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New host for *Dissodactylus crinitichelis* (Decapoda, Pinnotheridae): First record of occurrence on *Mellita quinquiesperforata* (Echinodermata, Echinoidea)

(Decapoda; Echinodermata)

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This paper presents the first report on the association between *Dissodactylus crinitichelis* Moreira, 1901 and *Mellita quinquiesperforata* (Leske, 1778) based on specimens found in Brazilian waters. Eighty-two specimens of sand dollars were collected and about 18 % harboured a total of 16 pea crabs. All crabs were found clinging underneath the oral surface of *M. quinquiesperforata*. The association found here suggests that the pinnotherid has a non-obligatory symbiotic association with *M. quinquiesperforata*.

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Introduction

The coast of Brazil has considerable potential for interactions among marine invertebrates due to the diversity of ecosystems, which favours the existence of different ecological regimes. In this ecoregion, sponges, cnidarians, polychaetes, molluscs, echinoderms and crustaceans are among the metazoans with a remarkable variety of interspecific interactions (Coelho & Ramos-Porto 1995, Wirtz et al. 2009, Almeida et al. 2010, Queiroz et al. 2011a,b, De Assis et al. 2012, Padua et al. 2013, Queiroz et al. 2013).

The many groups of symbiotic crustaceans include members of the family Pinnotheridae De Haan, 1833. Pinotherid crabs (informally named pea crabs) comprise a small group of decapods commonly living in symbiotic association with other marine invertebrates such as tunicates (Hernández & Bolaños 1995), polychaetes (McDermott 2005), burrowing shrimp (McDermott 2006), molluscs (Geiger & Martin 1999) and echinoderms (Queiroz et al. 2011a). Among Echinodermata Bruguière, 1791, Holothuroidea de Blainville, 1834 and Echinoidea Leske, 1867 are the only taxa with which pea crabs have previously been found in association (Queiroz et al. 2011a).

