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# Intertidal burrowing shrimps (Axiidea: Callianassidae, Callichiridae; Gebiidea: Axiannassidae, Upogebiidae) collected along the Brazilian coast

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## ABSTRACT

An annotated checklist of the intertidal species of burrowing shrimps of the Brazilian coast is provided from samples collected during latitudinal research expeditions between 2015 and 2018. A total of 1166 specimens of nine species were collected in these expeditions. These species are listed by infraorder and family as follows: Axiidea: Callianassidae (*Biffarius botterae*), Callichiridae (*Audacallichirus mirim*, *Callichirus corruptus*, *Lepidophthalmus siriboia*, *Neocallichirus guara*, *N. maryae*, *N. pinheiroi*); Gebiidea: Axianassidae (*Axianassa australis*), Upogebiidae (*Upogebia omissa*). For each species, the diagnostic features, distribution and habitat are recorded. The taxonomic information is discussed and compared with the information reported in literature for each taxon.

## ARTICLE HISTORY

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## KEYWORDS

Decapoda; ghost shrimps; mud lobsters; Thalassinidae; south-western Atlantic

## Introduction


The infraorders Axiidea Saint Laurent, 1979 and Gebiidea de Saint Laurent, 1979, formerly known as Thalassinidae Latreille, 1831, are comprised by the so-called ghost shrimps and mud lobsters, respectively; two clades of marine decapods with a body form completely adapted for a fossorial lifestyle (Hernandez 2018). These organisms, referred to here as ‘burrowing shrimps’, can be found in soft sediments of primarily intertidal and subtidal areas, although several species are common into deeper habitats (e.g. Kensley 1996; Felder and Kensley 2002; Dworschak et al. 2012; and references therein). Burrowing shrimps are known for constructing burrows of different shapes and depths (Griffis and Suchanek 1991) and for playing an important role in shaping the community structure (Pillay 2019). Bioturbation produced by these organisms, relative with the activity of water and sediment expulsion from its galleries, contributes to the suspension of organic matter, nitrogen fixation, and increases the food availability among the trophic levels (Ziebis et al. 1996; Bertics et al. 2010).

At the end of 2015, we initiated a project to document the diversity and geographic distribution of intertidal ghost shrimps (Axiidea) and mud lobsters

(Gebiidea) along the coast of Brazil. The development of this study facilitated the collection of a large number of specimens, as well as the collection of ecological and environmental data about these fossorial organisms. Here, we present the results of this large-scale study, by providing information about the morphology and distribution of nine intertidal burrowing shrimps found along the coast of Brazil. All species collected during this project are illustrated and ecological notes of the sampling points are provided. We hope that the results of this study may contribute to a better understanding of the biology of these ecologically important decapods of the soft sediments in the coast of Brazil.

## Materials and methods

Fieldwork was conducted from October 2015 to December 2018, at a total of 61 localities along the Brazilian coast, representing about 7,000 km out of the 8,500 km of the total coastline (Figure 1; Fernandez et al. 2019). At each locality, specimens of burrowing shrimps were extracted from their burrows using a steel suction pump (diameter = 77 mm, length = 100 cm) from the intertidal and immediate subtidal

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**Figure 1.** Distribution of collecting sites from which specimens of intertidal burrowing shrimps were collected (between 2015 and 2018) along the Brazilian coast.

zone (<1 m depth), pumping in each burrow up to five times. After collection, each specimen was carefully rinsed with seawater, placed in a plastic bag, anaesthetized in ice and preserved in 80–90% ethanol until further examination in the laboratory.

In the laboratory, each specimen was identified and sexed according to the morphology of the first pair of pleopods; when this criterion did not allow a definitive sex determination, the location of the gonopores was revised, too (Hernández et al. 2018). Material examined is listed by location followed by date, collector, number of specimens per sex and catalogue number. Size is expressed as postorbital carapace length (cl) measured along the middorsal line of the carapace from the anterior margin of rostrum to the posterior margin of the carapace. Measurements (mm) were made under a stereomicroscope (Zeiss® Stemi® SV-6) equipped with a digital analysis image system (Zeiss® AxioCam® MRc5). Figures of morphological structures with taxonomic relevance (e.g. frontal region of carapace, pleopods, among others) were digitized using an electronic tablet for graphic design (Wacom®). The material is partly deposited in the Museu de Zoologia, Universidade de São Paulo, São Paulo, Brazil (MZUSP) and partly in the Scientific Collection of the Research Group in Crustacean Biology (CRUSTA), Universidade Estadual Paulista. Abbreviations include: A1 (antennule or first antenna), A2 (antenna or second antenna), tl (total length), coll. (collector or collected by), Mxp3

(third maxilliped), Pl (first pereopod), Plp 1–2 (first and second pleopods).

