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Mollusk fauna from shallow-water back reef habitats of Paraíba coast, northeastern Brazil

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ABSTRACT

Back reef systems, represented by seagrass beds, algal banks, lagoons, mangroves, patch reefs, and other underwater habitats of the back reef zone, often harbor a great biological diversity and high abundance of many species. In this study, we provide the first inventory of the molluscan fauna associated to three shallow-water back reef habitats (algal banks, seagrass beds, and patch reefs) along the coast of Paraíba state, northeastern Brazil. During random searches, we recorded 65 mollusk species distributed in the classes Polyplacophora (2 spp.), Gastropoda (48 spp.), Cephalopoda (1 sp.), and Bivalvia (14 spp.), belonging to 40 families and 51 genera. Five gastropod species were recorded for the first time for the coast of Paraíba State: the large *Lobatus costatus* (Gmelin, 1791) (Strombidae), and the opisthobranchs *Bursatella* cf. *leachii* Blainville, 1817 (Aplysiidae), *Discodoris evelinae* Er. Marcus, 1955 (Discodorididae), *Oxynoe antillarum* Mörch, 1863 (Oxynoidae), and *Elysia subornata* A.E. Verrill, 1901 (Plakobranchidae). The variety of habitats provided by different back reef biotopes favors colonization of small species, large gastropods, including some species of commercial value such as *Turbinella leavigata* Anton, 1838 (Turbinellidae) and *Voluta ebraea* Linnaeus, 1758 (Volutidae), and uncommon bivalves, which makes these biotopes of special relevance for monitoring and conservation.

Keywords: Algal banks, biodiversity inventories, Mollusca, patch reefs, seagrass beds.

INTRODUCTION

In the Marine Coastal Zone, tropical marine ecosystems are composed of a complex mosaic of interconnected habitats and communities. Among these habitats, environments with consolidated substrates, such as reefs and rocky shores, are among the most studied and with the greatest biodiversity on the planet (Dahlgren & Marr 2004). However, there are other underwater biotopes associated with reef habitats that remain subsampled, but which harbor a rich and mostly unknown biodiversity. These habitats are located in the back reef (known as back reef systems), the portion between the beach and the reef structure (Dahlgren & Marr 2004). These biotopes include patch reefs, mangroves, seagrass beds, intertidal and subtidal sandy banks, coastal lagoons, and algal beds.

According to Dahlgren & Marr (2004), the environments associated with the back reef serve as a site of critical damping of stress between land and reef ecosystems. The back reef systems harbor a great biological diversity and high abundance of many taxa, particularly in juvenile stage, which are characterized as nursery habitats for several fish and invertebrates species, some of them of high commercial relevance (*e.g.*, Heck *et al*. 1997; Lipcius & Eggleston 2000; Adams & Ebersole 2002; Adams *et al.* 2006).

The back reef systems can also function as ecological corridors by promoting connectivity between these habitats and adjacent reefs (Adams *et al*. 2006). These authors emphasize that, due to its proximity to the reef, back reef systems provide shelter and protection to juvenile individuals, allowing them to reach the reef to complete its development, a fact already shown in some studies worldwide (*e.g.*, Cowen *et al*. 2007). This further reinforces the importance of a greater knowledge of the biodiversity of these habitats, which are increasingly suffering with severe stresses resulting from anthropogenic impacts (Hughes 1994).

Mollusca is one of the most diverse animal phyla, with about 130,000 species (Geiger 2006). Mollusks present a wide structural variety, being able to live in different environments. Moreover, due to their trophic diversification, they occupy almost all possible ecological niches (Sparks 2006).

In Brazil, research on the fauna associated to the back reef systems is still scarce, and in the case of molluscan fauna, the few studies include Laborel-Deguen (1963), who examined the macrofauna associated to the seagrass beds, and Dijck (1980), who inventoried the mangrove mollusks along the Restinga Island, both in the coast of Paraíba state, northeastern Brazil. Considering the Brazilian coast, Paraíba state is one of the least studied sites for malacofauna. Published information is restricted to specific studies on punctual species and/or in specific locations (*e.g.*, Dijck 1980; Muniz *et al*. 2000; Dias 2009; Gondim *et al*. 2011; Dias *et al*. 2013; Gondim *et al*. 2014).

It is evident that the molluscan fauna living along the coast of Paraíba state need to be investigated, and in this context, particularly useful is the compilation of a biological inventory, since this is the first step to understand a specific place or ecosystem. According to Mikkelsen & Cracraft (2001), systematic inventories provide essential data to support the conservation and sustainable use of biodiversity. Therefore, this study aims to inventory the malacofauna from three biotopes of back reef systems in four coastal areas of João Pessoa and Cabedelo cities, with the aim to expand the knowledge about the marine molluscan fauna of the state of Paraíba, northeastern Brazilian coast.

MATERIAL AND METHODS

The study was carried out in three shallow coastal areas along the coast of Paraíba State, northeastern Brazil: Ponta de Campina beach (7º02'04.68"S, 34º49'38.62"W), Cabo Branco reefs (7º09'18.52"S, 34º47'10.57"W), and Formosa beach (7º17'59.74"S, 34º47'54.29"W) (Figs. 1–4). For each area, a biotope type was studied, namely: algal banks (at Cabo Branco reefs), seagrass beds (at Ponta de Campina beach), and patch reefs (at Formosa beach).

For the species inventory, intensive searches for mollusks were conducted by snorkeling in standardized periods of four hours. During the random searches, the mollusks were collected manually or with the aid of a spatula, packed in plastic bags and/or jars, and then transported to the laboratory and acclimated in aerated tanks for anesthesia and subsequent triage and analysis. To study the molluscan fauna associated to the macroalgae, thalli from the following species were collected: *Caulerpa racemosa* (Forsskål) J. Agardh, 1873 (Caulerpaceae), *Padina gymnospora* (Kützing) Sonder, 1871 (Dictyotaceae), and *Sargassum* sp. C. Agardh, 1820 (Sargassaceae). These were carefully removed from the substrate and wrapped in plastic bags to prevent loss of individuals.