The pinotherid genus *Dissodactylus* Smith, 1870

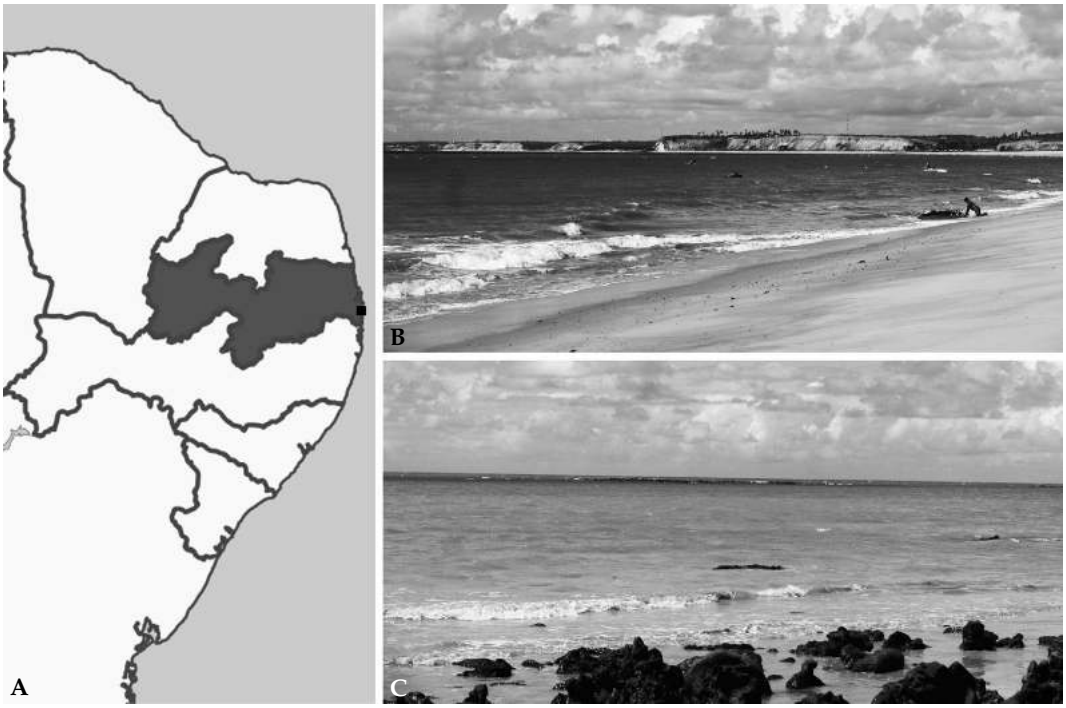

Fig. 1. A. Map of study area (northeastern Brazil: state of Paraíba). **B–C.** Photos of intertidal zone on Jacarapé Beach (state of Paraíba) showing sandy bottoms and diffuse rocky aggregations.

is represented by nine species distributed primarily along the Atlantic and Pacific coasts of the Americas and specifically associated with irregular echinoids (Spatangoida L. Agassiz, 1840 and Clypeasteroida A. Agassiz, 1872) (Griffith 1987a, b, Campos & Griffith 1990). *Dissodactylus crinitichelis* Moreira, 1901 is one of the four congeners reported for the Atlantic Ocean, the distribution of which ranges from the United States of America (state of North Carolina) to Argentina (Griffith 1918, Martins & D'lncao 1996, Fumis et al. 2006). To date, *D. crinitichelis* has been reported in association with five echinoids: four Clypeasteroida [*Encope emarginata* (Leske, 1778); *E. michelini* Agassiz, 1841; *Clypeaster subdepressus* (Gray, 1825) and *Leodia sexiesperforata* (Leske, 1778)] and one Spatangoida [*Meoma ventricosa* (Lamarck, 1816)] (Rathbun 1918, Telford 1978, 1982, Campos & Solís-Marín 1998, Wirtz et al. 2009). On the coast of Brazil, *D. crinitichelis* has been found in association with *E. emarginata*, *L. sexiesperforata*, *M. ventricosa*, *Clypeaster* sp., *Mellita* sp. and *Luidia* sp. (Martins & D'lncao 1996, Wirtz et al. 2009, Queiroz et al. 2011a). The present paper reports the association between *Dissodactylus crinitichelis* and *Mellita quinquiesperforata* (Leske, 1778) for the first time. In addition, a checklist of associations of Atlantic species of the genus *Dissodactylus* is presented based on data from the literature.

Materials and methods

The present study was carried out in the intertidal zone of Jacarapé Beach (07°11'47.19"S, 34°47'44.31"W), city of João Pessoa, state of Paraíba, northeastern Brazil. This coastal environment is characterized mainly by the presence of cliffs in a state of high erosion lashed by the highest levels of water movement, as well as reefs, corals, calm waters with a light current, sandy bottoms and detritic bottoms, the homogeneity of which is at times broken up by scattered rocks and diffuse rocky aggregations (Fig. 1).

Sand dollars were collected manually (randomly) and checked macroscopically for the presence of pea crabs on May 22nd and June 29th, 2013 during low tide at depths of 0.2 to 1 m. Immediately after collection, some echinoids and their associated crabs were placed on the sand and photographed in situ. Each host with its symbiont was placed in a plastic bag with sea water and stored in a cold container in an attempt to reduce stress and avoid the separation of the associated organisms. The specimens were taken to the laboratory and photographed alive under a stereomicroscope. The crabs were than fixed in 70% ethanol and the sand dollars were dried.

The prevalence (P = percentage of infested hosts) and mean burden (MB = mean number of crabs per sand dollar) were recorded during each sampling based on Bell (1988).

