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SHORT COMMUNICATION

Fish cleaning interactions on a remote island in the Tropical Eastern Pacific

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Abstract Cleaning interactions are an essential feature of marine ecosystems since they help maintain a healthy community. However, knowledge on the magnitude of the cleaning interactions in the Tropical Eastern Pacific (TEP) is scarce, especially in remote places like oceanic islands. Here, we describe for the first time the cleaning interactions among reef fishes at Malpelo Island, a World Heritage site located in the TEP. In 120 cleaning events at Malpelo, we have observed five fish species acting as cleaners and nineteen acting as clients. We observed one local endemic and four regional endemic species of the TEP among the cleaners, and five elasmobranchs and fourteen ray-finned species as clients. Our results show that *Johnrandallia nigrirostris* was the cleaner with the largest number of events and client species, whereas *Lepidonectes bimaculatus* was the most specific cleaner (i.e. it has only one client species). We observed that 56 % of the cleaning interactions involved a top predator as client. Our results suggest that the role of cleaner is executed by just few fish species at Malpelo Island, and that a high number of cleaning interactions occur with top predators (groupers, snappers, sharks, and rays), which could be an indication of the good conservation status of Malpelo.

Keywords Mutualism · Malpelo Island · Oceanic island · Reef fishes · Elasmobranch · Colombia

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Introduction

Reef fish fauna is recognized as one of the most diverse and important components of coral reefs due to its high number of species and functional roles on reef ecosystems (Bellwood et al. 2006; Mora 2015). Among the key functions they perform, cleaning interactions are an important one, because during these associations one cleaner organism removes ectoparasites, mucus, and injured and/or wounded tissue from a client organism, helping to maintain healthy communities (Losey 1972; Côté 2000). Cleaning behavior has been reported in ca. 130 species of fish and crustaceans, which can be classified as facultative (i.e. species cleaning only during juvenile stages or sporadically exploring cleaning interactions as a source of resources) or obligate cleaners (i.e. species that clean during their entire lifetime) (Côté 2000). Cleaning interactions often occur at fixed sites known as 'cleaning stations', which usually include prominent habitat structures (Losey 1972) like massive corals, sponges and large rocks (Côté 2000). In this sense, identifying cleaners and clients and quantifying matches between them are the first step toward understanding cleaning interactions in natural ecosystems.

Despite the importance of cleaning interactions as a key function on coral reefs, most studies have been conducted

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primarily in the Indo-Pacific and Caribbean regions (Johnson and Ruben 1988; Sims et al. 2014). Although having 26 % of the world's cleaning fish fauna (34 species; Hobson 1965; Côté 2000; Alzate et al. 2006; Quimbayo et al. 2010; Robertson and Allen 2015), the Tropical Eastern Pacific (TEP) has received little attention. This lack of knowledge increases when considering remote sites such as oceanic islands, considered worldwide as key sites in providing refuge, food and/or cleaning services for the oceanic mega-fauna (Oliver et al. 2011; Soler et al. 2013). Malpelo Island is one example of such a remote, yet ecologically important, site in the TEP region where cleaning has not been characterized. Malpelo Island is considered a World Heritage site given its high endemism level (Zapata and Robertson 2007), high density of top predators (groupers, snappers, sharks, and rays), and its zoogeographic position linking the transit of species between the Galapagos, Cocos Island and the mainland (Bessudo et al. 2011; Soler et al. 2013).

Here, we provide for the first time a detailed description of cleaning interactions at Malpelo Island. More specifically, this study aims to answer (1) how many reef fish species act as cleaners and and how many as clients; (2) how does the cleaning frequency vary among cleaners and clients; and (3) which trophic group of clients are the most attended by cleaners.

Materials and methods

Cleaning interactions were observed at Malpelo Island (4°00′05″N, 81°36′30″W), a Sanctuary of Marine Fauna and Flora located 380 km off the coast of Colombia in the Tropical Eastern Pacific region (TEP) (Zapata and Vargas-Ángel 2003). It is the top of a submerged mountain chain and has an uneven relief giving the impression of an inaccessible and inhospitable naked rock (López-Victoria and Rozo 2006). The aquatic environment of this island is composed mainly of a rocky substrate, but some small zones present high coral cover (Garzon-Ferreira and Pinzón 1999; Chasqui and Zapata 2007).

