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Cleaning mutualism in Santa Luzia (Cape Verde Archipelago) and São Tomé Islands, Tropical Eastern Atlantic

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This work reports for the first time cleaning activity by fish and shrimps in Santa Luzia, Cape Verde Archipelago and São Tomé Islands. Three new records of facultative cleaner fish species are presented. Facultative cleaners dominated by Labridae were the most observed cleaner fishes in the two studied islands. Multi-specific cleaning stations were prevalent in Santa Luzia, while cleaner shrimps were more observed interacting in the São Tomé Islands.

Keywords: cleaner fish, cleaner shrimp, client fish, Labridae, Africa

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INTRODUCTION

Reef environments are one of the most diverse habitats in the world (Reaka-Kudla, 1997), where many intriguing ecological relationships are observed. Among those relationships, cleaning mutualism is defined as the interaction between the 'cleaner' which removes parasites, dead skin, scales and mucus from the body surface of its 'clients', which include fishes, turtles, marine iguanas, whales and octopuses (Feder, 1966; Sazima & Moura, 2000; Grutter, 2002; Sazima *et al.*, 2004, 2010; Floeter *et al.*, 2007a). Cleaning is considered disproportionately important in reefs, with very few species and individuals acting as cleaners but affecting a much larger fraction of client species (Grutter *et al.*, 2003; Floeter *et al.*, 2007a).

According to Côté (2000), about 130 species of fish and crustaceans are known to be cleaners, the majority are facultative cleaners (organisms that rely only in small part on cleaning as a source of food), but some are obligate cleaners, which clean during their entire lifetime. Cleaning events may occur up in the water column or close to the substratum (Darcy *et al.*, 1974). Frequently, these interactions happen in fixed sites, such as massive coral colonies, sponges or large rock formations called 'cleaning stations' (Feder, 1966; Losey, 1974; Côté, 2000; White *et al.*, 2007), which can be occupied by a variable number of individuals from one or more species of cleaners (Johnson & Ruben, 1988; Wicksten, 1998).

Cleaning stations are described as an important factor affecting the small-scale distribution and density of fish populations on a given reef, because clients tend to aggregate at or near cleaning stations searching for the cleaner's 'services' (Slobodkin & Fishelson, 1974; Grutter *et al.*, 2002, 2003; Whiteman & Côté, 2002; Waldie *et al.*, 2011).

Cleaning interactions are well studied in many places in the Indo-Pacific (e.g. Grutter & Poulin, 1998; Côté, 2000), Caribbean (e.g. Johnson & Ruben, 1988; Arnal *et al.*, 2000, Côté, 2000) and south-western Atlantic (e.g. Sazima *et al.*, 1998, 1999, 2000; Francini-Filho *et al.*, 2000; Sazima & Sazima, 2001; Gasparini *et al.*, 2008; Coni *et al.*, 2011). However, little is known about cleaning mutualism in the Tropical Eastern Atlantic. This study is the first to address the diversity of reef fish clients and cleaners, and the frequency of interactions in two oceanic islands from the Tropical Eastern Atlantic: Santa Luzia Island in the Cape Verde Archipelago and São Tomé Island. We also present the first records of three cleaner fish species and cleaner shrimps for this region.

MATERIALS AND METHODS

Fieldwork was carried out in the island of São Tomé (0°00′N 7°24′W; located ~250 km off the African coast) in February

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2006 summing up ~135 hours of underwater activities and the island of Santa Luzia (Cape Verde Archipelago; 16°45′N 24°23′W, ~560 km off the African coast) in September 2009 summing up ~60 hours of underwater activities.

These islands are characterized by volcanic rocky reefs with the presence of sparce hard corals. All the work was conducted from 10:00 to 16:00 h in relatively shallow waters at 3 to 20 m depth. Replicated underwater visual censuses (N = 198) of 20 × 2 m (see Floeter *et al.*, 2007b for details of the method) were used to assess the reef fish community at Santa Luzia Island.