All specimens studied are deposited in the following scientific collections: Crustacea collection of Museu Nacional, Universidade Federal do Rio de Janeiro (MNRJ), Rio de Janeiro, Brazil; Crustacea collection of Museu de Zoologia, Universidade Federal da Bahia (UFBA), Salvador, Bahia, Brazil; Echinodermata and Crustacea collections of Laboratório de Invertebrados Marinhos do Ceará, Universidade Federal do Ceará (LIMCE-UFC), Fortaleza, Ceará, Brazil; Aquatic Invertebrates collection of Departamento de Zoologia, Universidade Federal de Pernambuco (UFPEINV), Recife, Pernambuco, Brazil.

Results

Description of association

The associated organisms were found in shallow waters, on sandy bottoms in the intertidal zone. In all cases, specimens of *Dissodactylus crinitichelis* were found clinging underneath the oral surface of *Mellita quinquiesperforata* (Fig. 2A-B) closely attached to the lunules or ambital notches (Fig. 2C-D). The crabs remained clinging firmly to the spines of the sand dollars, mainly around the lunules, even after the hosts were removed from the water. No crabs were observed on the aboral surface. The carapace and appendices of the crabs had slightly variable colour tones, rather convergent to the oral surface of the hosts, especially the spines of the region between the petaloids (Figs 2C–D, 3A–D).

A total of 82 individuals of *Mellita quinquiesperforata* and 16 specimens of *Dissodactylus crinitichelis* were sampled on 22.v.2013 and 29.vi.2013. During the first sampling 30 sand dollars were collected and nine of them had crabs: five males, three females and one couple. P on this date was 30 % and MB was 0.33, ranging from 0 to 2 crabs per sand dollar. During the second sampling 52 sand dollars were collected and six had crabs: two males and four females (no couples). P on this date was 11.5 % and MB was 0.11 crabs per sand dollar.

Material examined. *Dissodactylus crinitichelis* occurring on *Mellita quinquiesperforata*: 6 specimens (3 ♂, 3 ♀), UFBA 1703, 1704, UFBA ECH 01807; 4 specimens (3 ♂, 1 ♀) are with the authors – northeastern Brazil, Paraíba State, João Pessoa, Jacarapé Beach (7°11' 47.19"S, 34°47' 44.31"W, 0.2 to 1.0 m depth, 22.v.2013, collected by I. H. Bravo de Laguna and R. Mioso); 2 ♀, LIMCE–UFC 706; 2 ♀, MNRJ 23567; 2 ♂, UFPEINV03 – northeastern Brazil, Paraíba State, João Pessoa, Jacarapé Beach (7°11'47.19"S, 34°47'44.31"W, 0.2 to 1.0 m depth, 29.vi.2013, collected by I. H. Bravo de Laguna and R. Mioso).

Discussion

Crustaceans have a wide variety of lifestyles ranging from primarily free to admittedly parasitic (Queiroz et al. 2011a). However, divergences among researchers are found regarding the feeding habits of some groups, such as *Dissodactylus* (Pohle & Telford 1981, Telford 1982, Queiroz et al. 2011a). According to Pohle & Telford (1981), *D. crinitichelis* is an obligate parasite requiring a host to complete its lifecycle. Based mainly on stomach contents, Telford (1982) deduced that *D. mellitae* (Rathbun, 1900) and *D. crinitichelis* are obligate parasites, while *D. primitivus* Bouvier, 1917 is a facultative one. However, no studies have been conducted on the feeding preference and behaviour of pea crabs on one or more hosts, and inferences on these factors are therefore weakened (Queiroz et al. 2011a).

The association found herein suggests that *Dissodactylus crinitichelis* has a non-obligatory symbiotic association with *Mellita quinquiesperforata*. The behavioural pattern and camouflage may be important adaptations for the association between this pinnotherid and sand dollars.