We analyzed cleaning interactions from 29 remote video records and 79 photographic records obtained during five expeditions to Malpelo Island made between August 2010 and April 2015. We noted all cleaning interactions at cleaning stations and/or in the water column while SCUBA diving (6–30 m in depth). We did not calculate the rate of cleaning interactions per unit of time because only a fraction of the time spent underwater was used for observations. The identity of both client and cleaner was determined after examining video footage and photographs to assess the frequency of cleaners involved in cleaning interactions and the number of clients attended by each cleaner species. Additionally, we classified each client species according to the trophic categories defined by Mouillot et al. (2014), and obtained the maximum body size from Robertson and Allen (2015).

Results

We observed 120 cleaning interactions (Table 1) involving five facultative cleaners, one of which is endemic to Malpelo and four with a broader distribution, albeit restricted to the TEP (Fig. 1). Adults of *Johnrandallia nigrirostris* (Chaetodontidae) were the most frequent cleaners, followed by *Bodianus diplotaenia* (Labridae), *Lepidonectes bimaculatus* (Tripterygiidae, endemic to Malpelo), *Holacanthus passer* (Pomacanthidae) and *Thalassoma lucasanum* (Labridae; Table 1, Fig. 2). The species *J. nigrirostris* and *B. diplotaenia*, were only observed cleaning in large groups over large rocks or at sites with massive coral cover (cleaning stations; Fig. 1a, b). The species *T. lucasanum* and *L. bimaculatus* were observed cleaning only near the bottom and did not interact with pelagic clients (e.g., elasmobranchs or large species in the water column; Table 1). On the other hand, adults of *H. passer* performed most of their cleaning interactions with elasmobranch clients (Figs. 2, 3). *Lepidonectes bimaculatus* was the most specific cleaner as it was observed cleaning a single client, *Epinephelus labriformis*, several times (Fig. 2).

We observed 19 client species belonging to 12 families (14 ray-finned fishes, 4 sharks and 1 ray; Table 1). Most of the observed clients were piscivores (47 %), followed by herbivore–detritivores (15 %), planktivores (15 %), macroalgivores (10 %), mobile invertebrate feeders (5 %) and omnivores (5 %). The most attended clients were *Lutjanus jordani* and *Kyphosus ocyurus* (40 % of cleaning frequency), while other clients had low frequences (from 1 to 8 % of cleaning interactions; Fig. 2). The body size of clients varied from 30 cm to 12 m in total length. The smallest species were *Paranthias colonus*, *Lutjanus viridis* and *Zanclus cornutus* (range 30–36 cm) and the largest client being *Rhincodon typus* (about 12 m; Figs. 2, 3).

Discussion

Our data revealed that the richness of cleaners is low relative to the local species pool of Malpelo (2.5 %; Robertson and Allen 2015). However, a great proportion of the cleaner species found in the TEP region (34 species) were registered in Malpelo (15 % or 5 species). This result suggests that the isolation of Malpelo limits the number of cleaner fishes from nearby coastal areas and that the cleaning behavior is performed by a few species from the local pool. The species *Johnrandallia nigrirostris* and *Bodianus diplotaenia* dominated the cleaning interactions at Malpelo in terms of the

Table 1 Number and frequency of cleaning interactions among cleaners and clients at Malpelo Island, Tropical Eastern Pacific

Clients species	Cleaners					
	Johnrandallia nigrirostris	*Bodianus diplotaenia*	*Holacanthus passer*	*Thalassoma lucasanum*	*Lepidonectes bimaculatus*[a]	Trophic category
Acanthuridae						
Acanthurus xanthopterus		6		3		HD
Prionurus laticlavius	1					HD
Carcharhinidae						
Carcharhinus falciformis	2	1	1			PS
Carcharhinus galapagensis			1			PS
Balistidae						
Canthidermis maculata	2	9				PK
Carangidae						
Seriola rivoliana		3	2			PS
Epinephelidae						
Epinephelus labriformis					14	PS
Dermatolepis dermatolepis	5		4			PS
Paranthias colonus	3	1				PK
Mycteroperca olfax		1				PS
Kyphosidae						
Kyphosus vaigiensis	3	1	1			HM
Kyphosus ocyurus	17		1			HM
Labridae						
Scarus rubroviolaceus	1					HD
Lutjanidae						
Lutjanus jordani	27					PS
Lutjanus viridis	4	1				PS
Myliobatidae						
Aetobatus narinari	1					IM
Rhincodontidae						
Rhincodon typus			1			PK
Sphyrnidae						
Sphyrna lewini			1			PS
Zanclidae						
Zanclus cornutus				2		OM
Frequency of cleaning	55	19.17	10	4.17	11.67	
Number of attended clients	10	8	8	2	1	
Number of exclusive clients	4	1	3	1	1	