Cleaning associations were recorded from direct observations, and digital images and videos obtained during two expeditions aimed at documenting the marine biota from both islands. All instances of cleaning observed were recorded at stations or in the water column, but only a fraction of the time spent underwater was used for this, so calculation of the cleaning rate per unit time was not possible.

RESULTS

Santa Luzia Island, Cape Verde Archipelago

Four fish species were recorded as cleaners in Santa Luzia Island (Table 1). Two of them were responsible for almost all (~91%) interactions (Table 1): *Bodianus speciosus* (52% of cleaning events) (Figures 1A & 2A, B, C), and *Coris atlantica* (39%), the latter recorded as a cleaner for the first time (Figure 2A). *Bodianus speciosus* and *C. atlantica* were found together tending multi-specific cleaning stations in eight out of 12 observations. *Bodianus speciosus* was recorded cleaning alone on three occasions (25%), and *C. atlantica* was never observed cleaning without *B. speciosus* in the same station. *Thalassoma pavo* (6%) (Figure 1A, B) and *Canthisgaster capistrata* (3%; also recorded as a cleaner for the first time, Figure 1A) were recorded in only 9% of all events, and always in multi-specific stations. Each cleaning station ocuppied an area around 2 to 4 m², with clients posing to solicit inspection. *Sparisoma cretense* usually laid down in the reef to elicit cleaning (Figure 1A, B). In 8% of the encounters, the clients initiated the cleaning event, and in half of the events clients changed colour to bring attention of the cleaners. Clients were inspected in all body parts, but in many instances cleaners concentrated around the gills (Figures 1A & 2C).

Sixty-seven reef fish species were recorded as potential clients but only 13 species in eight families were recorded as clients in Santa Luzia (Table 1). Six of these (*Chelon bispinosus*, *Diodon holocanthus*, *Diplodus prayensis*, *Mulloidichthys martinicus*, *Pseudupeneus prayensis* and *Scarus hoefleri*) were recorded interacting only once (<1%), what may be considered an indication of the low frequency of such events. We

Table 1. Number and proportion of cleaning events involving clients with more than one recorded interaction in the island of Santa Luzia, Cape Verde Archipelago. Families are disposed alphabetically. Taxonomy follows that of Nelson (2006) except for Epinephelidae (Craig *et al.*, 2011) and Labridae (Cowman *et al.*, 2009).

Clients species	Cleaners				Total	%	Multi-specific station
	Bodianus speciosus (a)	*Coris atlantica*** (b)	*Thalassoma pavo* (c)	*Canthigaster capistrata*** (d)			
Acanthuridae							
Acanthurus monroviae	4	2			6	5.71	a, b
Epinephelidae							
Cephalopholis taeniops	2	1		1	4	3.80	a, b
Labridae							
Bodianus speciosus	4	1			5	4.76	
Thalassoma pavo	2				2	1.90	
*Scarus hoefleri**		1			1	0.95	
Sparisoma cretense	16	3	1	1	21	20.0	a, b, c, d
Mugilidae							
*Chelon bispinosus**	1				1	0.95	
Mullidae							
*Pseudopneus prayensis**	1				1	0.95	
*Mulloidichthys martinicus**	1			1	2	1.90	
Pomacentridae							
Chromis lubbocki	10	24	3		37	35.23	a, b
Chromis multilineata	12	9	2		23	21.90	a, b
Sparidae							
Diplodus prayensis	1				1	0.95	
Tetraodontidae							
*Diodon holocanthus**	1				1	0.95	
Total number of events	55	41	6	3	105		
percentage	52.45	39.0	5.71	2.84	100		
Number of species per host	7	6	3	2	7		
Density 40m²	1.04	4.16	27.8	1.19			

*, species recorded in only one event; **, new record of facultative cleaner.

