ROVH		0.58 ± 0.29
	Sparisoma axillare (Steindachner, 1878)	ROVH	1.42 ± 0.28	0.75 ± 0.22
	Sparisoma frondosum (Agassiz, 1831)	ROVH	2.58 ± 0.52	
Labrisomidae	*Labrisomus nuchipinnis* (Quoy & Gaimard, 1824)	CAR	0.13 ± 0.10	
Bleniidae	*Ophioblennius trinitatis*	TERH	0.13 ± 0.09	
Gobiidae	*Coryphopterus glaucofraenum* (Gill, 1863)	MIF		1.5 ± 0.75
Acanthuridae	*Acanthurus bahianus* (Castelnau, 1855)	ROVH	0.08 ± 0.06	0.67 ± 0.33
	Acanthurus chirurgus (Bloch, 1787)	ROVH	6.29 ± 1.40	0.08 ± 0.08
	Acanthurus coeruleus (Bloch and Schneider, 1801)	ROVH	0.46 ± 0.17	0.33 ± 0.19

CAR, carnivores; MIF, mobile invertebrate feeders; PLK, planktivores; PIS, piscivores; OMN, omnivores; TERH, territorial herbivores; ROVH, roving herbivores; SE, standard error.

only between 'before' and 'after' periods. For trophic categories, difference was only detected for mobile invertivores (Friedman test; $P = 0.0183$), also for 'before' and 'after' periods. The fish community composition did not differ between 'before', 'during' and 'after' feeding treatments (ANOSIM; $R = 0.124$, $P = 0.44$).

The effect of fish feeding was evident immediately after the treatment: the correlations between the number of tourists 'before' and 'during' treatment were highly significant for total abundance and richness (Spearman; $r = 0.579$, $P = 0.0148$ and $r = 0.6079$, $P = 0.0096$, respectively). After 1 hour (correlations between during and after treatments), the abundance and richness did not change (Spearman; $r = -0.1741$, $P = 0.504$ and $r = 0.2883$, $P = 0.2617$, respectively), indicating that the food offer effect remains within the activity area for some time after the tourists departed (Figure 3).

In the Maragogi reefs, 31 species belonging to 21 families were recorded. All species were recorded during the censuses in the treatment and control areas (Table 1). The fish community of the Maragogi reefs is characterized by the high abundance of three species: *Stegastes fuscus* (45.42 ± 8.85), *Haemulon aurolineatum* (9.25 ± 5.34) and *Cephalopholis fulva* (Linnaeus, 1758) (3.25 ± 0.80) (Table 1). The trophic category most abundant were territorial herbivores (45.75 ± 8.82), followed by mobile invertebrate feeders (19.83 ± 5.44) (Figure 2).

Among species recorded for the treatment area, the most abundant were *A. saxatilis* (296 ± 151.43) and *S. fuscus* (64.62 ± 8.74), the latter being also the most abundant in the control area (76.5 ± 4.88) and the former, rarely detected (2 ± 1.13) (Table 2). Other species not present in the treatment area, such as *Anisotremus surinamensis*, *Carangoides*

Table 2. Species mean abundance (±SE) and frequency of occurrence (F%) among treatments in the Maracajaú and Maragogi reefs.

