



Rediscovery and redescription of *Cassidulus infidus* (Echinoidea: Cassidulidae) from Northeastern Brazil

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Abstract

Cassidulus infidus Mortensen 1948b is one of the few recent species of the family Cassidulidae Agassiz & Desor 1847 and known only from its poorly described holotype. In Brazil, this family is represented only by two extant species and, to date, both are endemic to Bahia (*C. infidus*) and Rio de Janeiro (*Cassidulus mitis* Krau 1954). After a century of its first capture, some topotypes of *C. infidus* were found enabling its redescription, which are provided herein. The characterization of some of its ecological aspects and a key to the known species of *Cassidulus* are also given.

Key words: Echinodermata, taxonomy, identification key, Cassiduloidea, Bahia State

Resumo

Cassidulus infidus Mortensen 1948b é uma das poucas espécies recentes da família Cassidulidae Agassiz & Desor 1847 e conhecida apenas pelo seu holótipo, pobremente descrito. No Brasil, esta família é representada apenas por duas espécies recentes e, até o momento, ambas são endêmicas da Bahia (*C. infidus*) e Rio de Janeiro (*Cassidulus mitis* Krau 1954). Após um século da sua primeira captura, alguns topótipos de *C. infidus* foram encontrados, possibilitando a sua redescrção, provida neste trabalho. A caracterização de alguns dos seus aspectos ecológicos e uma chave de identificação para as espécies conhecidas de *Cassidulus* também são apresentadas.

Palavras-chave: Echinodermata, Taxonomia, chave de identificação, Cassiduloidea, Estado da Bahia

Introduction

Cassidulids appeared in the Late Cretaceous (Maastrichtian) and reached their peak in the Eocene, after passing through certain morphological changes such as reduction of the number of pores beyond petals from two to one, change from a tetrabasal to a monobasal apical disc and the introduction of buccal pores (Kier 1962). Cassidulidae is composed by about two to six fossil and two to five extant genera, depending on the classification used (e.g., Mooi 1990b; Smith 2005; Saucède & Néraudeau 2006; Kroh 2010 following the Treatise on Invertebrate Paleontology). Regarding the extant genera, *Cassidulus* Lamarck 1801, *Rhyncholampas* Agassiz 1869 and *Eurhodia* d'Archiac & Haime 1853 are well established in the family (Kier 1962; Smith 2005); and *Oligopodia* Duncan 1889 and *Studeria* Duncan 1889, however, were provisionally included by Mooi (1990b). Indeed, this inclusion has been supported by many cladistic analyses, which have shown that these genera are closely related to the other cassidulids (Suter 1994a; b; Wilkinson *et al.* 1996; Saucède & Néraudeau 2006). According to Suter (1994b), the monophyly of this family is supported by four synapomorphies, comprising an aboral lip above periproct (character reversed in *Cassidulus malayanus* Mortensen 1948b), a broad interambulacrum 5 naked zone, an ambulacral III naked zone, and the pitted test surface of the naked zones.

The genus *Cassidulus* appeared in the Paleocene (Early Palaeogene) as a sister clade of *Rhyncholampas* (Suter 1994a). Presently, it is the most extensive genus of the Cassidulidae, being composed of four extant species: *Cassidulus caribaeorum* Lamarck 1801, *Cassidulus malayanus*, *Cassidulus infidus* Mortensen 1948b, and *Cassidulus mitis* Krau 1954. Although Krau (1960) described the species *Cassidulus delectus* from Rio de Janeiro, Tommasi and Lima-Verde (1970) considered it as a synonym to *C. mitis*. To date, *C. infidus* and *C. mitis* are endemic to Brazil (Bahia and Rio de Janeiro, respectively). All mentioned species occur in sandy environments and, except for *C. malayanus*, which is found at 250–290 meters deep, all *Cassidulus* species inhabit warm shallow waters, probably up to 24 meters deep (Tommasi & Lima-Verde 1970; Mooi 1990a). In Brazil, *C. mitis* is far better studied (e.g., Freire *et al.* 1992; MacCord & Ventura 2004) than *C. infidus*, which is considered a poorly known species (Mooi 1990b) and has been put aside from the test of robustness of the analysis performed by Suter (1994b) due to the lack of information.

Cassidulus infidus was first identified by Sven Lovén and deposited at the Stockholm Museum, where it remained as a museum name (*nominum nudum*) until 1948, when Mortensen described it and decided to use the same name proposed by Lovén. The species is known only from a single specimen, without descriptions of morphological variations, information about its ecology, habitat and bathymetric range. In view of the absence of information, Mortensen (1948a) suggested that it could belong to a genus of its own because its test shape was quite distinct from *C. caribaeorum*.

After a century of its first capture, some specimens of *C. infidus* were found at the type locality, allowing this poorly documented species to be redescribed and providing new information on its ecology.

Material and methods

Abbreviations used: UFBA, Museu de Zoologia da Universidade Federal da Bahia, Brazil; SMNH, Swedish Museum of Natural History, Stockholm, Sweden; UFISITAB, Coleção de Equinodermos da Universidade Federal de Sergipe – Campus Itabaiana, Brazil; UFRJ, Universidade Federal do Rio de Janeiro, Brazil; CAS, California Academy of Sciences, USA. Measurement abbreviations are TL, test length; and TH/TL, height/length ratio.