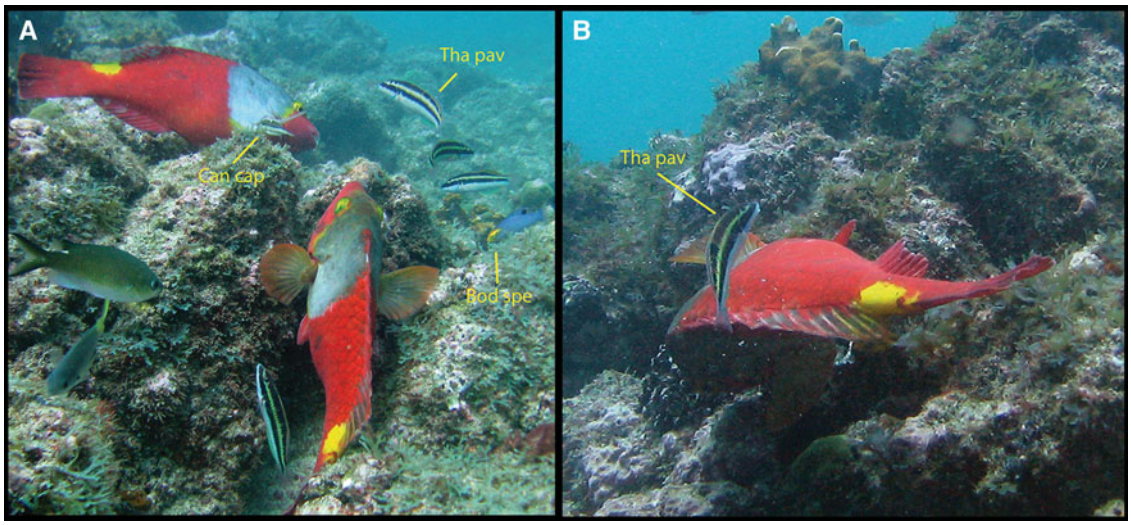

Fig. 1. Cleaning interactions at a multi-specific cleaning station at about 10 m deep in Santa Luzia Island, Cape Verde Archipelago, September 2009: (A) *Bodianus speciosus*, *Canthigaster capistrata* and *Thalassoma pavo* cleaning two *Sparisoma cretense*; (B) *T. pavo* interacting with *S. cretense* laying down to solicit inspection.

observed 98 cleaning events for the remaining seven species. The most common clients were of the genera *Chromis* (Pomacentridae, 57.1% of cleaning events) and *Sparisoma* (Labridae, 27.6%) (Table 1).

São Tomé Island

Six fishes and two crustaceans were recorded as cleaners in São Tomé Island (Table 2). The shrimp *Lysmata* spp. had most