In the laboratory, all mollusks were anesthetized in 7% magnesium chloride, and fixed and preserved in 70% alcohol. After removal of mollusks, the collected macroalgae were fixed in 4% formalin. Sampled molluscan specimens were labeled and identified to the lowest possible taxonomic level, using specialized appropriate literature (*e.g.*, Hartmann 2006; Mikkelsen & Bieler 2008; Rios 2009; Tunnell Jr. *et al*. 2010) or with the aid of experts (*e.g.*, Dr. Carlo M. Cunha, Academy of Natural Sciences of Drexel University; Dr. Martin L. Christoffersen, Federal University of Paraíba).

The classification adopted here follows Malacolog 4.1.0 (Rosenberg 2009), Bouchet & Rocroi (2005), and Mikkelsen & Bieler (2008). The specimens were deposited in the Paulo Young Invertebrate Collection, Department of Systematics and Ecology of the Federal University of Paraíba (CIPY/DSE/UFPB) and in the Reference Collection of Mollusca in the State University of Paraíba, Campus I.

To evaluate the differences in species composition between biotopes, Nonmetric Multidimensional Scaling (NMDS) (Clarke & Gorley 2006) was performed using Primer 6 software. For this, data were tabulated into a presence-absence matrix, and the Jaccard similarity coefficient calculated.

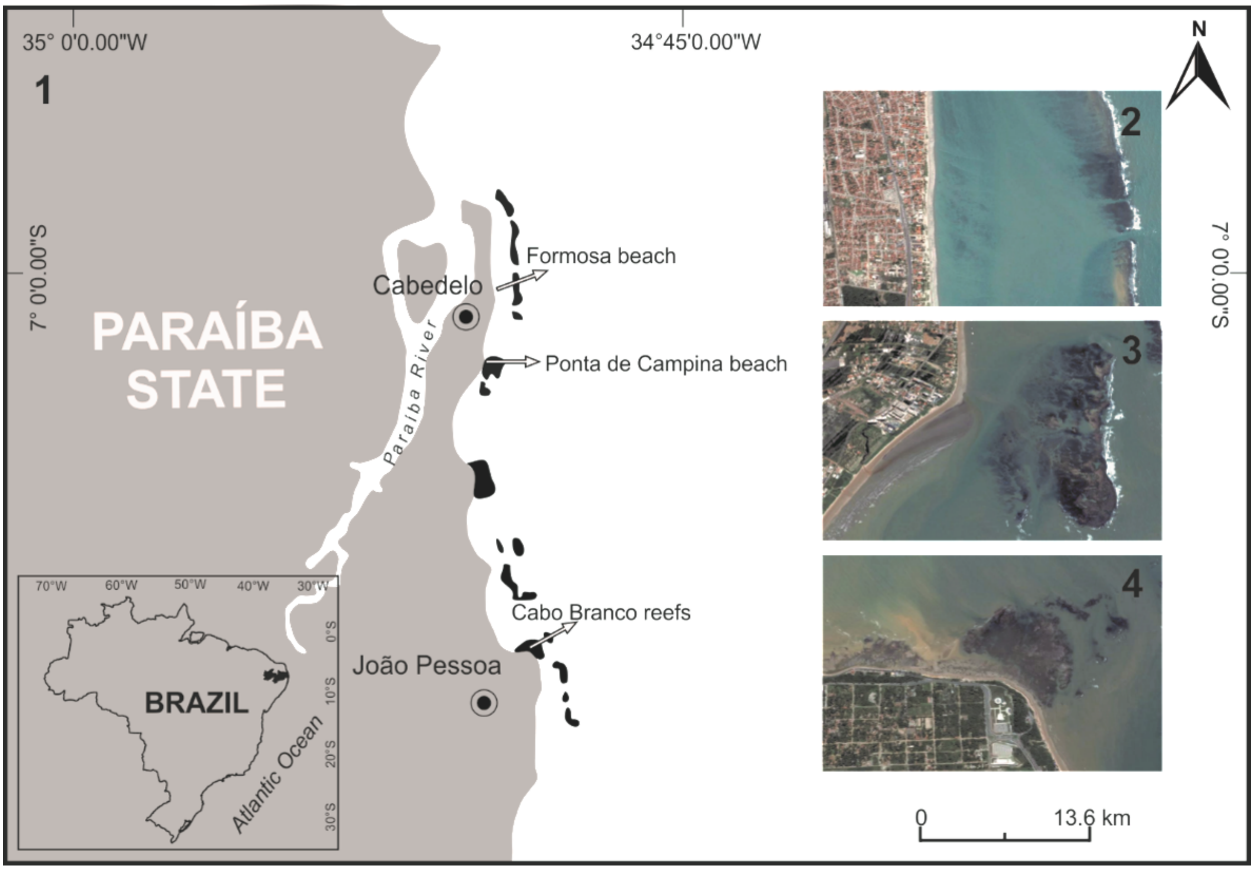
RESULTS

In the three studied sites a total of 65 mollusks species was found, distributed in the classes Polyplacophora (2 spp.), Gastropoda (48 spp.), Cephalopoda (1 sp.), and Bivalvia (14 spp.), comprising in total 40 families and 51 genera (Table 1). The Gastropoda were represented by 27 families and 36 genera, while Bivalvia totalized 11 families and 14 genera; Figures 5–12 illustrate some of the mollusk species recorded.