Eight specimens of *Cassidulus infidus* deposited at the UFBA and UFISITAB collections were examined and measured using the software Image-Pro Express (v. 6.0) linked to stereo microscope Olympus SZ61 and optical microscope Olympus CX31-RTSF, as well as photographs from the holotype. Measurements were obtained according to Mooi (1990a). Dehydrated pedicellariae and sphaeridia were mounted on metal stubs with double-sided tape, coated with gold and examined with a JEOL JSM-6390LV scanning electron microscope. Test and spines were also drawn using a *camera lucida* linked to the microscope.

Specimens of *C. caribaeorum* and *C. mitis* from collections at UFBA, CAS and UFRJ were also examined for comparison.

Systematics

Class Echinoidea Leske 1778

Order Cassiduloida Agassiz & Desor 1847 (*sensu* Kroh & Smith 2010)

Family Cassidulidae Agassiz & Desor 1847

Cassidulus infidus Mortensen 1948b

(Figs. 1–7)

Cassidulus infidus Mortensen 1948a: 215; Mortensen 1948b: 67; Tommasi 1966: 21 [as *Cassidulus infidus*]; Manso *et al.* 2008: 184.

Material. Baía de Todos os Santos, BA, Brazil (12°48' S; 38°30' W), 29 August 1996, 3.5 m, 6 specimens (UFBA-314); Salvador, BA, Brazil (13°01' S; 38°29' W), February 2008, 11 m, 1 specimen (UFBA-757); Bahia, Brazil, 1 specimen (SMNH-Type-4859).

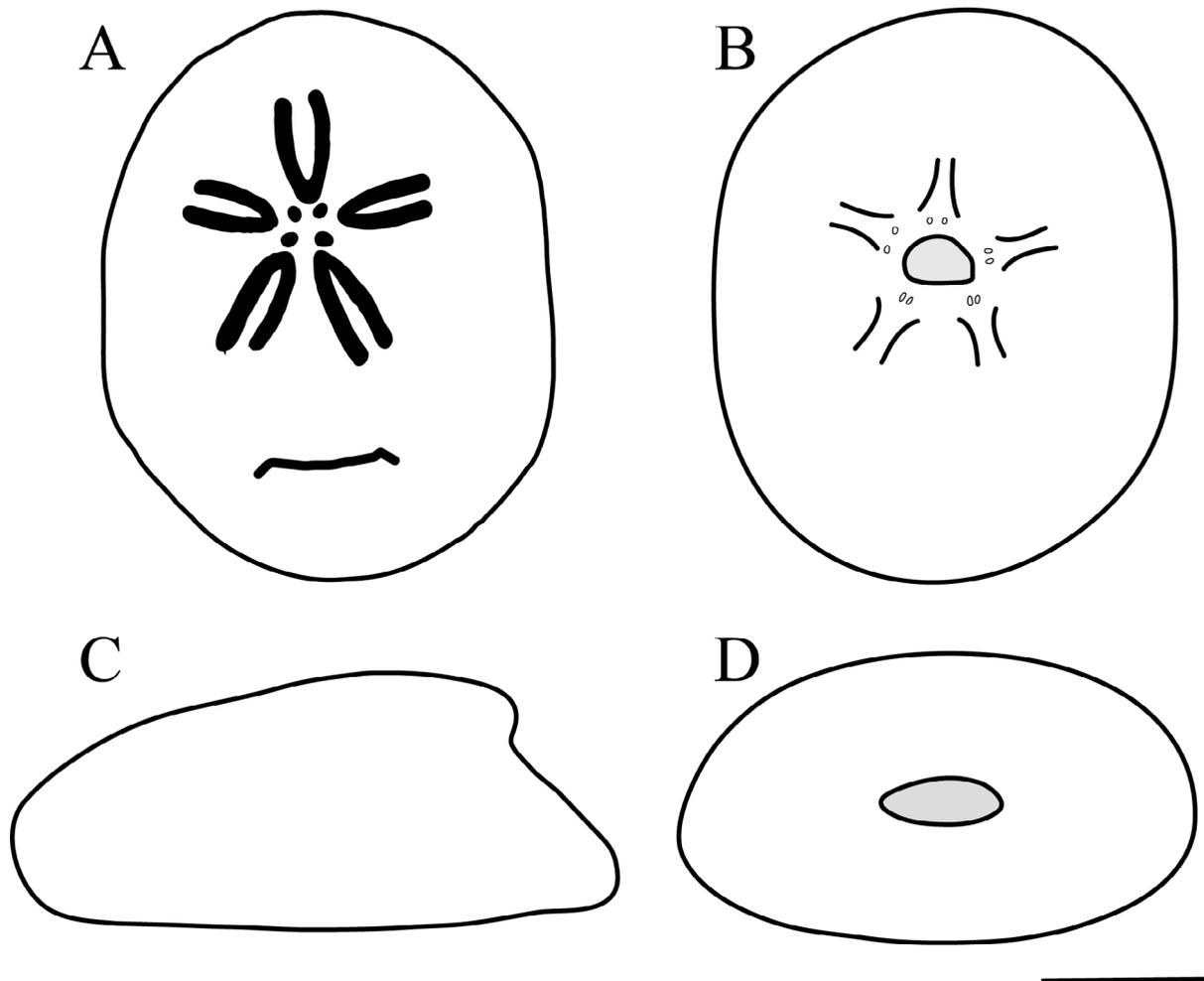


FIGURE 1. Drawings of *Cassidulus infidus* UFBA-314 showing: shape of test in (A) aboral, (B) oral, (C) side and (D) posterior views. Scale bar is 2 mm long.