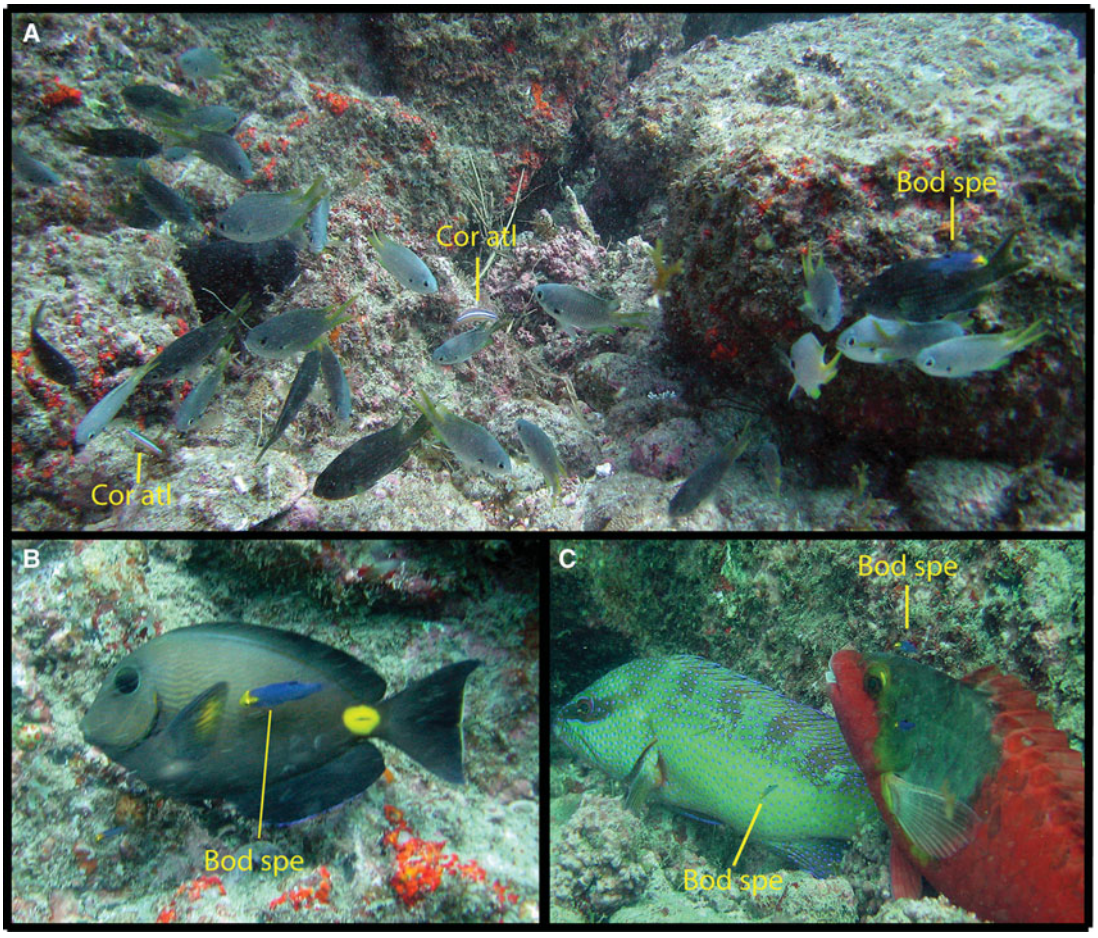

Fig. 2. Cleaning interactions at a multi-specific cleaning station from 6 to 10 m deep in Santa Luzia Island, Cape Verde Archipelago, September 2009: (A) *Bodianus speciosus* and *Coris atlantica* cleaning client species *Chromis lubbocki* and *C. multilineata*; (B) *B. speciosus* cleaning *Acanthurus monroviae*; (C) *B. speciosus* cleaning *Cephalopholis taeniops* and *Sparisoma cretense*.