Species	Maracajaú reef						Maragogi reef			
	Before	F%	During	F%	After	F%	Control	F%	Treatment	F%
Abudefduf saxatilis	34.71 ± 4.73	100	29.29 ± 4.52	100	25.85 ± 2.9	100	2 ± 1.13	50	296 ± 151.43	87.5
Acanthurus bahianus	–	–	–	–	–	–	–	0	0.375 ± 0.25	25
Acanthurus chirurgus	3.14 ± 2.01	71.43	0.29 ± 0.18	28.57	0.14 ± 0.14	14.29	–	–	–	–
Acanthurus coeruleus	–	–	–	–	–	–	–	0	0.5 ± 0.31	25
Anisotremus moricandi	–	–	–	–	–	–	–	–	0.25 ± 0.15	25
Anisotremus surinamensis	–	–	–	–	–	–	0.125 ± 0.12	12.5	–	–
Anisotremus virginicus	–	–	–	–	0.14 ± 0.14	14.29	–	–	0.13 ± 0.12	12.5
Bodianus rufus	–	–	–	–	–	–	0.25 ± 0.15	25	0.38 ± 0.25	25
Carangoides bartholomaei	–	–	–	–	–	–	0.13 ± 0.12	12.5	–	–
Cephalopholis fulva	–	–	0.43 ± 0.3	28.57	0.14 ± 0.15	14.29	2.5 ± 0.5	87.5	2.5 ± 0.4	100
Chaetodon striatus	–	–	–	–	0.14 ± 0.16	14.29	–	0	0.13 ± 0.12	12.5
Coryphopterus glaucofraenum	–	–	–	–	–	–	0.13 ± 0.12	12.5	0.63 ± 0.47	25
Dasyatis marianae	–	–	–	–	0.14 ± 0.17	14.29	–	–	–	–
Decapterus macarellus	–	–	1 ± 1	14.29	–	–	–	–	–	–
Epinephelus ascensionis	–	–	0.14 ± 0.14	14.29	–	–	0.25 ± 0.15	25	0.13 ± 0.12	12.5
Eucinostomus gula	–	–	–	–	–	–	0.13 ± 0.12	12.5	0.13 ± 0.12	12.5
Eucinostomus lefroyi	–	–	0.14 ± 0.14	14.29	–	–	0.13 ± 0.12	12.5	–	–
Eucinostomus melanopterus	–	–	–	–	–	–	0.25 ± 0.23	12.5	–	–
Haemulon aurolineatum	280 ± 66.33	100	507.14 ± 56.09	100	557.14 ± 75.93	100	0.13 ± 0.12	12.5	0.63 ± 0.47	25
Haemulon parra	–	–	0.14 ± 0.14	14.29	–	–	1.75 ± 1.13	50	0.38 ± 0.17	37.5
Haemulon plumieri	1.14 ± 0.26	85.71	2 ± 0.38	100	1.57 ± 0.37	85.71	–	–	–	–
Haemulon squamipinna	–	–	–	–	–	–	0.38 ± 0.25	25	–	–
Halichoeres brasiliensis	–	–	–	–	0.43 ± 0.3	28.57	2.25 ± 0.46	100	1.75 ± 0.66	75
Halichoeres poeyi	–	–	0.14 ± 0.14	14.29	0.14 ± 0.14	14.29	1.75 ± 0.55	75	4.63 ± 0.97	100
Holocentrus ascensionis	0.29 ± 0.29	14.29	0.29 ± 0.18	28.57	0.14 ± 0.15	14.29	1.75 ± 0.34	87.5	0.63 ± 0.25	50
Lutjanus synagris	0.43 ± 0.43	14.29	1.14 ± 0.55	57.14	1 ± 0.69	42.86	–	–	–	–
Mugil curema	–	–	0.86 ± 0.86	14.29	0.14 ± 0.14	14.29	–	–	–	–
Myripristis jacobus	–	–	–	–	0.14 ± 0.15	14.29	0.63 ± 0.25	50	0.13 ± 0.12	12.5
Ocyurus chrysurus	5.29 ± 1.51	100	8.86 ± 2.49	85.71	2.86 ± 1.83	42.86	–	–	–	–
Pseudupeneus maculatus	–	–	0.14 ± 0.14	14.29	0.29 ± 0.18	28.57	0.25 ± 0.23	12.5	0.25 ± 0.15	25
Selar crumenophthalmus	–	–	7.14 ± 7.14	14.29	–	–	–	–	–	–
Sparisoma amplum	–	–	–	–	–	–	0.38 ± 0.25	25	–	–
Sparisoma axillare	0.43 ± 0.2	42.86	–	–	0.14 ± 0.14	14.29	0.38 ± 0.25	25	1.25 ± 0.42	62.5
Sparisoma frondosum	0.43 ± 0.3	28.57	0.57 ± 0.37	28.57	0.29 ± 0.18	28.57	–	–	–	–
Stegastes fuscus	–	–	–	–	–	–	76.5 ± 4.88	100	64.62 ± 8.74	100
Stegastes variabilis	–	–	–	–	–	–	0.13 ± 0.12	12.5	0.25 ± 0.15	25

SE, standard error.