Comparative material. *Cassidulus caribaeorum* – Anegada, Virgin British Islands, 2 specimens (CASIZ 112633: 12.89 and 16.21 mm in TL); *Cassidulus mitis* – Rio de Janeiro, RJ, Brazil, 3 specimens (UFBA-756: 26.76 and 31.76 mm in TL ; IBZ/UFRJ-EE338: 20 mm in TL).

Amended Diagnosis. Lateral edges of test straightened, anterior and posterior margins rounded. Aboral surface inflated with greatest height posterior to the apical disc; oral surface strongly concave. Phyllodes with one row per half ambulacrum. Large deep pits on posterior ambulacrum. Periproct small, wider than long, almost round; periproctal groove narrow and deep.

Redescription. Test small, wide and low (Fig. 1A–D); largest specimen with 12.86 mm in length, 10.44 mm wide and 5.07 mm in height. Aboral surface inflated (Fig. 2F) with greatest height posterior of apical disc on a small elevation above the periproct (Fig. 2A, C); oral surface (Fig. 2B, D) concave, especially in the midline. Test height between 40–52% of TL (Table 1). Smallest specimens (6.67–8.84 mm of TL) oval in outline. Large specimens (9.46–12.86 mm in length) have straightened lateral edges, and rounded anterior and posterior margins, being slightly wider in the posterior region. Young specimens (3.58 – 3.68 mm in length) almost circular and flattened (Fig. 2G).

Apical disc: Anterior, monobasal (Fig. 3A), less than 40% of TL from anterior edge and bearing four genital pores. These were completely developed in individuals larger than 6.67 mm; however, they were opened only in the specimens with 7.71, 8.84 and 12.86 mm TL. Ocular plates small and differ in size from one another. Number of hydropores in madreporic plate varies according to the size of the specimen, but not exceeding 30 pores in the largest specimens.

Ambulacra: Petaloid region occupying 1/3 of the aboral region (Fig. 1A). Petals narrow; short (18–22% of TL); almost equal in length, with 10–12 pores per row in petals II, III and IV, and 10–16 in petals I and V (10–13 in inner and 14–16 in outer rows). Petal I slightly shorter than petal V; opened distally. Poriferous zones (Fig. 3B)

almost equal in length. Two, rarely three, primary tubercles, surrounded by miliary tubercles between the consecutive pore pairs. Interporiferous zones of petals wider than a single poriferous zone.. Ambulacral plates single; pores rounded and approximately equal in size when in the same row, except for the three proximal pore pairs, which are smaller. Outer pores larger than inner. Outer and inner pores not conjugated by a deep furrow. One primary tubercle and 3–4 miliary spines in each ambulacral plate of petals. Plates beyond petals with small single pores.