In general, the three biotopes show differences in species richness, with the highest value recorded for macroalgae (33 spp.) (Fig. 13); this difference was reflected in the relationship among biotopes, which showed a distinct composition of the molluscan fauna as demonstrated by the NMDS analysis (Fig. 14). In the patch reefs, 27 species were recorded, while in the seagrass beds 21 species were recorded (Fig. 13). In all biotopes, the gastropods were the richest taxon (Fig. 15); the families with the largest number of species were Columbellidae (7 spp.) and Caecidae (4 spp.) (Table 1). Families of bivalves represented by more than one species were Veneridae, Tellinidae, and Cardiidae (Table 1).

Analyzing the three macroalgae species studied, mollusks were represented by 33 species, belonging to 19 families and 24 genera, with 90.3% of them belonging to Gastropoda (n=31) (Fig. 16). On the three algal species, 303 individuals were found, among which *Schwartziella catesbyana* (d'Orbigny, 1842) (Rissoidae) (19.1%), and *Eulithidium affine* (C.B. Adams, 1850) (Phasianellidae) (14.1%) were the most abundant. The brown seaweed *Sargassum* sp. sheltered the largest number of species (16 spp.) and of individuals (n=131), contributing 43.2% to the total abundance recorded. Only two species of bivalves were recorded associated to the macroalgae: *Tellina* sp. and *Coralliophaga coralliophaga* (Gmelin, 1791) (Trapezidae).

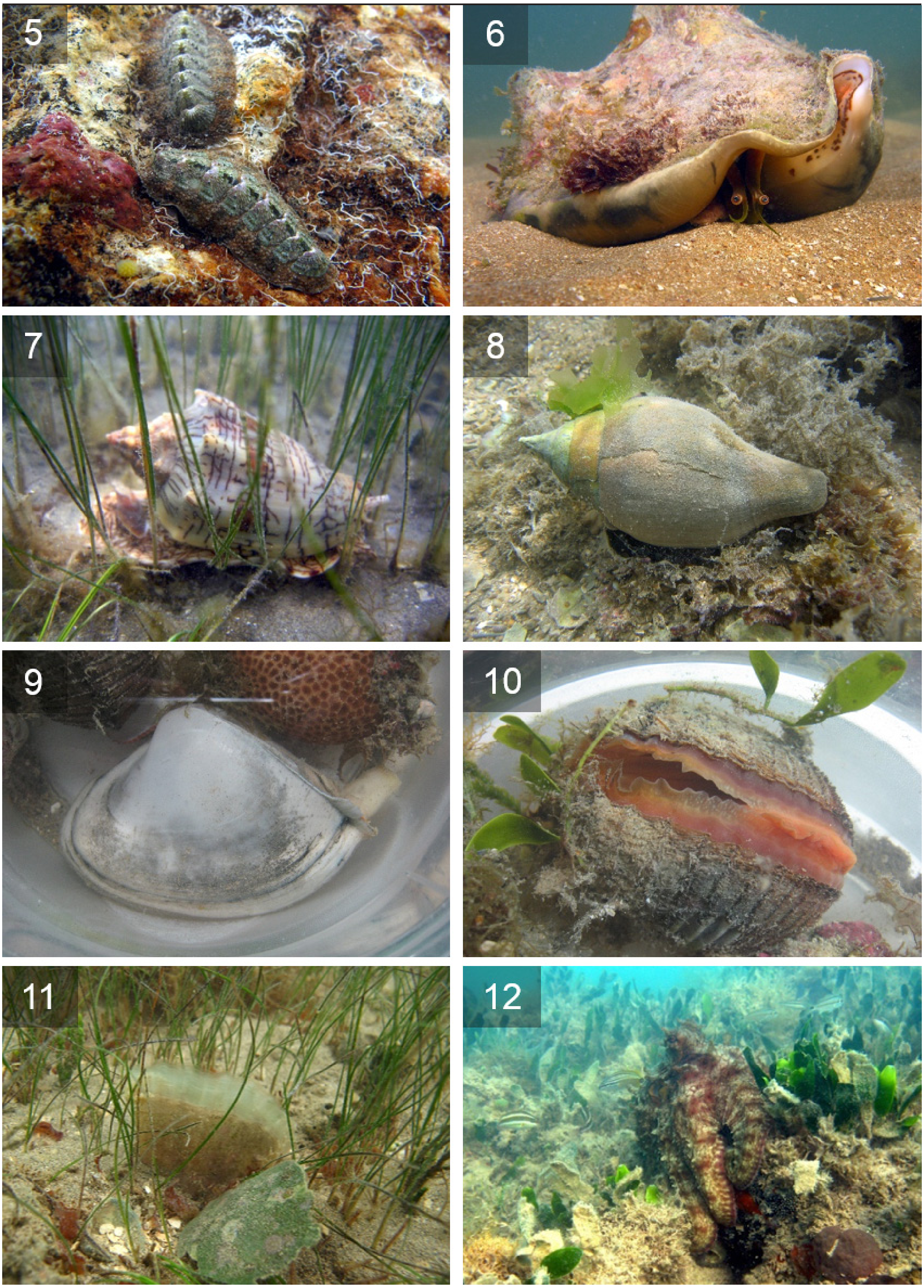
In the six patch reefs sampled, a total of 27 species were recorded, belonging to the Polyplacophora, Gastropoda, Bivalvia, and Cephalopoda, totaling 19 families and 23 genera. The family Columbellidae was the most rich, being represented by four species. Among the bivalves (n=8), all families found were represented by a single species, except Veneridae, with two species: *Chione* sp. and *Anomalocardia brasiliana* (Gmelin, 1791) (Veneridae). For the first time, an adult individual of *Lobatus costatus* (Gmelin, 1791) (Strombidae) (Fig. 6) was recorded for the Paraíba state coast. This specimen was 20 cm in shell length and was seen at one meter deep, on sandy bottom in the spaces between the patch reefs.