In particular, specimens of *Mellita quinquiesperforata* seem to act as a convenient substratum/microhabitat moving on the sediment surface (Alexander & Ghiold 1980), which allows easy occupation by *Dissodactylus crinitichelis*. This sand dollar has been found in high population densities and biomass values in regions of the western Atlantic (Alexander & Ghiold 1980, Matos et al. 2000, Tavares & Borzone 2006), making this species an important component of habitat diversity, dispersion and interactions with small invertebrates. *Mellita quinquiesperforata* seems restricted to terrigenous sediments, while *Leodia sexiesperforata* (another common host of *D. crinitichelis*) to biogenic carbonate sediments (Telford & Mooi 1986). Thus, these two echinoids rarely co-exist.

Regarding the behavioural pattern, *Dissodactylus crinitichelis* was always found on the underside of *Mellita quinquiesperforata* moving and sheltering between the spines, which must offer some refuge against predation. The crabs remained clinging firmly to the spines of the sand dollars even after the hosts were removed from the water. This behaviour is similar to that reported in previous studies involving *D. crinitichelis* and other congeners of the western Atlantic (Gray et al. 1968, Werding & Sanchez 1989; Almeida et al. 2010: fig. 8; Queiroz et al. 2011a: fig. 1F), except for *D. mellitae*, which generally drops off the host after its removal from the water (Gray et al. 1968). Competitive interactions and predation pressure have been recognized as key factors promoting variation in the habitat use and