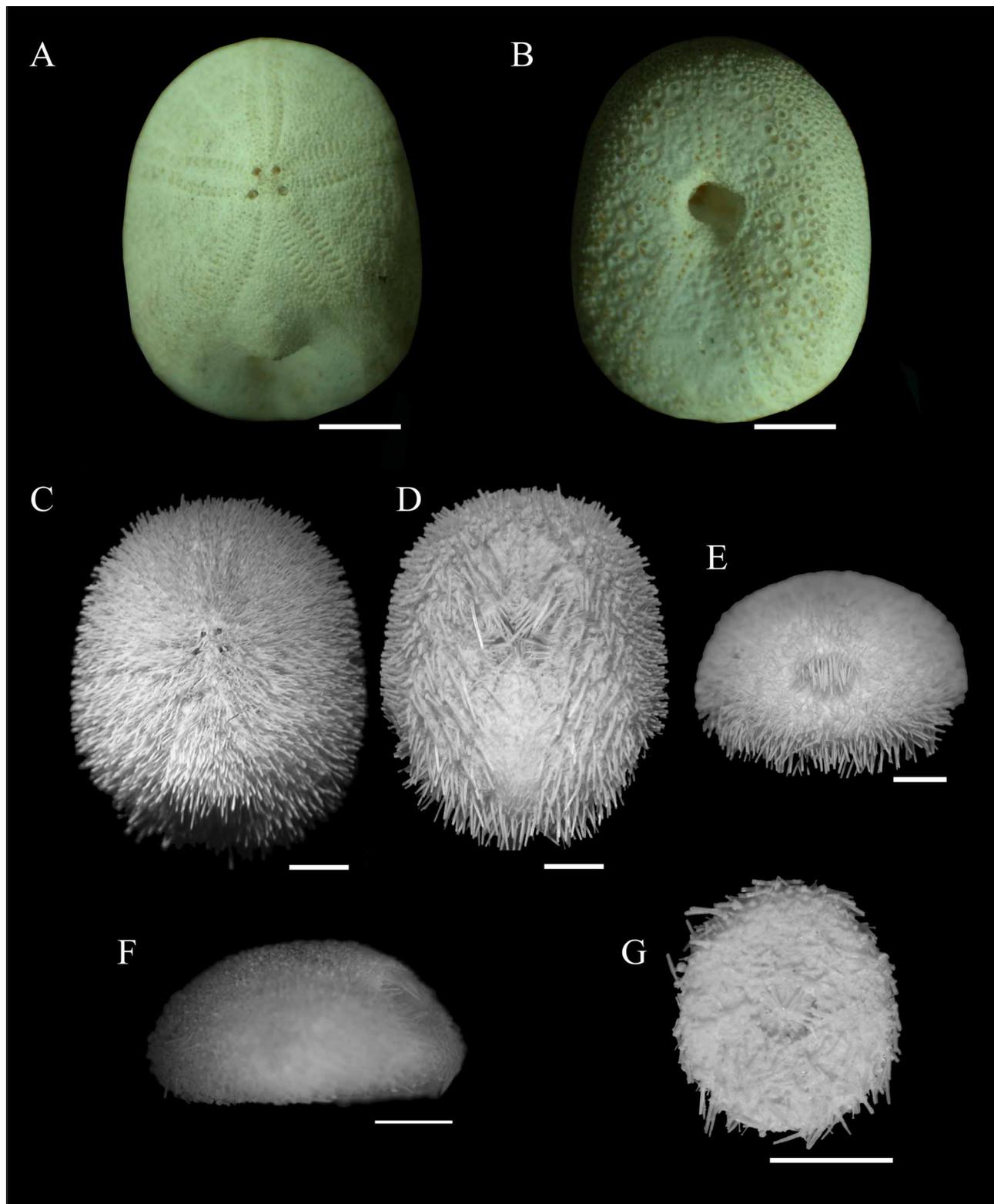
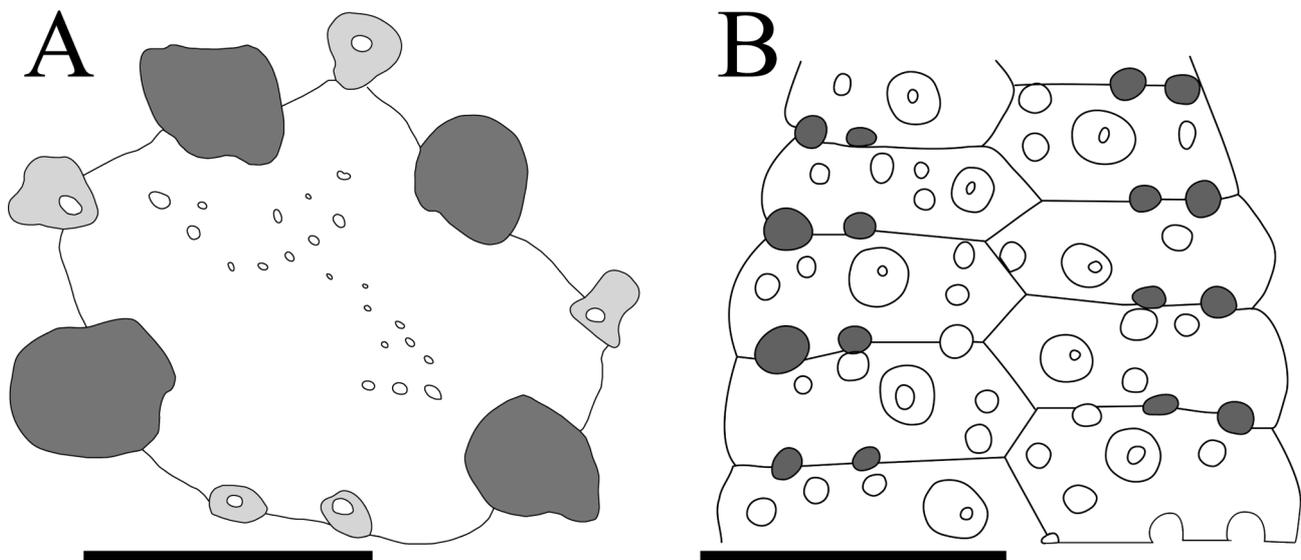


FIGURE 2. *Cassidulus infidus* SMNH-Type-4859 (holotype): (A) aboral and (B) oral surface; UFBA-314: (C) aboral, (D) oral and (E) periproctal surface of largest specimen; UFBA-757: (F) side view of test; and UFBA-314: (G) oral surface of smallest specimen. Scale bars are 2 mm long.

TABLE 1. Test measurements (in millimeters) of specimens of *Cassidulus infidus*.

Specimens	Length	Width	Height	TH/TL
UFBA-314 (1)	12.86	10.44	5.07	0.40
SMNH-Type-4859	10.03	7.80	5.33	0.53
UFBA-314 (2)	9.46	7.59	4.00	0.43
UFISITAB- ECH123 (1)	8.84	8.01	4.37	0.49
UFBA-757 (1)	7.98	6.57	3.71	0.46
UFBA-314 (3)	7.71	6.35	3.29	0.43
UFISITAB- ECH123 (2)	6.67	6.28	2.94	0.44
UFBA-314 (4)	3.68	3.26	0.60	0.16
UFBA-314 (5)	3.58	3.19	0.74	0.26

**FIGURE 3.** Drawings of *Cassidulus infidus* UFBA-314 showing: (A) apical disc with four genital pores in dark gray, five ocular plates in light gray enclosing ocular pores, and hydropores represented by small open circles; and (B) poriferous and interporiferous zones of ambulacrum II, pore pairs in dark gray, miliary tubercles represented by small open circles and primary by two concentric circles. Scale bars are 0.5 and 0.1 mm long, respectively.

Interambulacra: Interambulacral plates wide at the ambitus and narrowing towards the apical disc.

Floscelle: Bourrelets well developed (Fig. 4A), not tooth-like, bearing 40–55 spines which covers the entire peristomial aperture. Single buccal pore in each ambulacral basicoronal plate (Fig. 4B). Phyllodes single pored, parallel and enlarged near the peristome (Fig. 4C), with 6–8 pores in each row. Two to three (rarely four or five) sphaeridia (Fig. 4D) in deep pits (sometimes enclosed; Fig. 4A), arranged in a double series along the midline of the phyllodes.