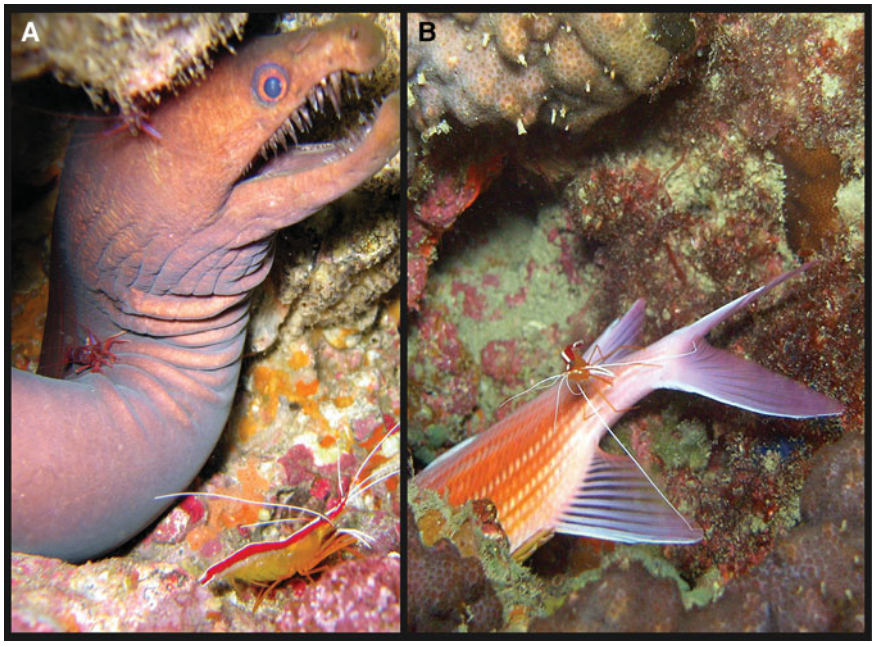

Fig. 3. Cleaning by shrimps under a reef structure at about 12 m deep in São Tomé Island, February 2006: (A) *Lysmata* spp. cleaning *Enchelycore nigricans*; (B) *Lysmata grabhami* interacting with *Sargocentron hastatum*.

clients, eight (38% of all clients) from three families of fish and one crustacean (Figure 3A, B). The wrasse *Bodianus speciosus*, had six clients (23% of all clients) from five families (Figure 4B), while *B. pulchellus* had three fish clients (Figure 4C). Other than the two *Bodianus*, two other species of the family Labridae were observed in cleaning activities: *Coris atlantica* and *Thalassoma newtoni*. In total, cleaner fishes of the family Labridae were observed cleaning 50% of all client species. Differently from Santa Luzia, no multi-specific cleaning stations were found in São Tomé. From the 66 species of reef fish observed during this expedition, a total of 16 (from 11 different families) were recorded as clients, as well as the green turtle *C. mydas* (Table 2).

We also report for the first time 'facultative' cleaning behaviour by the eastern Atlantic endemic butterflyfish (Chaetodontidae) *Chaetodon robustus*. It was observed cleaning the creole fish *Paranthias furcifer* and the goatfish *Mulloidichthys martinicus* (Figure 4A).

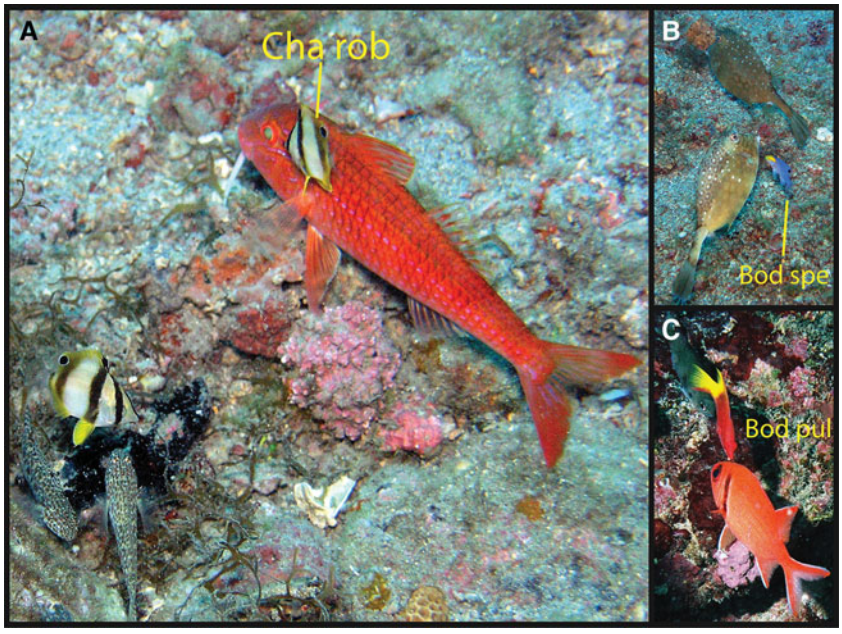

Fig. 4. Cleaning activity by fishes over rodolith beds at about 15 m deep in São Tomé Island, February 2006: (A) new record of the cleaner *Chaetodon robustus*, interacting with *Mulloidichthys martinicus* changing its predominant colour pattern; (B) *Bodianus speciosus* cleaning *Acanthostracion notacanthus*; (C) *Bodianus pulchellus* interacting with *Myripristis jacobus*.

