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Polyplacophora (Mollusca) from reef ecosystems and associations with macroalgae on the Coast of Alagoas, Northeastern Brazil

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ABSTRACT. Brazilian marine molluscs, especially Gastropoda and Bivalvia, are relatively well studied. However, information on the class Polyplacophora is more scarce, particularly on reef-dwelling forms. This study aimed to qualitatively and quantitatively analyze aspects of polyplacophorans from reef ecosystems and their associations with macroalgae on the coast of Maceió (state of Alagoas, Brazilian Northeast). The study area included five coral reefs at Ipioca, Ponta do Prego, Ponta do Meirim, Riacho Doce and Ponta Verde, as well as two sandstone reefs, located in Guaxuma and Sereia. The samples were obtained by snorkelling along the intertidal and subtidal reef zones to a depth of up to five meters during low tides, between 2009 and 2011. In addition, the chitons associated with three macroalgae of the Ponta Verde coral reef were studied based on collections made over 12 years (from the summer of 1998 to the winter of 2009). Three replicates with an area of 25 cm^2 were collected from each of the following species of macroalgal phytals: *Amphiroa fragilissima* (Rhodophyta), *Caulerpa racemosa* (Chlorophyta) and *Dictyota cervicornis* (Phaeophyta). A total of 715 individuals (110 juveniles and 605 adults) were identified, including *Acanthochitona terezae* Guerra, 1983, *Ischnochiton striolatus* (Gray, 1828) and *Ischnoplax pectinata* (Sowerby II, 1840). *Acanthochitona terezae* was found for the first time in the area. *Ischnochiton striolatus* was the most abundant species in the reef ecosystem and in association with macroalgae. The greatest number of individuals of all three polyplacophorans identified (adults and juveniles) was found on the phytal *A. fragilissima*.

KEY WORDS. Chitons; Brazilian reefs; biodiversity; phytal; temporal distribution.

The Polyplacophora differ from the other taxa of the phylum Mollusca in that their dorsal shell is formed by eight plates or valves, and the mantle forms a belt around the plates. They are benthic and photonegative, usually associated with rocky surfaces where specimens can be found on the undersurface (Kaas & Van Belle 1990, 1998, Kaas et al. 2006). They mostly occur in the intertidal zone, although some rare species inhabit greater depths (Chelazzi et al. 1987, 1990, Dell'Angelo et al. 2010, Ávila & Sigwart 2013). However, there is little information about their presence in reef ecosystems (Ferreira 1985, Lyons & Moretzsohn 2009, Dell'Angelo et al. 2011, Schwabe et al. 2008).

In Brazil, progress was made on the taxonomy of Polyplacophora in the last century by Righi (1967), who reported six species, and highlighted the variety of colors and spots in collected individuals. Four new species were later described by Righi (1971), who also discussed the distribution of the 15 species recorded along the coast of Brazil. In the Ilha Grande Bay, off the coast of Rio de Janeiro, five species were found, including a common species from the Antarctic and Sub-Antarctic. This occurrence was attributed to the transport of larvae by the upwelling of the Falklands current (Righi 1973). New species were described for the Brazilian coast, where they were found on algae attached to stones uncovered by the low tide (Guerra Júnior 1982, 1983, 1985). Brazilian marine molluscs were reported to include 24 Polyplacophora species (Rios 1994) and more recently, 34 species with expanded distributions (Rios 2009).

The chiton fauna was described by several studies on marine molluscs of the southeastern coast. At the São Paulo coast, three species were found in the São Sebastião channel, on the shore of the São Sebastião Island (Migotto et al. 1993, Salvador et al. 1998), and on the rocky shores of São Francisco (Denadai & Amaral 1999). The greatest colour plate diversity of individuals was observed on the coast of Rio de Janeiro (Rodrigues & Absalão 2005). Only three species were reported in the southern and southeastern regions of Brazil (Amaral et al. 2006). Polyplacophora were considered to be quite scarce on the northeastern coast. In the first study on marine molluscs from the coast of Alagoas, only two species were identi-

fied, *Ischnochiton erythronotus* (C. B. Adams, 1845) and *Ischnoplax pectinata* (Sowerby II, 1840) (Rios & Cardoso 1967). They were characterized by occasional associations with different macroalgae on the coral reef of Maceió, state of Alagoas, Brazil, compared with other invertebrate groups (Santos & Correia 1994, 1995, 2001), and only one species was present in shallow reefs on the coast of Paraíba (Gondim et al. 2011).