Peristome: Slightly wider than long (almost equant) (Fig. 4A, B), and located in a depression on the oral region of the test, displaced towards the anterior edge (center of opening situated 38–43% of TL from the anterior edge). Peristome of smallest specimens circular (Fig. 2G), becoming pentagonal as the individual grows.

Periproct: Supramarginal (Fig. 2E), wider than long, and situated in a deep depression near the posterior edge of test, beyond the petals (Fig. 2A). Anal opening surrounded by a fringe of depressed spines with serrated edges and placed in the top position (middle-left side). Periproct composed by eight large and four to seven small plates (Fig. 5A). Each periproctal plate bears 4–5 primary and 13–30 miliary tubercles (Fig. 5B), and tridentate pedicellariae. Periproct of smaller specimens almost circular in shape.

Naked zone: Along the midline of the entire oral surface (Fig. 2B, D), in ambulacrum III and interambulacrum 5, deeply pitted and bearing small and thin miliary spines, numerous in the former and sparsely distributed in the latter region.

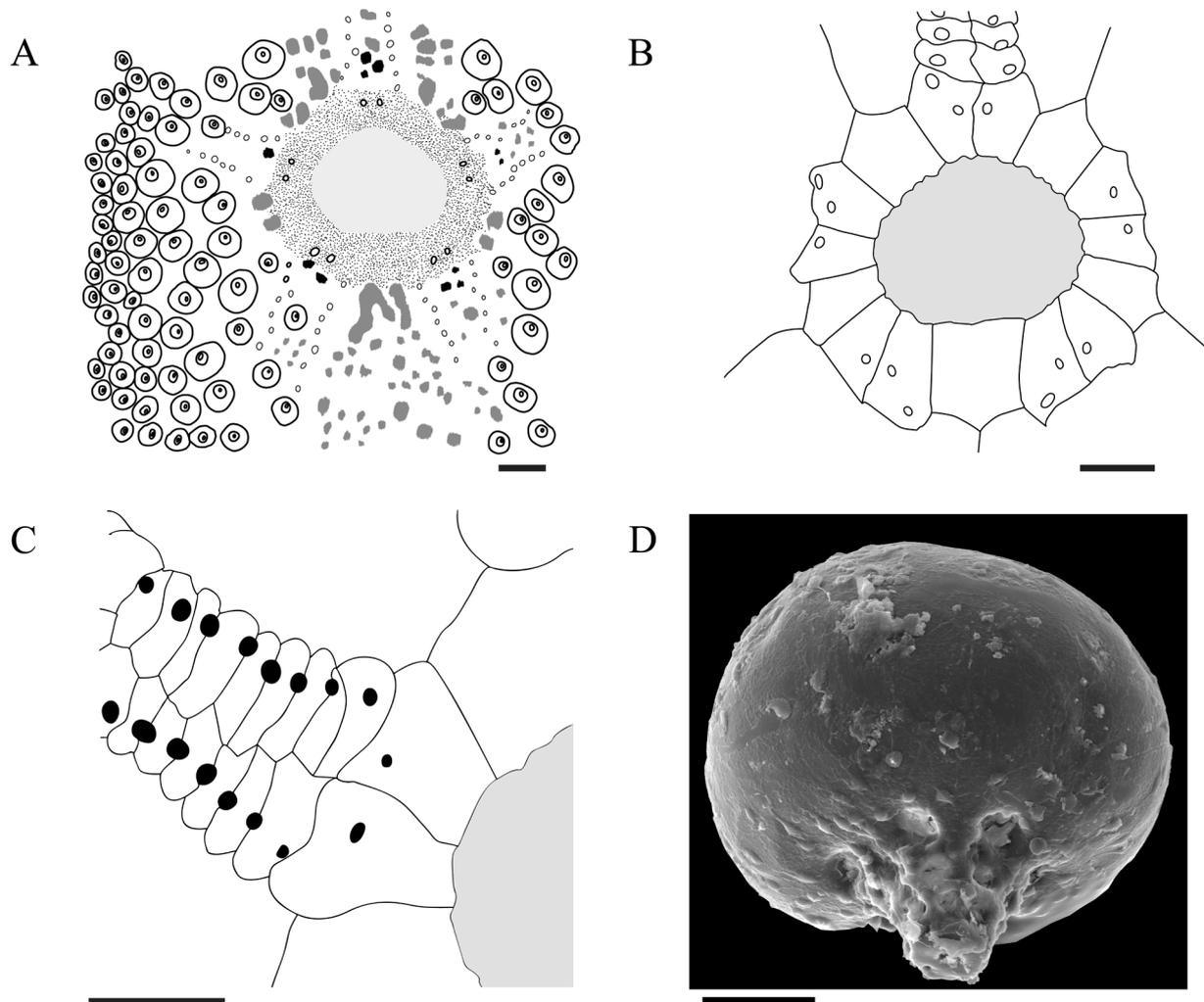


FIGURE 4. Drawings of *Cassidulus infidus* UFBA-314 showing: (A) floscele with peristome aperture in light solid gray, bourrelets shaded, naked zone pits in dark solid gray, sphaeridial pits in solid black, phyllopores and primary tubercles represented by small open circles and three concentric circles, respectively, and (B) basicoronal plates around peristome aperture in light gray, from specimen 12.86 mm long; (C) internal oral surface of phyllode IV (phyllopores in solid black) from specimen 9.46 mm long; and (D) SEM of sphaeridium from pit in interambulacrum 5. Scale bars for A-C are 1 mm and for D is 10 μ m long.