Table 2. Marine species reported as cleaners and clients in the islands of São Tomé and Príncipe.

Cleaners	Clients	Reference
FISHES		
Chaetodontidae		
*Chaetodon robustus**	*Paranthias furcifer*	Present paper
	Mulloidichthys martinicus	Present paper
Labridae		
Bodianus pulchellus	*Clepticus africanus*	Afonso *et al.*, 1999; present paper
	Myripristis jacobus	Present paper
	Paranthias furcifer	Present paper
	Turtle	
	Chelonia mydas	Wirtz *et al.*, 2007
Bodianus speciosus	*Acanthurus monroviae*	Afonso *et al.*, 1999
	Apsilus fuscus	Afonso *et al.*, 1999
	Paranthias furcifer	Present paper
	Chaetodon robustus	Afonso *et al.*, 1999
	Lutjanus goereensis	Debelius, 1997
	Acanthostracion notacanthus	Present paper
*Coris atlantica**	*Acanthurus monroviae*	Present paper
	Paranthias furcifer	Present paper
Thalassoma newtoni	*Acanthurus monroviae*	Present paper
Pomacentridae		
Abudefduf taurus	*Acanthurus monroviae*	Wirtz *et al.*, 2007; present paper
CRUSTACEANS		
Hyppolytidae		
Lysmata grabhami	*Acanthurus monroviae*	Wirtz, 2003, 2004; present paper
	Paranthias furcifer	Present paper
	Chromis multilineata	Present paper
	Enchelycore nigricans	Present paper
	Echidna peli	Present paper
	Muraena melanotis	Present paper
	Holocentrus adscensionis	Present paper
	Myripristis jacobus	Present paper
	Sargocentron hastatum	Present paper
Lysmata spp.	*Enchelycore nigricans*	Present paper

*, new record of facultative cleaner.

DISCUSSION

According to Côté (2000) all eight cleaner species found in the present study are considered facultative cleaners (i.e. species that do not rely on cleaning activities as a substantial part of their diets). The lack of specialized cleaner fishes (i.e. *Elacatinus* spp. and *Labroides* spp.) in the Tropical Eastern Atlantic is intriguing and is most probably related to biogeography and evolution of these lineages, restricted to richer coral reef regions. The most observed cleaner fishes in both islands are the labrids *Bodianus*, *Coris* and *Thalassoma*.

In Santa Luzia, we observed an atypically high occurrence of multi-specific cleaning stations (more than half of the stations). Despite reports of mixed stations in the western Atlantic (e.g. *Elacatinus evelynae* and juveniles of *Bodianus rufus* by Johnson & Ruber (1988) for the Caribbean, and *Elacatinus figaro* and juveniles of *Pomacanthus paru* in Abrolhos reef, Brazil by Sazima *et al.* (2000)), in many reefs around the world, multi-specific cleaning stations are not that common (e.g. less than 10% of the stations are multi-specific in most reef areas in Brazil, in the west Pacific and in the Tropical Eastern Pacific; authors, personal observations).

The important functional role of the obligate (Côté, 2000) cleaner shrimps of the genus *Lysmata* spp. is evident in São Tomé. These species were involved in 56% of all reported clients (Table 2). Interestingly, only four species of clients (~25%) were shared between fish and shrimps (*Acanthurus monroviae*, *Paranthias furcifer*, *Chromis multilineata* and *Myripristis jacobus*). Moreover, moray eels were clients exclusively of shrimps, as both prefer to live in refuge holes in the reef, which facilitates the interaction. The other two client species were *Holocentrus adscensionis* and *Sargocentron hastatum* which are predominantly nocturnal, but also stay in or close to refuge holes during the day. This behaviour may facilitate the interaction between the clients and the shrimps.