Figures 1–4. Location of the study sites on the coast of Paraíba state, northeastern Brazil. **1.** Map of the collection sites along the coasts of João Pessoa and Cabedelo cities. **2.** Partial view of Formosa beach. **3.** Partial view of Ponta de Campina beach. **4.** Partial view of Cabo Branco reefs. Source: Google Earth.

Two large gastropods of commercial value were also recorded: the Hebrew volute (*Voluta ebraea* Linnaeus, 1758; Volutidae) (Fig. 7) and the Brazilian chank (*Turbinella laevigata* Anton, 1838; Turbinellidae) (Fig. 8), both endemic to northeastern Brazil. These species were commonly observed in the patch reefs during the daylight hours. *Voluta ebraea* was usually moving over the patches, while *T. laevigata* was partially buried in the sand among the patch reef's boulders. Among the opisthobranch mollusks, four species represent the first formal record for the Paraíba coast: *Bursatella* cf. *leachii* Blainville, 1817 (Aplysiidae), *Discodoris evelinae* Er. Marcus, 1955 (Discodorididae), *Oxynoe antillarum* Mörch, 1863 (Oxynoidae), and *Elysia subornata* A. E. Verrill, 1901 (Plakobranchidae) (Figs. 17–20). Three large species of bivalves were recorded with soft parts: *Mactrellona alata* (Spengler, 1802) (Mactridae), *Atrina rigida* (Lightfoot, 1786) (Pinnidae), and *Anadara notabilis* (Röding, 1798) (Arcidae) (Figs. 9–11).

On the two seagrass beds studied (*Halodule wrightii* Ascherson, 1868; Cymodoceaceae), 21 species were recorded, distributed in 19 genera and 15 families. Among them, the gastropods had the highest number of species, confirming the pattern observed for all sampled biotopes. In general, mollusks associated with *H. wrightii* were adhered to its linear leaves or among them. The species commonly adhered were micromollusks such as juvenile *Neritina virginea* (Linnaeus, 1758) (Neritidae), *Olivella minuta* (Link, 1807) (Olivellidae), and *Cerithium atratum* (Born, 1778) (Cerithiidae). Larger species such as *T. laevigata* and *V. ebraea* were also seen using this biotope as a place for protection and spawning, as well as to forage.



Figures 5–12. Some mollusk species recorded in the studied back reef systems. **5.** *Ischnochiton pectinatus*. **6.** *Lobatus costatus*. **7.** *Voluta ebraea*. **8.** *Turbinella laevigata*. **9.** *Mactrellona alata*. **10.** *Anadara notabilis*. **11.** *Atrina rigida*. **12.** *Octopus insularis*. Photos by Thelma Dias.

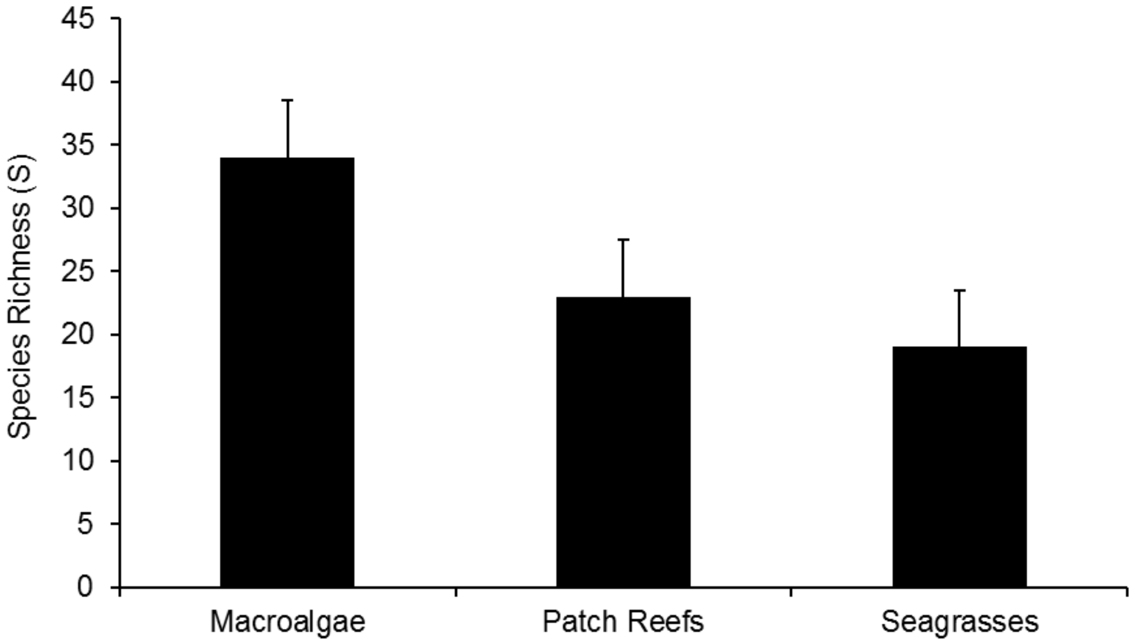


Figure 13. Species richness of mollusks associated with different back reef habitats studied in the coast of Paraíba state, northeastern Brazil.