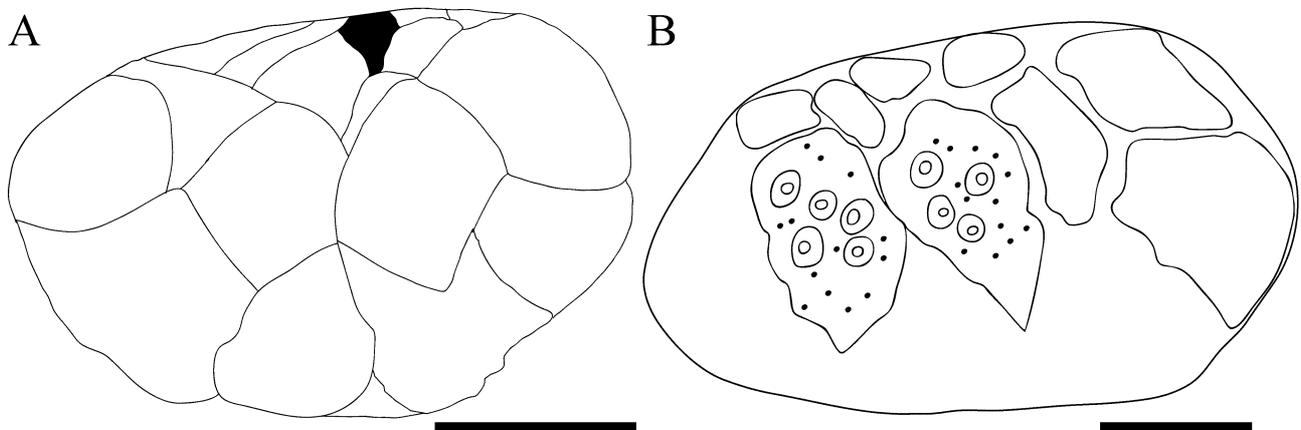


FIGURE 5. Drawings of *Cassidulus infidus* UFBA-314 showing: (A) internal view of periproct from specimen 9.46 mm long; and (B) periproctal plate pattern showing primary tubercles represented by two concentric circles and miliary tubercles represented by small black circles from specimen 12.86 mm long. Scale bars are 0.5 mm long.