Cleaners of the family Labridae (wrasses) are important in the studied sites, responsible for cleaning of all the client species in Cape Verde and half of the clients in São Tomé. The wrasse *Bodianus speciosus* is the most important cleaner fish in both islands and may be playing a similar role in the Tropical Eastern Atlantic as its western Atlantic congener *B. rufus* in the Caribbean and Tropical South-Western Atlantic (Johnson & Ruben, 1988; Feitoza & Correia, 2003; Sazima *et al.*, 2010; Coni *et al.*, 2011). Cleaning events by *Bodianus pulchellus* are rarely observed because this species prefers deeper parts of the reef (Sazima *et al.*, 2010). In São Tomé, *B. pulchellus* was found cleaning in shallow waters (5 to 15 m deep), as also noted by Luiz *et al.* (2008) on the south-eastern coast of Brazil.

Coris atlantica was the second most important cleaner in Santa Luzia, and was seen in large cleaning stations (Figure 5) in São Tomé. This new record adds to the list of facultative cleaners of the genus *Coris*. Its sister-species, *Coris julis* is reported to be a cleaner in the Mediterranean Sea (Zander & Sötje, 2002) and in the Azores islands (Bertoncini *et al.*, 2009). Cleaners of the genus *Thalassoma* have been traditionally considered as common cleaners that interact with a broad number of clients in reef environments (Johnson & Ruben, 1988). *Thalassoma pavo* and *T. newtoni*, however, were observed interacting in relatively low

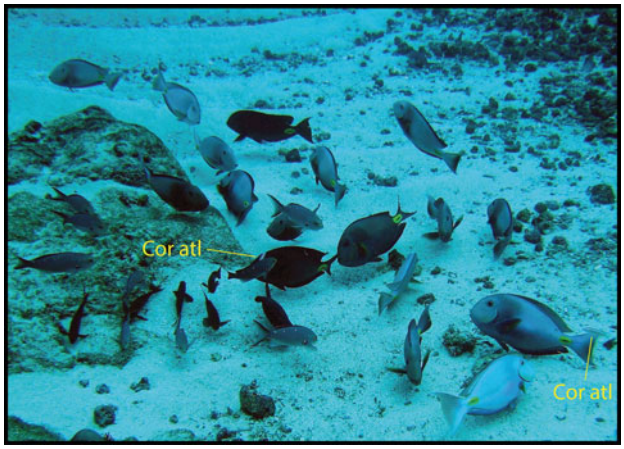

Fig. 5. Cleaning station tended by *Coris atlantica* in a sand patch at about 18 m deep, involving clients *Acanthurus monroviae* and *Paranthias furcifer* changing colour while being cleaned or inspected (São Tomé Island, February 2006).

frequency, differently from other species of the genus *Thalassoma* in the western Atlantic (Johnson & Ruben, 1988; Francini-Filho *et al.*, 2000; Sazima *et al.*, 2005).

The new record of *Canthisgaster capistrata* in Santa Luzia as a facultative cleaner adds to the list of cleaners of the genus *Canthisgaster*. Previously, only two other species from this genus were recorded (Côté, 2000).

The Pomacentridae *Abudefduf taurus* was an occasional cleaner in São Tomé (Wirtz *et al.*, 2007). This behaviour has been observed in its congener *A. troschelii* from the Tropical Eastern Pacific (McCourt & Thomson, 1984). *Abudefduf saxatilis* (juvenile) is recorded as occasional cleaner in the western Atlantic (Whiteman *et al.*, 2002), but was not observed cleaning in the studied islands.

Floeter *et al.* (2007a) found a strong correlation between abundance of a given fish in an assemblage and its tendency to be cleaned. In Santa Luzia, the high frequency of cleaning events involving *Chromis* as a client may be due to its high abundance (48% of all individuals counted in visual censuses are *Chromis*). Moreover, in São Tomé, the highly abundant *Paranthias furcifer* was cleaned by five out of eight observed cleaners, thus indicating the same trend. Quantitative data in the understudied Tropical Eastern Atlantic are needed for a comprehensive understanding of the role of cleaning mutualism in a relatively species-poor region that lacks obligate cleaners.

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