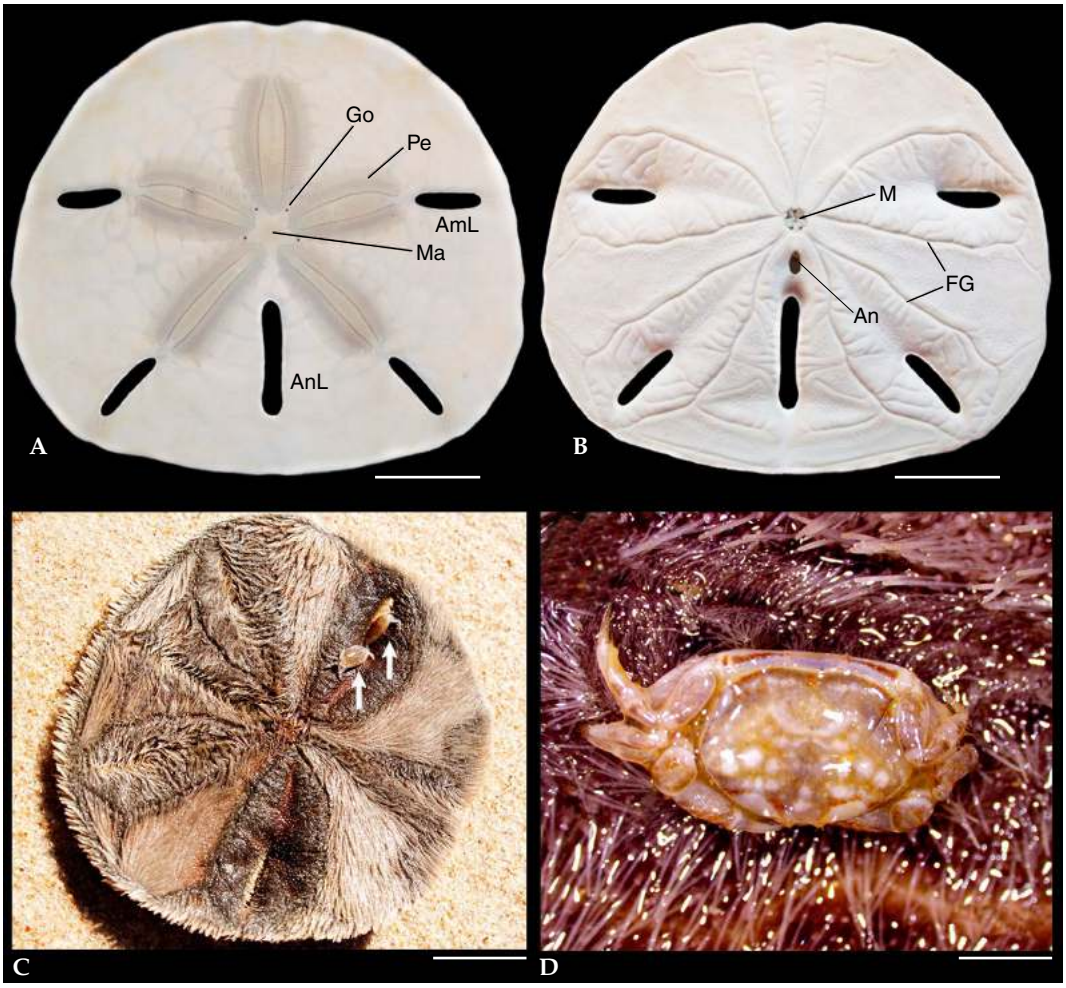

Fig. 2. *Mellita quinquiesperforata* and *Dissodactylus crinitichelis*. **A.** Aboral view (sand dollar). **B.** Oral view (sand dollar). **C–D.** Interaction between species showing crab on oral side of sand dollar (in vivo: arrows pointing to the crabs). Scale bars: A, B, C = 2 cm, D = 2 mm. Abbreviations: **AmL**, ambulacral lunule; **An**, anus; **AnL**, anal lunule; **FG**, food groove; **Go**, gonopore; **M**, mouth; **Ma**, madreporite; **Pe**, petaloid.

the existence of symbiotic lifestyles (Vance 1978, Thompson et al. 1993).

Experiments revealed that the lunules on *Mellita quinquiesperforata* function as important devices in the capture and passage of food particles (Alexander & Ghiold 1980). Specimens of *Dissodactylus crinitichelis* were always found closely attached to the lunules of the sand dollar. In general, pinnotherid crabs are well adapted to a typical commensal lifestyle as well as kleptoparasitic to parasitic lifestyles (Pohle & Telford 1981, Telford 1982, Thoma et al. 2009, Queiroz et al. 2011a). In this investigation, no areas of damage to the tissue of *M. quinquiesperforata* were observed in the presence of pea crabs. Previous studies on associations between *D. crinitichelis* and other sand dollars have described a rather monoxenous parasitic relationship based on analyses of stomach contents from *Leodia sexiesperforata* (Leske, 1778) (Pohle & Telford 1981, Telford 1982). This lends support to the notion that *D. crinitichelis* is a species with considerable ecological plasticity and different modes of feeding on a reasonable variety of hosts in the western Atlantic.

Dissodactylus crinitichelis exhibits a yellowish carapace and appendices on a slightly whitish to slightly transparent background, which suggests rather convergent colour matching with the host. According to Bell & Stancyk (1983), the congener

D. mellitae is cryptically coloured on the underside of *Mellita quinquiesperforata*, which helps reduce post-metamorphic mortality. In the present study, the specimens of *D. crinitichelis* captured had a soft carapace. According to Bell & Stancyk (1983), a soft carapace may be an adaptation to reduce irritation and death to the host.

Apparently, *Dissodactylus crinitichelis* has a rather different pattern of P and MB in comparison to *D. mellita*e. Bell (1988) found higher indices of *D. mellita*e per *Mellita quiquiesperforata* in winter (P = 39.3 %, MB = 0.51). In the present study, these values were lower for *D. crinitichelis* in samples collected in May (P = 30 %, MB = 0.33) and July (P = 11.5 %, MB = 0.11), when compared to the data provided by Bell (1988) for *D. mellita*e for the same host and seasonality. However, these findings should be compared based on the same sampling effort. The data provided herein suggest that 1) *D. crinitichelis* inhabits a greater variability of substrates for refuge, protection and/or feeding at Jacarapé Beach; and/or 2) *M. quinquiesperforata* is not the preferred host of *D. crinitichelis* (as suggested by Telford 1982).