Reef ecosystems on the coast of northeastern Brazil, such as those in the state of Alagoas, have a rich biological diversity (Correia & Sovierzoski 2009), including the fauna associated both with seagrasses and macroalgae, with numerous species of molluscs (Rios 2009), many of which belong to the subclass Opisthobranchia (Padula et al. 2012), some species of Ophiuroidea (Lima et al. 2011, 2013), and many sponges with new species (Bispo et al. 2014, Cedro et al. 2011, 2013). The reef ecosystems are abundant in Alagoas' coastal region, including coral reefs and sandstone reefs (Correia 2011), which provide various natural substrates for the Polyplacophora. However, this particular class of molluscs is poorly known in the region.

This study qualitatively and quantitatively characterized the chiton fauna that was found in reef ecosystems and in association with algae on the coast of Maceió.

MATERIAL AND METHODS

The present study was carried out in reef ecosystems along the coast of Maceió, located between the geographic coordinates 9°30'S, 35°35'W and 9°40'S, 35°41'W. The study area included five coral reefs from Ponta Verde, Riacho Doce, Ponta do Meirim, Ponta do Prego, and Ipioca, as well as two sandstone reefs situated in Guaxuma and Sereia (Fig. 1). The climate of the coast of Alagoas is tropical and is influenced by the Atlantic Ocean, which provides a warm and humid climate with small thermal differences throughout the year. However, rainy and dry periods are well defined and occur from May to September, corresponding to winter (rainy season), and from October to April, corresponding to summer (dry season) (Correia & Sovierzoski 2009). This rainfall distribution directly influences the invertebrate fauna on the coastal reefs that were studied, especially along the sandstone reefs that are most affected by river discharge (Figs. 2-4).

From 2009 to 2011, specimens were collected on the reefs in the intertidal and subtidal zones in depths up to five meters. The samples were collected manually along the shore and by snorkelling in the tide pool and along the edge of the reef platforms during low tide. The molluscs were placed in individual plastic bags with seawater and 10% $MgCl_2$, which served as an anesthetic, and transported to the laboratory at the Sector of Benthic Communities (UFAL). We also made a separate study of the Polyplacophora species associated with three macroalgae, namely *Amphiroa fragilissima* (Rhodophyta), *Caulerpa racemosa* (Chlorophyta), and *Dictyota cervicornis* (Phaeophyta), on the Ponta Verde coral reef. Samples of algae were obtained from