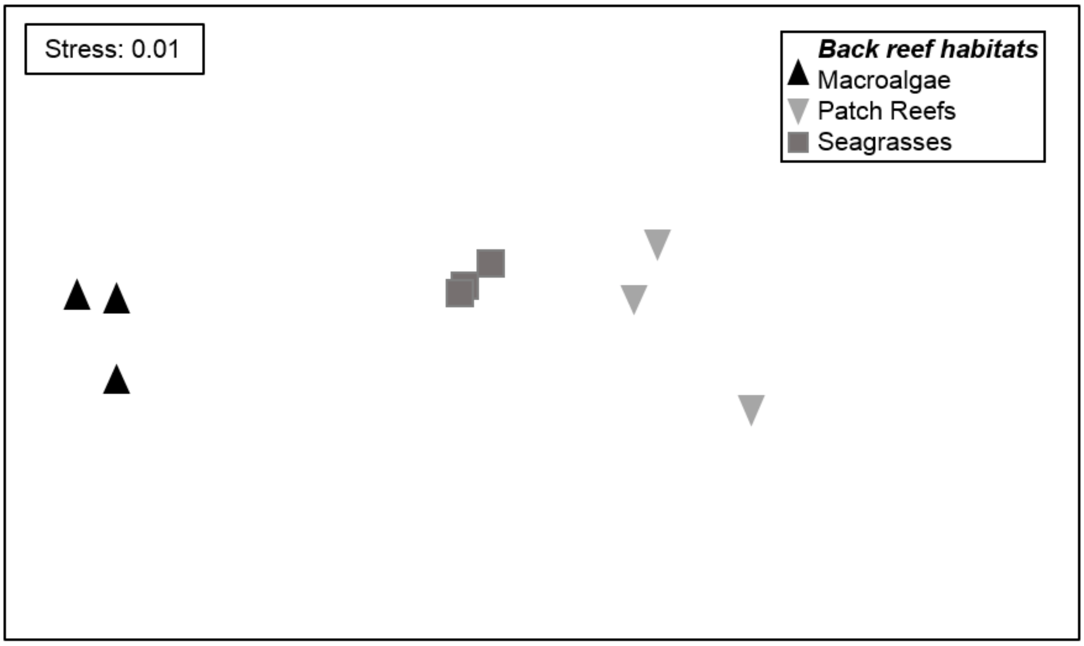


Figure 14. Nonmetric Multidimensional Scaling (NMDS) plot based on the composition of mollusk species recorded at the three studied back reef habitats.

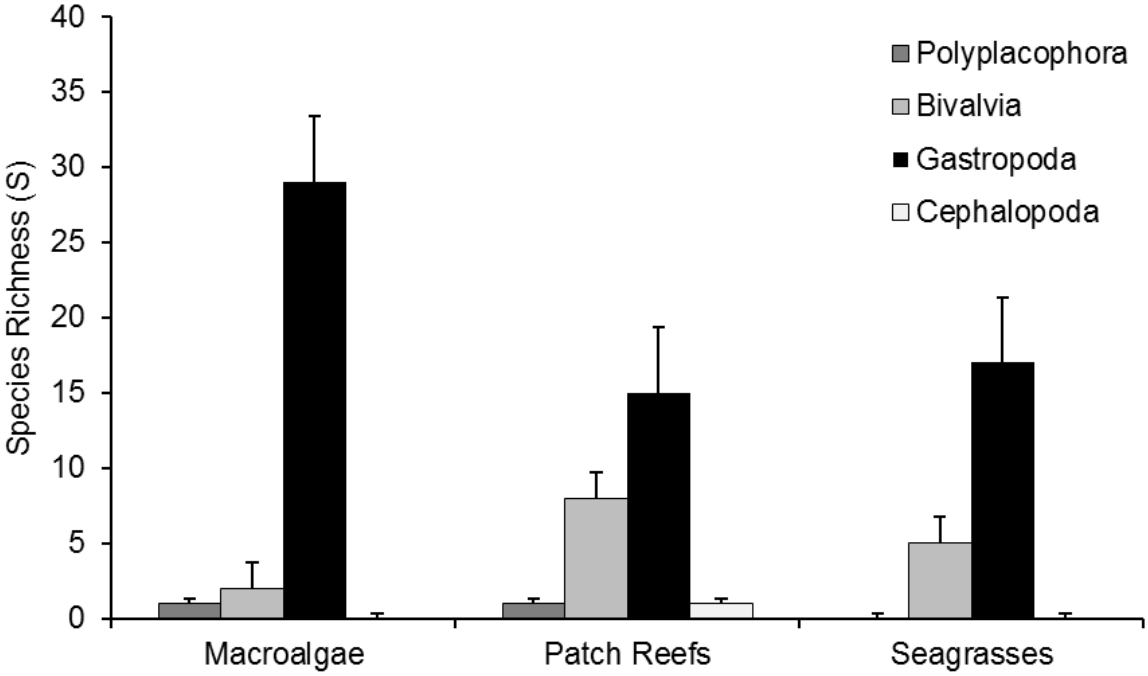


Figure 15. Mollusk species richness (S) recorded in each of the back reef habitats studied in the coast of Paraíba state, northeastern Brazil