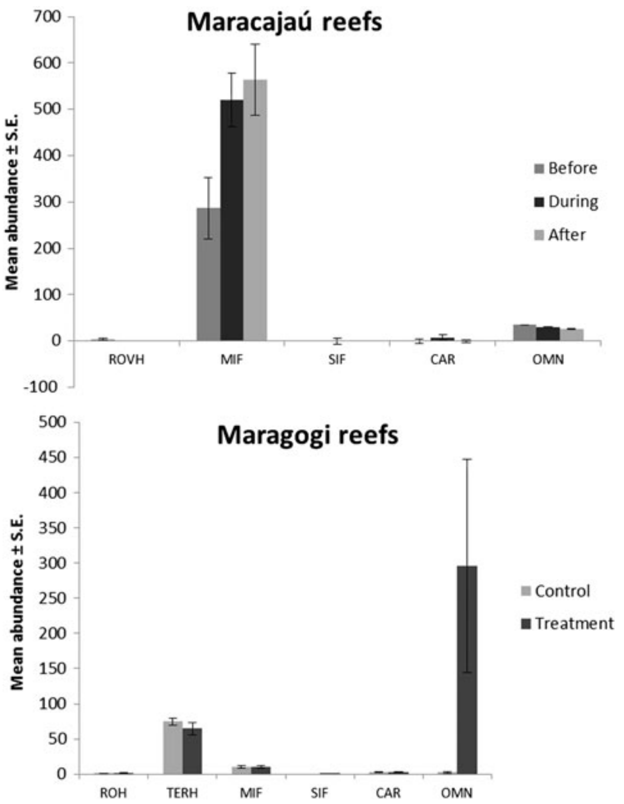

Fig. 2. Mean abundance with standard error (SE) of each trophic category presented in Maracajaú and Maragogi reefs.

bartholomei, *Eucinostomus melanopterus* and *E. lefroyi* could be considered as occasional species as they presented low frequencies (around 12%) and only few individuals were recorded in the control area. *Sparisoma amplum* which attained 25% of frequency also presented low abundance in the control area, preventing us making further assumptions concerning the effects of fish feeding.

A significant difference for fish total abundance between control and treatment areas was observed (Mann–Whitney; $P = 0.0027$), however this difference was not detected for richness ($P = 0.372$). As a consequence of the most abundant species, the most common trophic category in the control area was territorial herbivores (74.71 ± 4.85) and mobile invertebrate feeders (10.28 ± 1.64). In the treatment area, the omnivores (296 ± 151.42) and territorial herbivores (64.87 ± 8.79) predominated. Although there was a minor decrease on mean abundance of territorial herbivores on treatment areas, testing trophic categories between control and treatment areas showed that only omnivores were significantly different (Mann–Whitney; $P = 0.046$), especially for *A. saxatilis*. Changes were also confirmed when the fish community structure was significantly different between control and treatment areas, forming two distinct groups (ANOSIM; $R = 0.436$, $P = 0.005$).

The relationship between the number of tourists and total abundance and richness in Maragogi was similar to the Maracajaú reefs, where the number of tourists altered only abundance (Spearman; $r = 0.8454$, $P < 0.001$) (Figure 3).

DISCUSSION

The present study found that where the fish feeding activity was intense in a restricted area and bait was provided (Maracajaú reefs), by far the most abundant species (before, during and after feeding treatments) was a mobile invertebrate feeder, *Haemulon aurolineatum*, forming shoals of about 800 individuals, which were attracted by the activity. The