Taxonomy follows Nelson (2006) except for Epinephelidae (Craig et al. 2011), Labridae (Cowman et al. 2009) and Kyphosidae (Knudsen 2013)

Trophic category: *HD* herbivorous–detritivorous, *HM* macroalgal herbivorous, *IM* invertivorous targeting mobile prey, *PK* planktivorous, *PS* piscivorous, *OM* omnivorous

[a] Endemic species of Malpelo Island

frequency and richness of attended clients. *J. nigrirostris* has been documented as the dominant cleaner in the Gulf of California (Hobson 1965), whereas *Bodianus* species are among the most important cleaners at Gorgona Island (Alzate et al. 2006), St. Croix (Johnson and Ruben 1988), Cape Verde and São Tomé islands (Quimbayo et al. 2012). Indeed, these species have both a series of morphological traits and specific behaviors related to cleaning activity, such as aposematic color (Cheney et al. 2009; Côté 2000), high protrusion and fast jaw movements for prey capture (Baliga

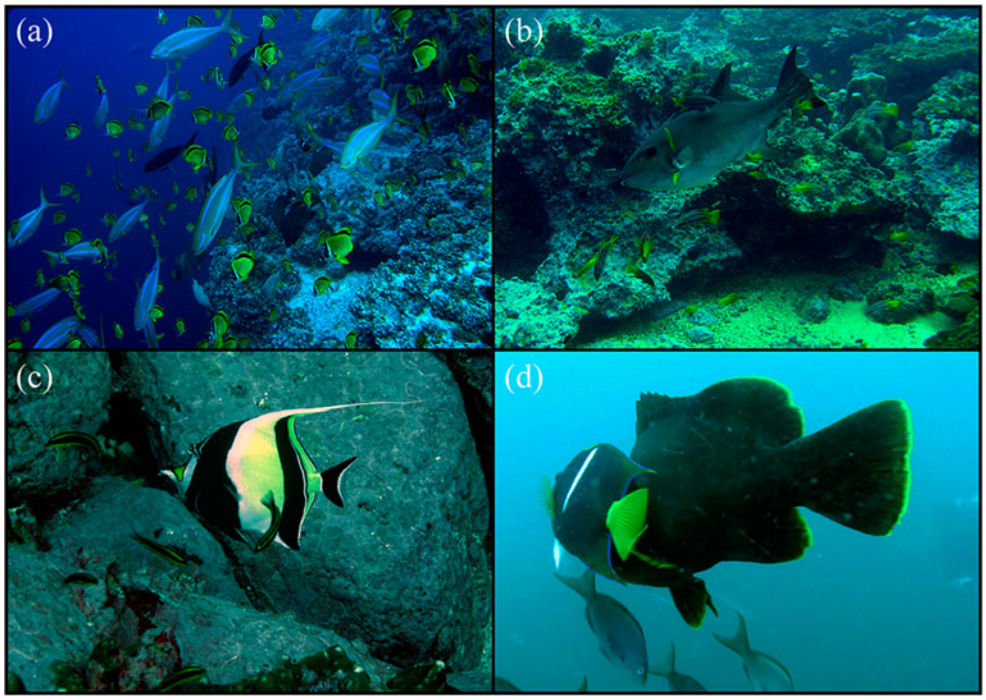

Fig. 1 Cleaning interactions at Malpelo Island. **a** Cleaning station: individual of *Johnrandallia nigrirostris* (yellow fish with black stripe) inspecting clients of *Kyphosus ocyurus*. **b** Cleaning station: individuals of *Bodianus diplotaenia* (yellow fish with black stripe) cleaning clients of *Canthidermis maculata*. **c** Individuals of *Thalassoma lucasanum* (black fish with yellow stripe) cleaning clients of *Zanclus cornutus*. **d** A client of *Dermatolepis dermatolepis* changing color to attract individual cleaners of *Holacanthus passer*

and Mehta 2015), and form large schools atcleaning stations that foster cleaning interactions with other species.