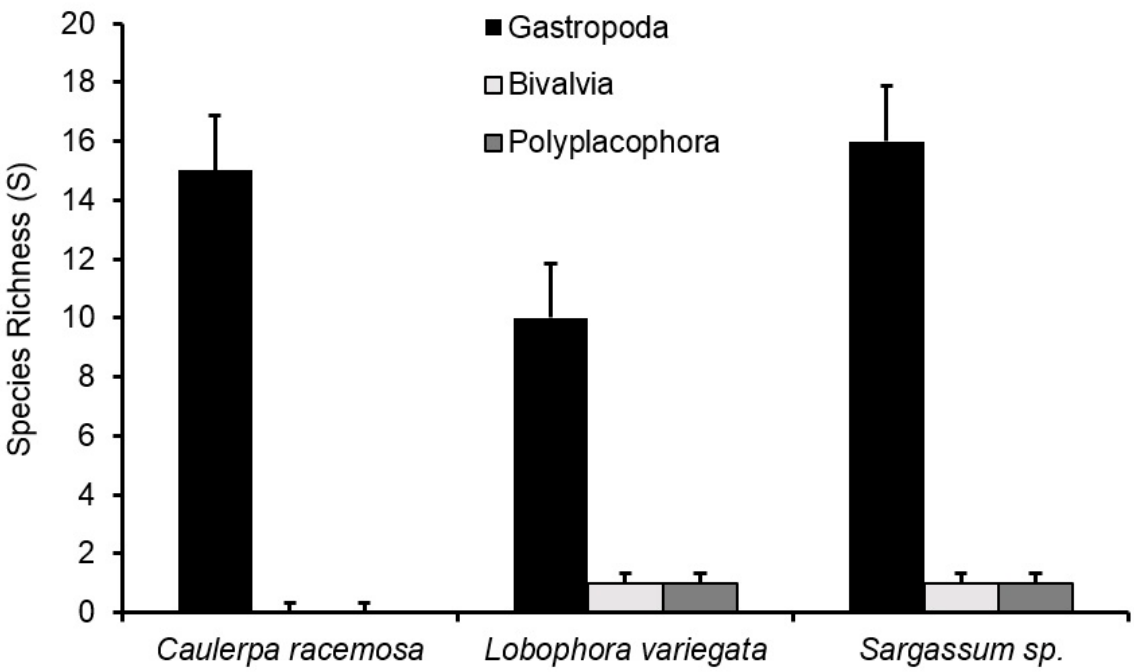
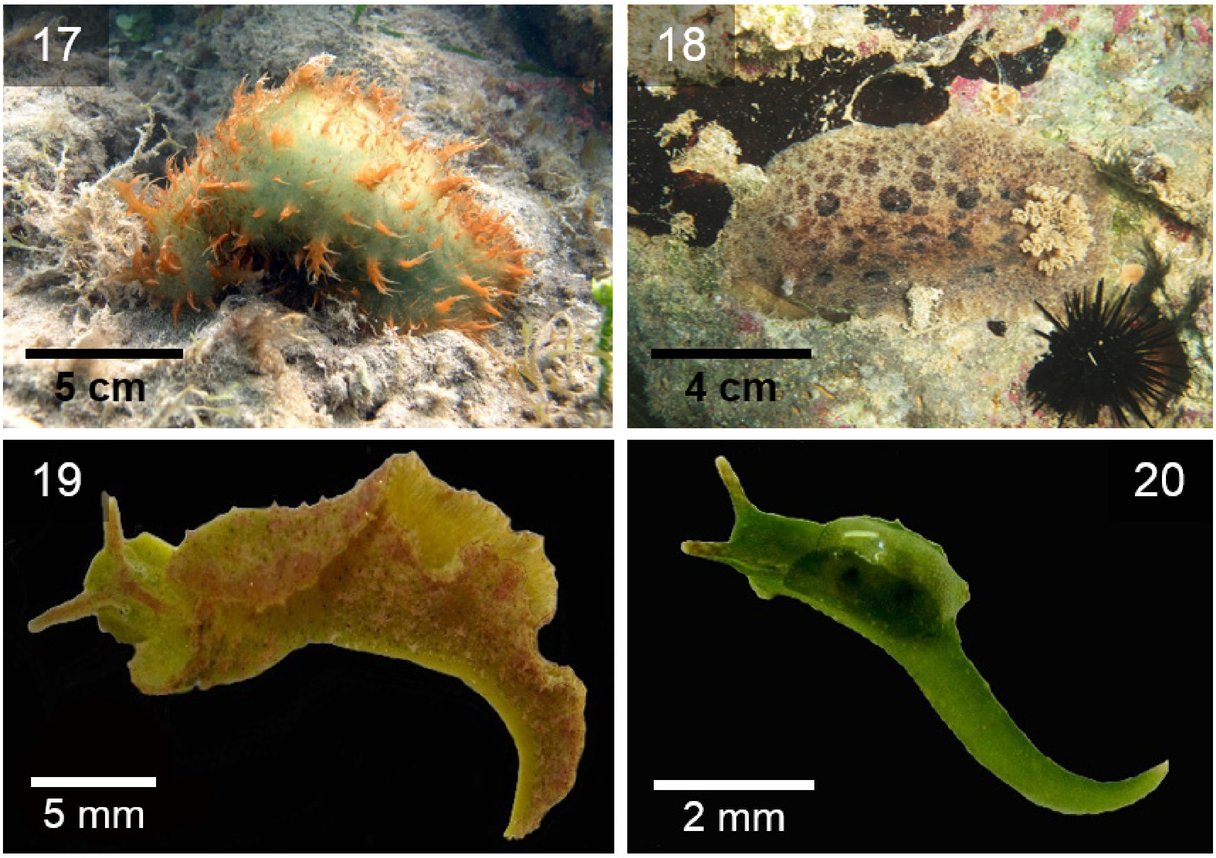


Figure 16. Mollusk species richness (S) associated with the fronds of three macroalgae species sampled in the back reef habitats.



Figures 17–20. Some opisthobranch mollusks recorded in the studied back reef systems. **17.** *Bursatella* cf. *leachii*. **18.** *Discodoris evelynae*. **19.** *Elysia subornata*. **20.** *Oxynoe antillarum*. Photos by Thelma Dias.

DISCUSSION AND CONCLUSION

In general, the molluscan fauna associated to the algal banks consisted mainly of small species that found in this biotope an environment that provides them with food, shelter, and protection from predators. The most abundant species in the macroalgae was the microgastropod *Rissoina sagraiana* (d'Orbigny, 1842) (Rissoidae), which reaches a maximum size of 6 mm (Rios 2009).