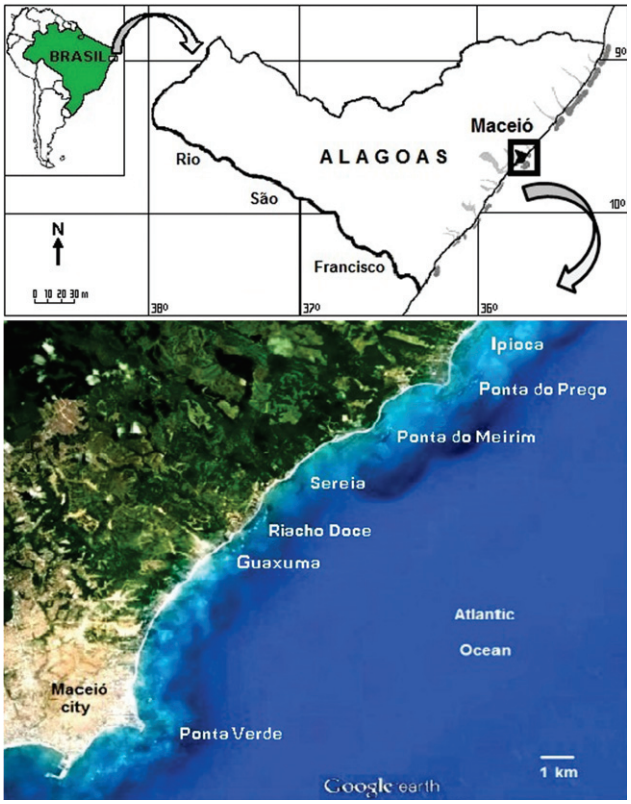


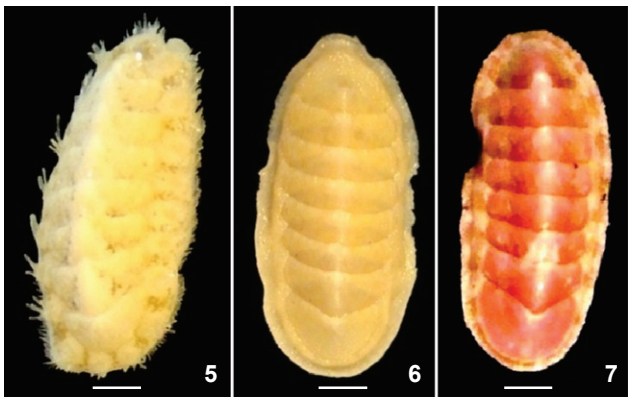
Figure 1. Map of the Alagoas state in northeastern Brazilian and, the coast of the Maceió with the location of reef ecosystems studied.

the tide pools over 12 years, with collections taking place twice per year, one in the dry season (summer) and the other in the rainy season (winter), using three replicates with an area of 25 cm^2 for each algal substrate. Specimens collected in the field were sorted and fixed in 10% formalin for 24 to 48 hours and then preserved in 70% alcohol. The external morphology of individuals was used for identification to the species level whenever possible, using the literature and taxonomic keys. All specimens are deposited in the Mollusca collection in the Sector of Benthic Communities at the Federal University of Alagoas. The total values and standard deviations of the number of individuals are presented in graphs according to the distribution in the summer and winter periods.

RESULTS

The reefs from the Maceió coast included two families and three species of the class Polyplacophora: Acanthochitonidae with *Acanthochitona terezae* Guerra, 1983 and Ischnochitonidae with two subfamilies, namely Ischnochitoninae, represented by *Ischnochiton striolatus* (Gray, 1828), and Callistoplacinae, represented by *Ischnoplax pectinata* (Figs. 5-7). On the seven reef eco-

Figures 2-4. Reef ecosystems on the Maceió coast in Alagoas, Brazil: (2) Urban area: Ponta Verde coral reef; (3) Central coast: (A) Guaxuma, (B) Riacho Doce, (C) Sereia. (4) North coast: (D) Ponta do Meirim, (E) Ponta do Prego, (F) Ipioca. Photos M.D. Correia.



Figures 5-7. Polyplacophora species from reef ecosystems on the Maceió coast, Alagoas: (5) *Acanthochitona terezae*, UFALMOL 0406; (6) *Ischnochiton striolatus*, UFALMOL 0415; (7) *Ischnoplax pectinata*, UFALMOL 0434. Scale bars: 5 = 1 mm, 6 = 2 mm, 7 = 5 mm. Photos M.D. Correia.

systems along the coast of Maceió, 381 adults and six juveniles were found, including *I. pectinata* and *I. striolatus*, where the last species was the most abundant on coral reefs, but *A. terezae* was not found (Tab. 1). Most likely, the reduced number of chitons found on the sandstone reefs was associated with greater influence of freshwater in these habitats.