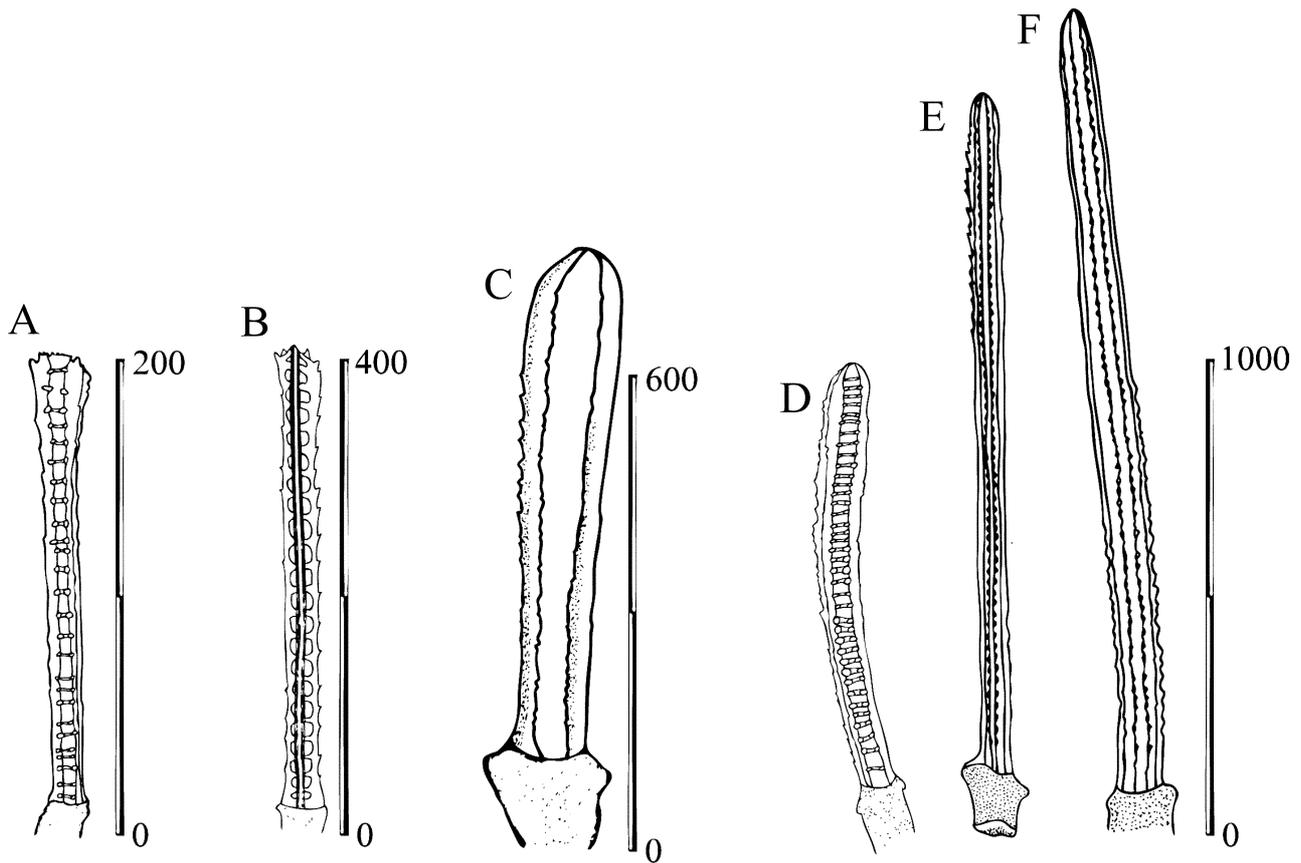


FIGURE 6. Drawings of *Cassidulus infidus* UFBA-314 showing: miliary spines from (A) aboral and (B) oral surface; and primary spines from (C) aboral surface, (D) bourrelets, (E) oral surface, and (F) just under hood, near periproct. Scale bars are in μm .

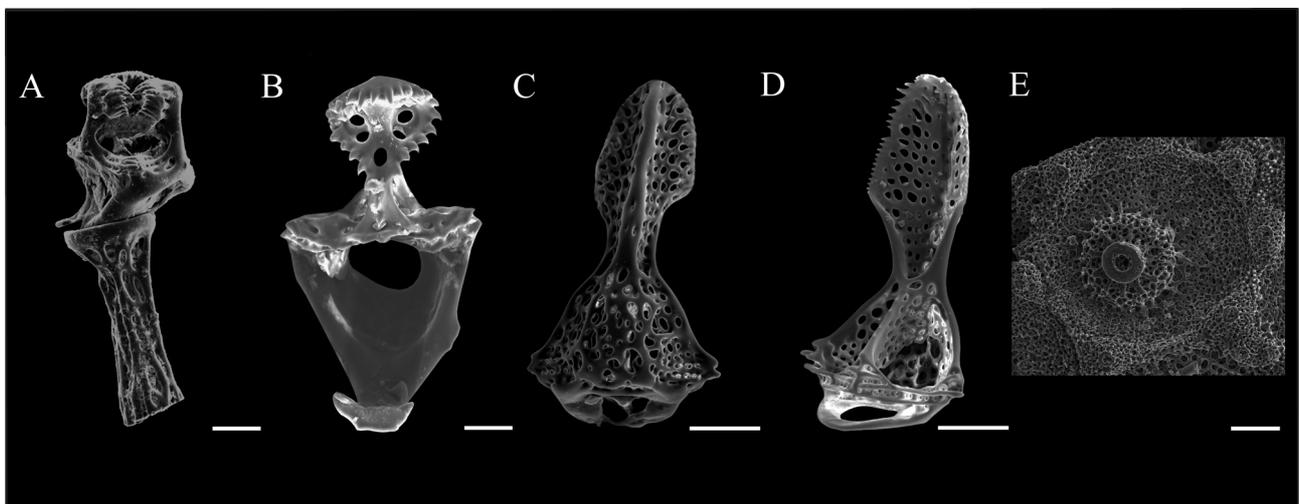


FIGURE 7. SEM of external appendages of *Cassidulus infidus* UFBA-314: (A) complete opificephalous pedicellaria from the edge of the test, (B) single valve of opificephalous pedicellaria depicted in (A), (C) external and (D) internal view of tridentate pedicellaria from periproctal plate; and (E) SEM of primary tubercle from the oral side of the test. Scale bars for A-D are 10 μm and for (E) is 100 μm long.

Tuberculation: Slightly crenulate tubercles with circular scrobicules and small perforated mamelons (Fig. 7E). Oral tubercles larger than adoral ones.

Spines: Four types of primary spines cover the test: aboral spines short, thick, distally serrated, with enlarged tip, sometimes club-shaped (Fig. 6C); spines at bourrelets thick, serrated, slightly curved and with enlarged tip

(Fig. 6D); oral spines near the edges are long, straight, smooth proximally, distally serrated (Fig. 6E) and positioned towards the center, partially covering the naked zone (Fig. 2D); spines above periproct long and straight, covering the whole depression (Fig. 2E), and proximally serrated (Fig. 6F). Miliary spines throughout the test small (aboral smaller than oral), serrated, widening distally where there is a crown (Fig. 6A, B).

Pedicellariae: Ophicephalous pedicellariae (Fig. 7A, B) sparsely distributed at aboral surface, but numerous on the margins. Coarse teeth only on blades; teeth on distal edge of blades longer and sharper than along its sides. Valves ending in a hook, which articulates with a hollow stalk, with a broad, smooth and circular neck. Tridentate pedicellariae (Fig. 7C, D) only around the periproct and on periproctal plates. Three large tridentate valves (c. 200 μm in length) mounted on thick and small stalk (c. 235 μm in length). Valves widen distally and bear fine teeth on their distal edges, which interdigitate with those on adjacent valves. Globiferous and triphyllous pedicellariae not found.