Microgastropods belonging to the genus *Caecum* Fleming, 1817 were also abundant, being associated to all three studied macroalgae species. This genus typically inhabits algal banks, but can also be found on hard substrates such as mangrove roots, among the grains of sand adjacent to reefs and on the seagrass beds sediments (Mello & Maestrati 1986). Microgastropods of the genus *Caecum* were also abundant in association with the branches of *Caulerpa racemosa* on beaches with different degrees of hydrodynamics in southeastern Brazil (Leite *et al.* 2009a). According to these authors, small gastropods of the genera *Schwartziella* G. Nevill, 1885, *Turbonilla* Risso, 1826, *Anachis* H. & A. Adams, 1953, and *Boonea* Robertson, 1978 are also part of the molluscan fauna associated with *C. racemosa*, similar to that observed in this study. The molluscan fauna associated to *Caulerpa prolifera* (Forsskål) J.V. Lamouroux, 1809 (Caulerpaceae) in Spain was also dominated by microgastropods, including those of the family Rissoidae (Rueda & Salas 2003). This suggests that the leaves of macroalgae may be important habitats for micromollusks regardless of geographic region or even regardless of algal species. The first record of some species of opisthobranch mollusks provides additions to the marine biodiversity of Paraíba state, since according to Garcia *et al*. (2008), this taxon is still subsampled in this area.

Table 1. List of species recorded in the three back reef habitats studied along the coast of Paraíba state, with voucher numbers. Macroalgae, patch reefs and seagrasses were studied, respectively, at Cabo Branco reefs, Formosa beach and Ponta de Campina beach.

Class/Families/Species	Macroalgae	Patch reefs	Seagrasses	Vouchers
POLYPLACOPHORA				
Ischnochitonidae				
Ischnochiton striolatus (Gray, 1828)	*			UEPB/Mol.1058
Ischnochiton pectinatus (Sowerby, 1840)		*		UEPB/Mol.1059
GASTROPODA				
Fissurellidae				
Fissurella sp.	*			UEPB/Mol.13
Diodora cayenensis (Lamarck, 1822)	*	*		UEPB/Mol.27, 15
Diodora dysoni (Reeve, 1850)		*		UEPB/Mol.1060
Diodora sp.	*			UEPB/Mol.1061
Calliostomatidae				
Calliostoma sp.	*			UEPB/Mol.11
Phasianellidae				
Eulithidium affine (C. B. Adams, 1850)	*		*	UEPB/Mol.25, 1062
Eulithidium thalasicola (Robertson, 1958)	*			UEPB/Mol.10
Neritidae				
Neritina virginea (Linnaeus, 1758)			*	UEPB/Mol.1063
Cerithiidae				
Cerithium atratum (Born, 1778)			*	UEPB/Mol.1064
Cerithium eburneum Bruguière, 1792			*	UEPB/Mol.1065
Bittiolum varium (Pfeiffer, 1840)			*	UEPB/Mol.1066
Modulidae				
Modulus modulus (Linnaeus, 1758)			*	UEPB/Mol.1067
Calyptraeidae				
Bostrycapulus sp.	*			UEPB/Mol.22
Bostrycapulus odites R. Collin, 2005		*		UEPB/Mol.208
Naticidae				
Natica marochiensis (Gmelin, 1791)			*	UEPB/Mol.1068
Rissoidae				
Rissoina sagraiana (d'Orbigny, 1842)	*			UEPB/Mol.6
Schwartziella bryerea (Montagu, 1803)	*			UEPB/Mol.12
Schwartziella sp.	*			UEPB/Mol.1069
Caecidae				
Caecum sp.1	*			UEPB/Mol.1070
Caecum sp.2	*			UEPB/Mol.1071
Caecum sp.3	*			UEPB/Mol.1072
Caecum pulchellum Stimpson, 1851	*			UEPB/Mol.1073
Triphoridae				
Cerithiopsis gemmulosa (C. B. Adams, 1850)	*			UEPB/Mol.1074
arshallora nigrocincta (C. B. Adams, 1839)	*			UEPB/Mol.1075
Strombidae				
Lobatus costatus (Gmelin, 1791)		*		UEPB/Mol.1076
Buccinidae				
Engina turbinella (Kiener, 1836)	*			UEPB/Mol.1077
Columbellidae				
Columbella mercatoria (Linnaeus, 1758)	*	*	*	UEPB/Mol.16, 314, 1078
Anachis lyrata (Sowerby I, 1832)	*		*	UEPB/Mol.03, 1079
Parvanachis obesa (C. B. Adams, 1845)	*	*	*	UEPB/Mol.1104, 1107, 1108
Zafrona idalina (Duclos, 1840)		*		UEPB/Mol.1080