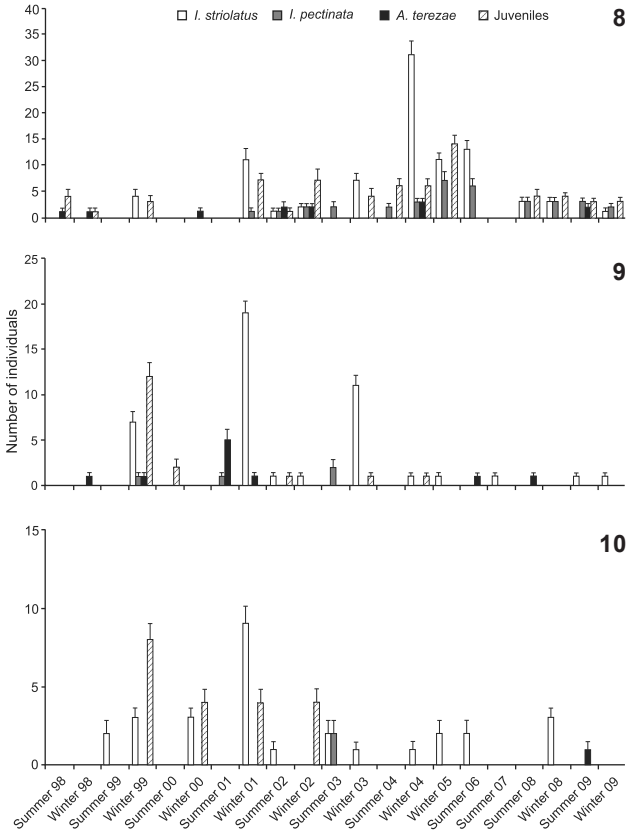
Table 1. Polyplacophora species distribution from reef ecosystems on the Maceió coast in Alagoas.

Reef ecosystems	*Ischnochiton striolatus*	*Ischnoplax pectinata*	Juveniles	Total
Ponta Verde	104	8	–	112
Guaxuma	3	2	3	8
Riacho Doce	26	47	3	76
Sereia	11	15	–	26
Ponta do Meirim	18	14	–	32
Ponta do Prego	78	7	–	85
Ipioca	40	8	–	48
Total	280	91	6	387

Three species, with 328 individuals (224 adults and 104 juveniles), were found to be associated with phytals: *I. striolatus*, *I. pectinata* and *A. terezae*. The phytal *A. fragilissima* had 201 Polyplacophora, of which *I. striolatus* was the most abundant, with a few individuals of each species, *I. pectinata* and *A. terezae*, being found, mostly juveniles (Fig. 8). On the phytal *C. racemosa*, only a small number of associated chitons were observed and a significant percentage of those were juveniles (Fig. 9). The fewest number of Polyplacophora was found on the phytal *D. cervicornis*, but the numbers peaked temporally in the winter with the highest peak in the winter of 2001 (Fig. 10). The different peaks observed in the three algae habitats were most likely related to reproduction being positively influenced by rainfall during the winter periods. However, the high numbers observed on *A. fragilissima* were related to the morphological structures of the alga, with more interstitial space among the filaments, and also the presence of food supply, as well as the low hydrodynamics on the tide pool reefs.

Ischnochiton striolatus was the numerically dominant species on the three phytals and occurred in more abundance on the phytal *A. fragilissima* during the winters of 2001, 2004 and 2005, and in the summer of 2006. Abundance peaks on the other two phytals were observed in the winter of 2001 on *D. cervicornis* and in the winters of 1999, 2001, and 2003 on *C. racemosa*.

Ischnoplax pectinata was numerically important on the phytal *A. fragilissima*, with a similar distribution during some periods and with peaks in the winter of 2005 and the summer of 2006. On the phytals *C. racemosa* and *D. cervicornis*, specimens occurred mainly during summer 2001 and 2003.