The level of specificity of *Dissodactylus* on echinoid hosts in the Atlantic is variable. *Dissodactylus crinitichelis* is the most generalist species, based on the greater variety of environmental conditions and the six echinoid hosts, on which it can live along the western Atlantic (Table 1). Although *D. mellitae* is restricted to a narrow range of the northwest Atlantic, it also appears to be a generalist species, based on the variety of symbiotic associations with five echinoid hosts (*Echinarachnus parma* (Lamarck, 1816), *Encope michelini*, *Mellita isometra* Harold & Telford, 1990,

Table 1. Checklist of association records between Echinoidea and species of *Dissodactylus* in Atlantic Ocean.

Dissodactylus	Echinoidea (host)	Localities	References
D. crinitichelis	*Clypeaster subdepressus*	Gulf of Mexico	Schmitt et al. (1973), Powers (1977), Werding & Sanchez (1989)
	Leodia sexiesperforata	Cuba; Barbados; Bahia (Brazil)	Schmitt et al. (1973), Pohle & Telford (1981), Telford (1982), Griffith (1987a), Campos & Solís-Marín (1998), Queiroz et al. (2011a)
	Encope emarginata	North Carolina, Florida (USA); Gulf of Mexico, Yucatan; Pernambuco, Bahia, São Paulo and Santa Catarina (Brazil)	Rathbun (1901), Costa (1967/69), Williams et al. (1968), Schmitt et al. (1973), Werding & Sanchez (1989), Coelho & Ramos-Porto (1995), Martins & D'Incao (1996), Fumis et al. (2006), Almeida et al. (2010)
	Encope michelini	Gulf of Mexico	Wass (1955), Schmitt et al. (1973), Powers (1977), Werding & Sanchez (1989)
	Mellita quinquiesperforata	Paraíba (Brazil)	Present study
	Meoma ventricosa	Santa Marta (Colombia); Espírito Santo (Brazil)	Werding & Sanchez (1989), Wirtz et al. (2009)
D. mellitae	*Echinarachnus parma*	North Carolina (USA)	Rathbun (1918), Williams (1965), Pollock (1998)
	Mellita isometra	Georgia (USA)	Hendler et al. (1995), George & Boone (2003)
	Encope michelini	North Carolina (USA)	Williams (1965), Williams et al. (1968)
	Mellita quinquiesperforata	North and South Carolina, Florida (USA)	Rathbun (1918), Wass (1955), Gray et al. (1968), Telford (1982), Bell & Stancyk (1983), Bell (1984, 1988), Griffith (1987a), Pollock (1998)
	Mellita tenuis	Florida (USA)	Marques & Pohle (1996)
D. latus	*Clypeaster subdepressus*	Florida (USA)	Griffith (1987a)
	Encope michelini	Florida (USA)	Griffith (1987a)
	Leodia sexiesperforata	Florida (USA)	Griffith (1987a)
D. primitivus	*Meoma ventricosa*	Barbados; Jamaica	Chesher (1969), Telford (1978, 1982), Griffith (1987a), Hendler et al. (1995), Campos & Solís-Marín (1998), De Bruyn et al. (2009, 2010, 2011), Jossart et al. (2013)
	Plagiobrissus grandis	Barbados; Jamaica	Chesher (1969), Telford (1982), Griffith (1987a), Hendler et al. (1995), De Bruyn et al. (2010, 2011), Jossart et al. (2013)