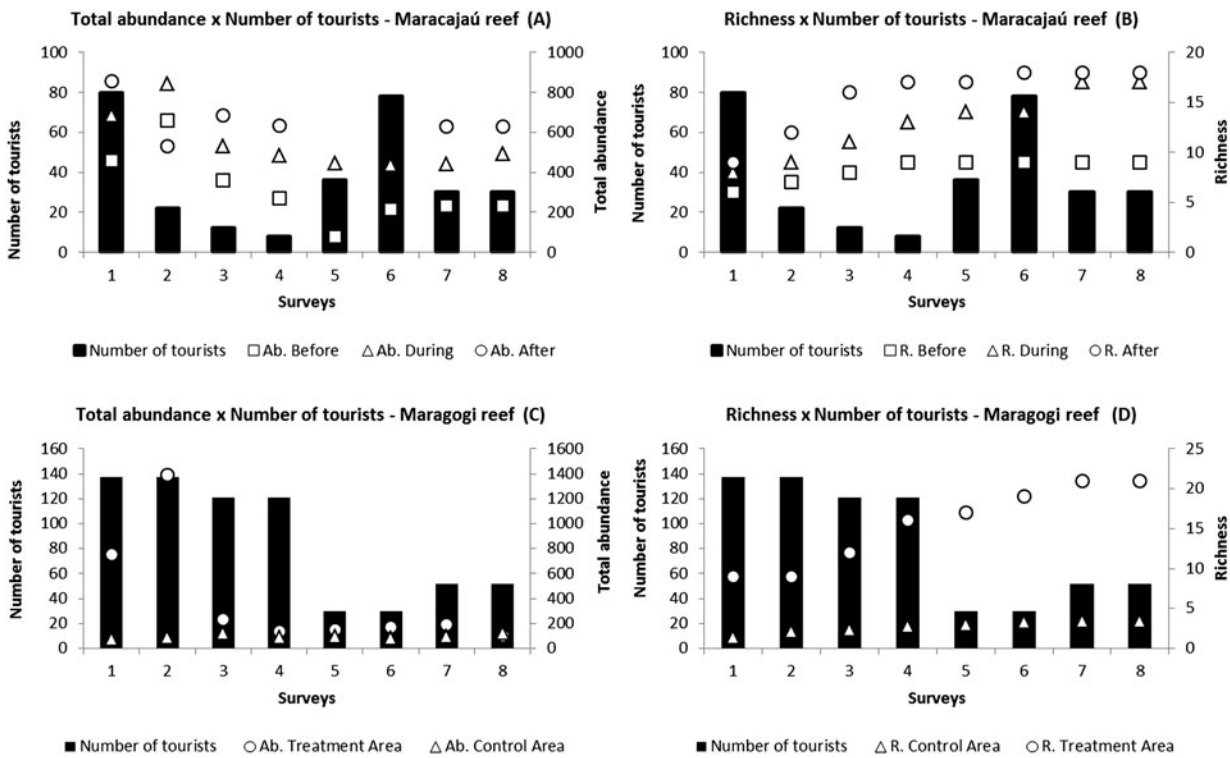

Fig. 3. Number of tourists, total abundance and richness/surveys for Maracajaú (A and B) and Maragogi (C and D) reefs.

ecological role of high concentrations of schools of the genus *Haemulon* includes protective mimicry and foraging facilitation behaviour (Pereira *et al.*, 2011) and they are important to several reef fish species in mixed-species schooling behaviour, especially aggregated individuals with limited populations. This emphasizes the great ecological and social importance of these schools on reef fish communities and consequently, that minor changes in abundance could alter complex ecological processes (e.g. competition for food and space; foraging associations) (Pereira *et al.*, 2011). Although a higher abundance of *H. aurolineatum* is also observed on non-fish feeding areas, it was strikingly exacerbated on the floating dock vicinities and more research is needed on this matter.

The second most abundant and frequent species at the three periods of activity, was an omnivore (*Abudefduf saxatilis*), which was quickly attracted by the external source of food provided by tourists. Although not especially abundant, changes between treatments were not observed as expected, especially because the floating dock also functions as a substratum for the spawning activity of this species, where guarding nests were often observed. Therefore, it can be suggested that both species are already used to consume the artificial food constantly available, reflecting on the community found.

In contrast, where the activity is more random and human food is offered by tourists (Maragogi reefs), data indicate that *A. saxatilis* is the most common species, although rarely observed in the control area. This result corroborates the work of Medeiros *et al.* (2007), who found that *A. saxatilis* corresponds for almost 2/3 of total individuals during feeding activity recorded in north-eastern Brazil (Picãozinho reefs—Paraíba State). This species is opportunistic, cosmopolitan, forms shoals and behaves in a peculiar manner in relation to tourists, as it is unafraid and readily attracted by the presence of humans (Feitosa *et al.*, 2002). The Sergeant-major responds rapidly when food is offered, probably moving from adjacent areas to where tourists or boats are present. Sazima *et al.* (2003) observed that this species feeds also on the faeces and vomit of the spinner dolphin (*Stenella longirostris* Gray, 1828), with a quick response to the presence of food.