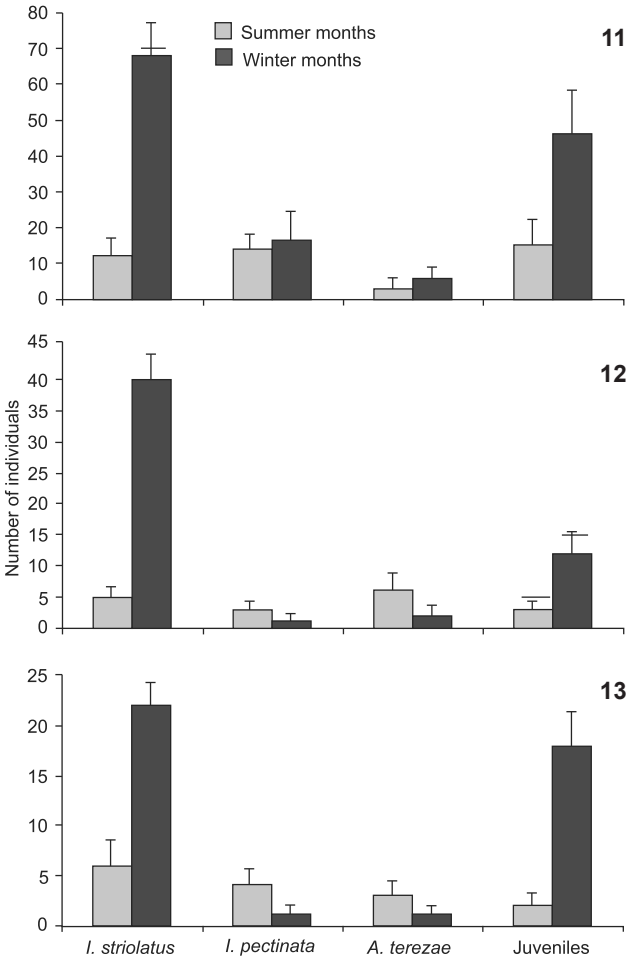


Figures 8-10. Temporal distribution of Polyplacophora on associated phytals of the Ponta Verde coral reef in Maceió, Alagoas: (8) *Amphiroa fragilissima*; (9) *Caulerpa racemosa*; (10) *Dictyota cervicornis*.

Acanthochitona terezae was the least abundant species on the three phytals analysed in this study, with a total of only 12 individuals found on the phytal *A. fragilissima* and 10 specimens on the phytal *C. racemosa*, where the majority of specimens occurred in the summer with a peak in 2001. The phytal *D. cervicornis* had only a single individual of *A. terezae* in the summer of 2009.

Juveniles occurred in relatively high numbers on all three phytals analysed: 67 individuals were found on *A. fragilissima*, 20 individuals on *D. cervicornis* and 17 individuals on *C. racemosa*, totalling 104 juveniles. The temporal variation of the abundance of juveniles was quite similar to that reported for *I. striolatus*, with dominance during winters and a peak occurring in 2005 on the phytal *A. fragilissima*, as well as peaks on *C. racemosa* and *D. cervicornis* in the winter of 1999.

The distribution in summer and winter periods on *A. fragilissima* demonstrated that all chitons species that were found in the present study prefer winter periods. *Ischnochiton striolatus* and juveniles presented high number of individuals also in winter periods on the phytal *C. racemosa* and *D. cervicornis*. The results suggest a positive relationship, in the winter periods, between species abundance and lower salinity and small photoperiod, which probably also influence the chitons' reproduction during the year (Figs. 11-13).



Figures 11-13. Summer and winter distribution of Polyplacophora on associated phytals of the Ponta Verde coral reef in Maceió, Alagoas: (11) *Amphiroa fragilissima*; (12) *Caulerpa racemosa*; (13) *Dictyota cervicornis*.