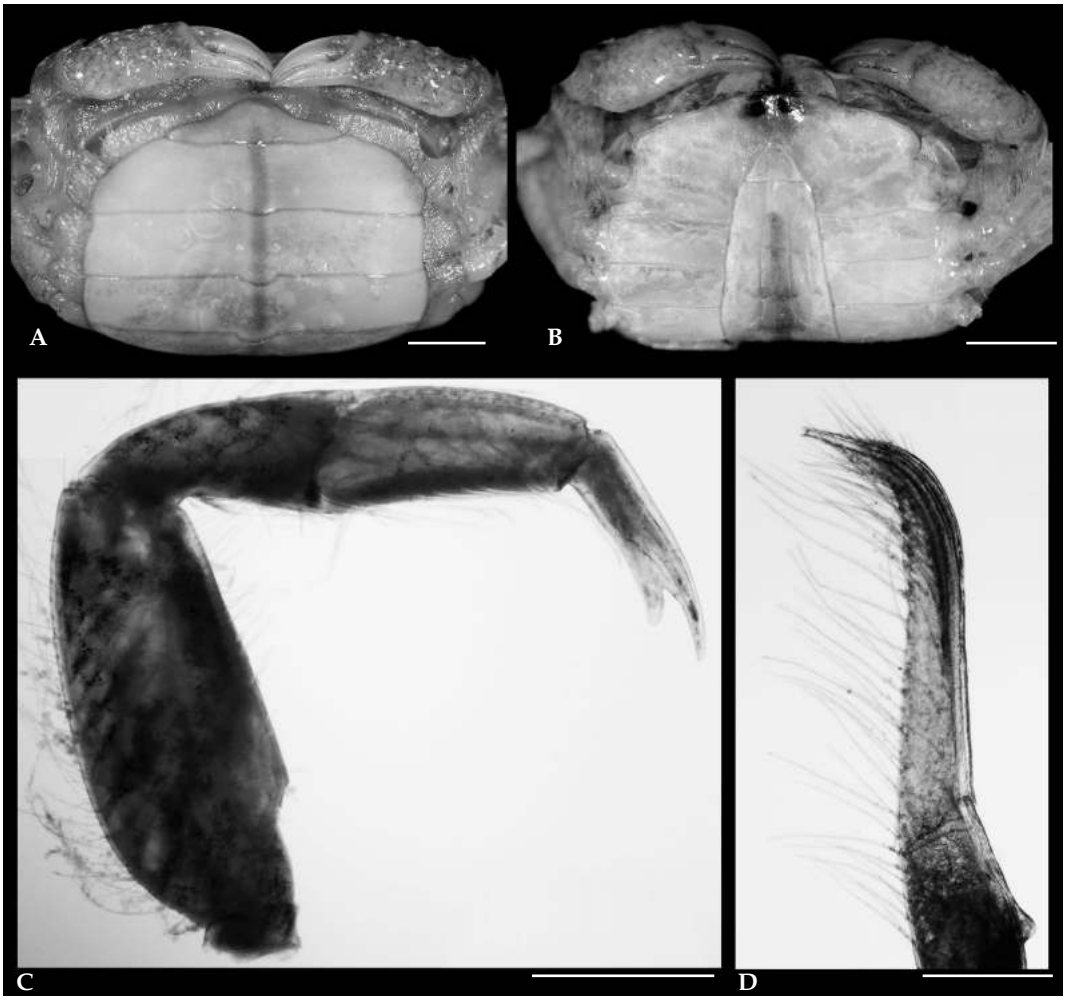

Fig. 3. *Dissodactylus crinitichelis*. **A.** Ventral view of female. **B.** Ventral view of male. **C.** Third ambulatory leg of male. **D.** Male gonopod. Scale bars: A, B = 1 mm, C = 500 µm, D = 250 µm.

Mellita quinquiesperforata and *M. tenuis* Clark, 1940) (Table 1). Apparently, *Dissodactylus latus* Griffith, 1987 and *D. primitivus* Bouvier, 1917 are known from a restricted distribution range and a lesser number of echinoid hosts (*Clypeaster subdepressus*, *Encope michelini* and *Leodia sexiesperforata*; *Meoma ventricosa* and/or *Plagiobrissus grandis* (Gmelin, 1788)) (Table 1), suggesting a group of specialist species.

The present findings support the hypothesis that the ecological understanding of pinotherid crabs on the Brazilian coast remains unsatisfactory and open to further research.

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