Opportunistic feeding on occasional or frequently available items has been reported for several reef fish species (Ilarri *et al.*, 2008; Chaves *et al.*, 2010), mainly generalists, thus indicating benefits for those with some level of feeding plasticity. It is very likely that over the years this ill-planned activity has continued and tourism has strongly benefited the individuals of *A. saxatilis*, increasing the overall abundance of this species. These findings demonstrate that this activity is responsible for increasing the abundance of determined species of fish, as has also been pointed out by several other authors (Harmelin-Vivien, 1992; Orams, 2002; Milazzo *et al.*, 2005).

The recreational fish feeding is amongst the most practised activity and is known to affect directly and indirectly the fish communities, especially fish distribution and trophic structure (Orams, 2002). Differences in ecological effects from artificial food or bait are more likely to be explained by the cumulative influence of many factors including: type, quantity (number of tourists), and distribution of food; duration of feeding; social behaviour of target species; and population and community composition. For instance, in Maragogi the main trophic category was territorial herbivores, however in treatment areas omnivores were significantly more abundant, although not necessarily detrimental to territorial herbivores, which remained the same. In the Maracajaú reefs, the type of food provided did not alter the trophic guilds, as mobile invertebrate feeders were the most abundant in both areas. In this case, the differences observed were related to the abundance and richness of some species between before and after fish feeding periods, which were attracted by the activity. In general, the offer of fish, shrimps and squids (naturally accessed by fish) favoured mobile invertebrate feeders, whereas animal ration and human food caused aggregations of omnivores.

Some authors defend recreational fish feeding, arguing that this activity is a popular attraction that can be used to keep the tourists away from the more vulnerable reef areas (Hawkins *et al.*, 1999), or even to provide self-sustainability for management actions inside the MPAs (Milazzo *et al.*, 2006). However, food artificially accessible to fish can still: (1) alter their natural behaviour patterns and population distribution (Eifler, 1996; Doenier *et al.*, 1997; Orams, 2002); (2) create addiction to food provided by the tourists (Orams, 2002); (3) increase aggressive behaviour and competition (Perrine, 1989); and (4) cause health problems to animals (Orams, 2002; Vignon *et al.*, 2010). The evidence of this study corroborates points (1) and (2) in the list above.

The artificial manner of attracting fish is common in marine tourism in Brazil and worldwide (Strong *et al.*, 1992; Cole, 1994; Sweatman, 1996; Orams, 2002; Milazzo *et al.*, 2005; Medeiros *et al.*, 2007). Although the direct effect of fish feeding was more explicit for *A. saxatilis* and *H. aurolineatum*, the food type offered, number of tourists and activity distribution are believed to be the major factors for modifications in the community structure of the studied reefs. This activity has been carried out in both locations for over 10 years, but effects of the great abundance of species such as *A. saxatilis* on other reef fish species, especially territorial ones, and on the fish community as a whole have not been yet addressed. Nevertheless, the data provided in this study were essential to the Recifes Costeiros Project and the Municipal Council of Environmental Defense. Based on these results, a Conduct Adjustment Term was established in the MPA Costa dos Corais and recreational fish feeding has been banned in the Maragogi reefs ever since. This measure has improved the quality of diving activity and some species which were not seen frequently before in the area (e.g. *Acanthurus coeruleus*, *A. bahianus*, *Epinephelus adscensionis* and *Lutjanus alexandrei*) have been recently recorded (C.V. Feitosa, personal observation).

The results presented in this study are sufficient to conclude that the potential for negative ecological effects exists, as a result of providing food through artificial feeding or baiting. The main fact is that fish feeding causes an increase in abundance of some species, as they converge toward focal food sources, changing the community trophic structure and consequently disrupting species' normal daily or seasonal movements. The quality of observations during diving activities is also significantly reduced. As this study focused on temporary changes in the reef fish community, it was not possible to analyse other ecological effects, such as the increase of competition among species. Future research is still needed to address this hypothesis and therefore, while fish feeding is proposed to be a tool providing an approximation between tourist and nature awareness, it should be used with caution in order to ensure both tourism activities and conservation goals.

ACKNOWLEDGEMENTS

We thank Ana Lídia Bertoldi Gaspar, Sigrid Neumann Leitão and William Severi for reading and making helpful comments on the first draft of the paper. We also thank Jim Ellis and two anonymous referees who improved this manuscript with suggestions. This research was partly funded by Fundação de Apoio ao Desenvolvimento (FADE) of the Universidade Federal de Pernambuco (UFPE).

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