Costoanachis sp.	*			UEPB/Mol.1081
Costoanachis sparsa (Reeve, 1859)		*		UEPB/Mol.1082
Astyris lunata (Say, 1826)	*			UEPB/Mol.21
Muricidae				
Stramonita rustica (Lamarck, 1822)	*			UEPB/Mol.1083
Trachypollia nodulosa (C. B. Adams, 1845)		*		UEPB/Mol.313
Fasciolariidae				
Pleuroploca aurantiaca (Lamarck, 1816)		*		UEPB/Mol.1084
Marginellidae				
Volvarina albolineata (Orbigny, 1842)		*		UEPB/Mol.316
Volvarina avena (Kiener, 1834)	*			UEPB/Mol.1085
Turbinellidae				
Turbinella laevigata Anton, 1838	*		*	UEPB/Mol.112
Volutidae				
Voluta ebraea Linnaeus, 1758	*		*	Photographic record
Olivellidae				
Olivella nivea (Gmelin, 1791)			*	UEPB/Mol.1086
Olivella minuta (Link, 1807)	*	*	*	UEPB/Mol.1103, 318, 1105
Olivella sp.		*		UEPB/Mol.1087
Conidae				
Conus jaspideus Gmelin, 1791			*	UEPB/Mol.1088
Pyramidellidae				
Boonea jadisi (Olsson & McGinty, 1958)	*			UEPB/Mol.34
Haminoeidae				
Haminoea sp.	*			UEPB/Mol.1085
Aplysiidae				
Phyllaplysia engeli Marcus, 1955	*			UEPB/Mol.1989
Bursatella leachii Blainville, 1817		*		Photographic record
Oxynoidae				
Oxynoe antillarum Mörch, 1863	*			UEPB/Mol.1090
Oxynoe sp.	*			UEPB/Mol.1091
Plakobranchidae				
Elysia subornata A. E. Verrill, 1901	*	*		UEPB/Mol.1092
Discodorididae				
Discodoris evelinae Marcus, 1955		*		UFPB/Mol.1107
BIVALVIA				
Arcidae				
Anadara notabilis (Röding, 1798)		*		UEPB/Mol.145
Noetiidae				
Arcopsis adamsi (Dall, 1886)		*		UEPB/Mol.1101, 1106
Chamidae				
Chama sp.		*		UEPB/Mol.31
Veneridae				
Anomalocardia brasiliana (Gmelin, 1791)		*		UEPB/Mol.1093
Chione sp.		*	*	UEPB/Mol.375
Choristodon robustus (Sowerby I, 1834)			*	UEPB/Mol.1094
Lucinidae				
Divalinga quadrisulcata (d'Orbigny, 1846)			*	UEPB/Mol.1095
Cardiidae				
Trachycardium muricatum (Linnaeus, 1758)			*	UEPB/Mol.1096
Laevicardium brasilianum (Lamarck, 1819)			*	UEPB/Mol.1097
Tellinidae				
Tellina sp.	*			UEPB/Mol.19
Eurytellina punicea (Born, 1778)			*	UEPB/Mol.1098
Trapezidae				
Coralliophaga coralliophaga (Gmelin, 1791)	*			UEPB/Mol.1099

Mactridae		
Mactrellona alata (Spengler, 1802)	*	UEPB/Mol.111
Pinnidae		
Atrina rigida (Lightfoot,1786)	*	UEPB/Mol.1100
CEPHALOPODA		
Octopodidae		
Octopus insularis Leite & Haimovici, 2008	*	Photographic record

The ecological importance of patch reefs for marine and estuarine molluscan fauna is largely unknown, given the lack of studies in this area. Several economically important invertebrate species in the Caribbean, *Panulirus argus* (Latreille, 1804) (red spiny lobster) (Palinuridae), for example, use the patch reefs as a place of recruitment and permanent habitat (Lipcius & Eggleston 2000). The exploited gastropod *Lobatus gigas* (Linnaeus, 1758) (Strombidae), which is a species of great commercial value in the artisanal fisheries in the Caribbean, also uses patch reefs as juveniles and adults, which draws attention to the importance of conservation for this nursery habitat (Stoner 1997).

The presence of large species such as *Lobatus costatus*, *Turbinella laevigata*, and *Voluta ebraea*, which are also economically relevant in northeastern Brazil, especially for the ornamental shell trade, makes patch reefs habitats of special importance for coastal monitoring, for harboring species whose conservation status is unknown. According to Dias *et al.* (2011), *V. ebraea* is a major commercial species in the marine curio trade along the coast of Paraíba state and its occurrence in shallow water facilitates its capture by artisanal and occasional fishermen. These authors emphasize that anecdotal data obtained from fishermen suggest population decline of this species in the last decade.

In addition, patch reefs were the only biotope sampled in which was recorded the presence of the cephalopod *Octopus insularis* Leite & Haimovici, 2008 (Octopodidae), a common species from northeastern Brazil and one of the most exploited cephalopods by artisanal fisheries (Fig. 12). Although *O. insularis* inhabits oceanic areas, it also occurs along the entire coastline of the Brazilian northeast, where it can be found in shallow water on rocks or associated with patch reefs, especially as juveniles (Leite *et al*. 2009b).

According to Casares & Creed (2008), the seagrass beds significantly increase the density and diversity of macrofauna in comparison with areas without vegetation. In a study conducted in Guanabara Bay, Rio de Janeiro, these authors recorded 22 species of mollusks associated with banks of *Halophila decipiens* Ostenfeld, 1902 (Hydrocharitaceae), and observed dominance of the gastropod *Cerithium atratum*. Although the present study did not provide quantitative data, the number of recorded species associated with the beds of *Halodule* in Paraíba (n=21) was similar to the total recorded by Casares & Creed (2008) in *Halophila* beds in Rio de Janeiro (n=22). Species such as *C. atratum*, *Olivella minuta*, and *Chione* sp. were present in both studies. Although most studies involving marine fauna associated with seagrasses refer to the fish fauna (*e.g.*, Nagelkerken *et al*. 2000), the importance of this ecosystem for marine and estuarine macrofauna has been globally recognized. Dahlgren & Marr (2004) highlight the environmental problems that affect the back reef systems, such as overfishing, sediment discharge, and direct destruction. The authors emphasize that these ecosystems are in disadvantage by not having the same publicity of reef environments, for example.

In conclusion, it was observed that the back reef systems might harbor a rich fauna of mollusks. The variety of habitats provided by different back reef biotopes favors colonization of small species, large gastropods and bivalves, and those of average size that are most commonly seen. This pioneering study provides data that can instigate new baseline research and more accurate ecological studies to understand the importance of these back reef habitats to adjacent reef ecosystems.

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