Although species from the genus *Thalassoma* have been recognized as specialized cleaners (Arnal et al. 2006; Baliga and Mehta 2014), we found that *T. lucasanum* interacts at low frequencies and with few client species. The cleaning behavior of individual adults of *Holacanthus passer* adults was also

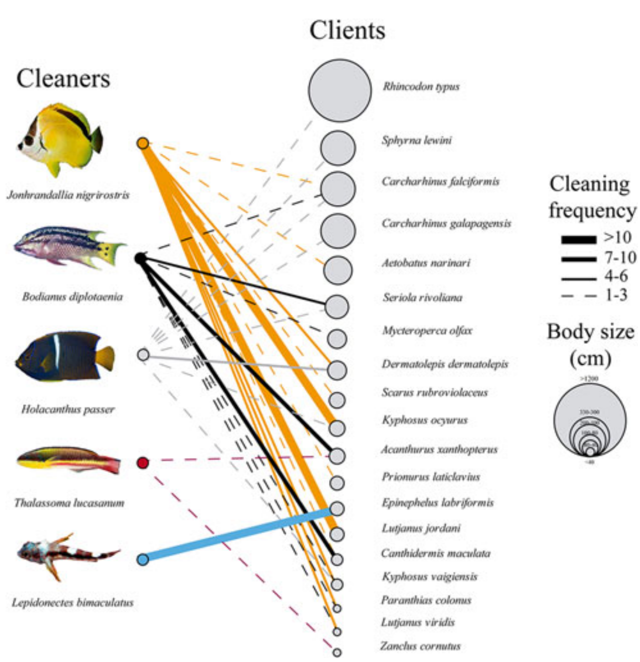

Fig. 2 Interaction cleaning network at Malpelo Island. *Circles* are proportional to body size (total length cm). *Lines* indicate cleaner–client interaction; line width is proportional to cleaning observed frequency (Table 1)

unexpected since only juveniles of this species have so far been recorded as cleaners (Hobson 1965; Thomson et al. 2000; Côté 2000). These unexpected results could both be related to the plastic diet of these species, since *T. lucasanum* may feed on organisms such as gastropods, bivalves, urchins, crustaceans and worms (Robertson and Allen 2015) and *H. passer* may use unusual items like feces as food resources (Aburto-Oropeza et al. 2000). Therefore, our results advance the knowledge on both the cleaning behavior and the food spectrum of these species. Furthermore, our observations confirm the cleaning behavior of the local endemic species, *Lepidonectes bimaculatus*, recorded by Quimbayo et al. (2010) as well as its specific association with *Epinephelus labriformis*. This specific association could have been established in order to reach more protein-rich food such as ectoparasites and mucus (Feary et al. 2009; Grutter et al. 2011; Eckes et al. 2015).

Additionally, our results suggest a predominance of large-bodied and piscivorous clients. This is probably linked to the protected conservation status of Malpelo, since marine protected areas tend to have high densities of top predators (Aburto-Oropeza et al. 2011). The geographic location of Malpelo may also contribute to this pattern since it is located between the Galapagos and Cocos Islands and the mainland, thus receiving new arrivals of large-bodied individuals like sharks, rays or pelagic species from nearby areas (McCosker and Rosenblatt 1975; Bessudo et al. 2011; Quimbayo et al. 2014).

Finally, our study extends previous reports on cleaning interactions at Malpelo Island (Quimbayo et al. 2010), and describes for the first time the cleaning interaction network,

Fig. 3 An individual of *Holacanthus passer* cleaning *Rhincodon typus* in water column

which may be used as a baseline for the regional conservation. Moreover, we extend the variability of the feeding behavior of a few cleaner species from the TEP region and highlight the importance of studying pristine islands considered as hotspots of biodiversity. The TEP is an important biogeographical region, where limited information on its reef-associated fish structure and their biological interactions is available. In this sense, Malpelo Island deserves more studies focusing on describing the functioning of its reefs and developing methods for its local conservation.

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