DISCUSSION

Three Polyplacophora species were recorded for seven reef ecosystems and for three phytals from one site, along the coast of Maceió. *I. striolatus* and *I. pectinata*, which occurred in greater numbers on these reefs, were also reported by Denadai & Amaral (1999) and Amaral et al. (2006), who considered them to be typical inhabitants of consolidated substrates, and to occur in tropical climates in regions of high temperatures and salinities. Such distribution was also reported by Guerra Júnior

(1985) who found a lower abundance of individuals on the southern coast of Brazil, also noting that the highest concentrations of these three species were found in the warmer waters of the northeast coast. The same author (Guerra Júnior 1983) recorded *A. terezae* in Bahia, occurring in large numbers in the warm shallow waters of intertidal regions, and suggested that this species is well adapted to the tropical region.

The quantitative dominance of *I. striolatus* over *I. pectinata* was most likely related to the hydrodynamic action in the reef areas studied and to the fact that the samples of algal substratum were collected in tide pools, because *I. pectinata* is most commonly found in breaker reef areas with greater hydrodynamics (Gondim et al. 2011). However, *I. striolatus* was the most abundant species in coastal areas with medium strength hydrodynamics, as reported by Rodrigues & Absalão (2005). Regarding substrate preference, according to Kaas & Van Belle (1990, 1998) and Kaas et al. (2006), some species of the family Ischnochitonidae can often be found on calcareous algae, and these species live on the coast associated with different substrates such as rocks, stones, and shells, as observed in this work. The recruitment of some species occur mainly in protected habitats and in association with coralline algae in the intertidal region, because the chitons feed on diatoms and bluegreen algae present in the biofilm commonly found in these algae (Lord 2011). The preference for calcareous algae may explain the large number of the two species belonging to this family that were found associated with the alga *A. fragilissima* on the Ponta Verde coral reef.

The low number of individuals associated with the phytal *C. racemosa* may have been a result of its location on the coral reef of Ponta Verde, where this alga occurred in areas near the edge of the reef platform with intense hydrodynamics (Santos & Correia 1994). In the same study, *A. fragilissima* was observed in tide pools of protected reef areas, which may possibly explain the great number of individuals associated with this phytal. However, *D. cervicornis* was recorded on irregular patches in tide pools and relatively protected reef areas, but this alga produces diterpenes that repel many invertebrate organisms (Bianco et al. 2010), which may explain its low number of associated Polyplacophora.

The difference in structure and hardness of algal stalks may be another factor that influences the number of individuals associated with the phytals studied in this work, as this factor could influence the habitat conditions for the associated faunal communities. Coralline algae had a higher rate of sediment retention by a stem, which benefits the associated invertebrate fauna by decreasing the negative effects of the physical stress of desiccation, reducing the mortality rate due to predation, increasing available space for the establishment of new larvae, refuge for many invertebrates that inhabit their fronds and also use them as food (Boström & Bonsdorff 2000, Kelaher 2002). In the present study all chitons species, both adults and juveniles, which were found on the three phytals demonstrated a preference for the winter periods, between May and September. This suggests a positive relationship with the winter periods: the rainy season with its lower salinities and photoperiods influence chiton reproduction, as found for photonegative animals. It is probable that in the very hot summer months the chitons move to deeper areas of the reefs (Deheyn et al. 2000). On the phytal *A. fragilissima*, *I. striolatus* was more abundant, with specimens peaking in four winter periods in 2001, 2003, 2004 and 2005, but also in the summer of 2006. The algae *C. racemosa* and *D. cervicornis* showed some similar temporal distribution for *I. striolatus*, with one peak in the winter of 2001 and with juvenile specimens peaking in the winter of 1999. The preference of *A. fragilissima* was also reported for nine species of Ophiuroidea at the same reef on the Maceió coast (Lima et al. 2013). The comparison between Polyplacophora and Ophiuroidea, both of which are photonegative organisms, indicated that the two invertebrate groups have algal preferences that correlate with their temporal distributions, such as demonstrated by Lord (2011). The highest number of specimens in both groups of invertebrates was found on the phytal *A. fragilissima*, most likely due to the morphological structure of this alga that has interstitial space among the algal filaments, and the same morphological preference has also been reported for the Amphipoda (Hacker & Steneck 1990).

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