Identification key to the recent species of *Cassidulus*

1. Periproct longer than wide, entirely opened on aboral surface without an aboral lip *C. malayanus*
- Periproct usually wider than long, but sometimes round, opened on the superior margin of the test and protected by an aboral lip . . . 2
2. Phyllodes with pores scattered between outer rows of each half ambulacrum; periproct opening less than 8% TL from posterior edge of test *C. mitis*
- Phyllodes with one row per half ambulacrum; periproct opening more than 8% TL from posterior edge of test 3
3. Greatest height anterior or at apical disc; anterior gonopores more elongated, slight aboral lip over periproct *C. caribaeorum*
- Greatest height posterior at apical disc; anterior gonopores circular, prominent hood over periproct *C. infidus*

Distribution. Mortensen (1948a; b) stated that *C. infidus* occurs in Bahia State (which has more than 1,800 km of coastline), at northeastern Brazil; however, he did not mention the exact collection site. The specimens examined herein were gathered between 3.5 and 11 m of depth near Ribeira Bay, during the Marine Evaluation of Todos os Santos Bay Project (MAREMBA) in 1996, and near the submarine emissary of Rio Vermelho during the Hydros Project in 2008. Several campaigns were performed from 2008 to 2010; however, additional specimens were not found.

Biological notes. Specimens were found burrowed in medium sand. Seven individuals were gathered in the same collection site, and, therefore, they may be gregarious. Besides sediment, there were foraminiferans in the gut content of one specimen. In the largest specimen of *C. infidus* there was settlement of three recruits among the aboral spines.

Discussion

Although Mortensen (1948a) suggested that *C. infidus* could be attributed to a new genus, the observed characteristics clearly show that it belongs to *Cassidulus*, and the test shape is indeed the most important characteristic to distinguish *Cassidulus infidus* from its Atlantic congeners. The type-species *C. caribaeorum* and *C. mitis* are more oval in outline and the greatest height of their test is located anterior or at the apical disc. *Cassidulus caribaeorum* has a more enlarged posterior region and flatter oral surface than *C. infidus*. *Cassidulus mitis* has a truncated posterior edge, instead of rounded as in *C. infidus*, its petals has strongly conjugated pore pairs and the pores of outer series are elongated.

Cassidulus infidus can be also distinguished from *C. mitis* by the depth of the periproctal groove, which is deeper in the *C. infidus*; the length of the petals, which is longer in *C. mitis*; the length of the spines, which cover all periproctal aperture in *C. infidus*, but do not in *C. mitis*; and the occasional presence of one to three internal pores in the phyllodes of *C. mitis*. Based on the figures presented by Mortensen (1948a), Krau (1954) incorrectly assumed that the periproct of *C. infidus* was placed between the posterior petals, distinguishing this species from *C. mitis*; however, the specimens described herein show that the periproct is placed beyond them, as in *C. mitis*.

Cassidulus malayanus resembles *C. infidus* in aboral test shape view, regarding the straightened lateral margins and rounded edges. The main differences between these two species lie in the location and shape of the periproct, which is longer than wide in *C. malayanus*, and its pore pairs of petals that are conjugated by a furrow.

Identification keys for *Cassidulus* are usually based on measurements and number of hydropores (e.g.,

Mortensen 1948a; Krau 1954; Tommasi 1966; Mooi 1990b), which are characters that varies greatly with the age of the specimens. For instance, the TH/TL has been largely used to distinguish *C. infidus* from *C. mitis*. Based on the holotype of *C. infidus* (TH/TL of 0.60), Tommasi (1966) considered that this species would have a high test (TH/TL of 0.56–0.64) and *C. mitis* a low test (0.42–0.56). Later, Mooi (1990b) suggested a cutoff ratio at 0.50.

Nevertheless, as advised by Tommasi and Lima-Verde (1970), our results show that this ratio is not a good taxonomic character since it varies greatly among the specimens, besides depending on the measuring tools used. Measurements of the holotype of *C. infidus* (Table 1) show that its real TH/TL ratio is 0.53, instead of 0.60, which would categorize it as possessing “low test” according to Tommasi (1966). Therefore, morphometric characters should be used carefully when identifying these species.

Species of *Cassidulus* live in shallow waters of the tropical Atlantic west coast, buried up to 20 cm (Gladfelter 1978). Apparently, *C. caribbearum* and *C. infidus* have similar bathymetric distribution (1–10 and 3.5–11 m of depth, respectively) and live in warmer waters (26–28 °C) and coarser sediment than *C. mitis*, which lives in thin sandy bottoms (\pm 2000–44 μ) and cooler waters (16–22.5 °C), up to 24 m of depth (Tommasi & Lima-Verde 1970; Freire *et al.* 1992). *Cassidulus malayanus* is the only species of this genus that lives in deeper waters of the Indo-Pacific Ocean (Mooi 1990b).

Because of its restricted distribution and lack of records since its first collection, *Cassidulus infidus* could be endemic from northern coast of Bahia. However, it is important to remember the difficulty in finding these specimens, because they are very small, fragile and live buried on sand.

Acknowledgements

We are grateful to Rich Mooi and Louis Zachos for providing valuable information; Angela Zanata and Guilherme Muricy for useful comments on early versions of this manuscript; Andreas Kroh and Marc Eleaume for providing great suggestions that significantly improved the quality of this manuscript; Sabine Stöhr for kindly sending us measurements and photographs of the holotype of *Cassidulus infidus*; Renato Ventura (MNRJ) and Lucia Campos (UFRJ), who very kindly donated and loaned specimens of *Cassidulus mitis*, respectively; Rafael Moura for providing bibliography; Orane Alves and Marlene Peso for donating the specimens of *C. infidus* to the UFBA collection; Julio Fernandez for laboratory assistance; the Instituto Gonçalo Moniz (FIOCRUZ/BA) for SEM images. C.S. was supported by a scholarship from the Fundação de Amparo à Pesquisa do Estado da Bahia.

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