## Results

Altogether 1166 specimens of nine species of intertidal burrowing shrimps were collected along the Brazilian coast, which were distributed in the following taxa listed by infraorder and family as: Axiidea: Callianassidae Dana, 1852 (one species), Callichiridae Manning & Felder, 1991 (six species); Gebiidea: Axianassidae Schmitt, 1924 (one species), Upogebiidae Borradaile, 1903 (one species). All species collected in this study are treated in detail in the systematics section below.

## Taxonomy

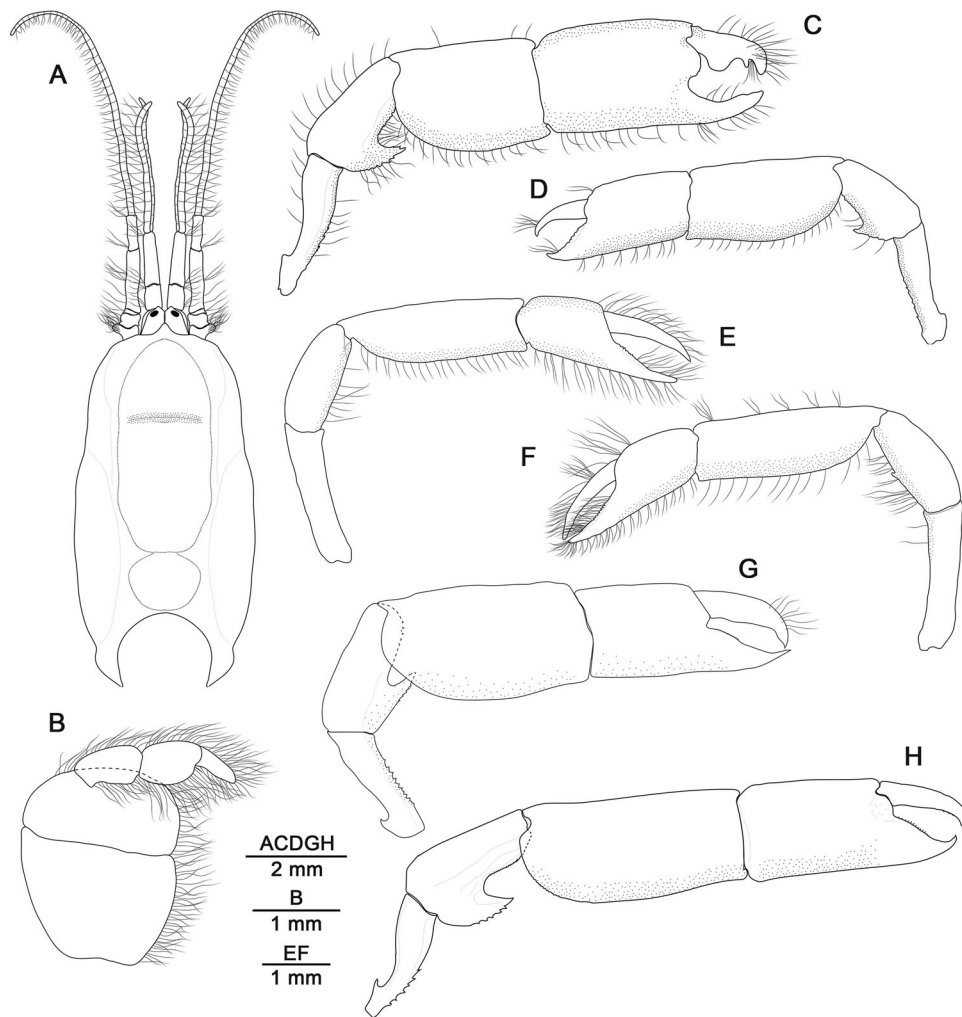
**Infraorder Axiidea** de Saint Laurent, 1979

**Family Callianassidae** Dana, 1852

**Genus *Biffarius*** Manning & Felder, 1991

*Biffarius botterae* Hernández, Miranda and Tavares, 2020 (Figures 2A–F, 3A–F)

**Material examined** – Brazil: Holotype, male, cl 4.6 mm, pereopods detached, Praia de Tutóia, 02° 45'40"S, 42°15'45"W, lower intertidal, Tutóia, Maranhão, P. Hernández coll., 7 July 2017, MZUSP 39002. Paratypes: 2 males, cl: 4.0–4.6 mm and 1 female, cl 4.1,



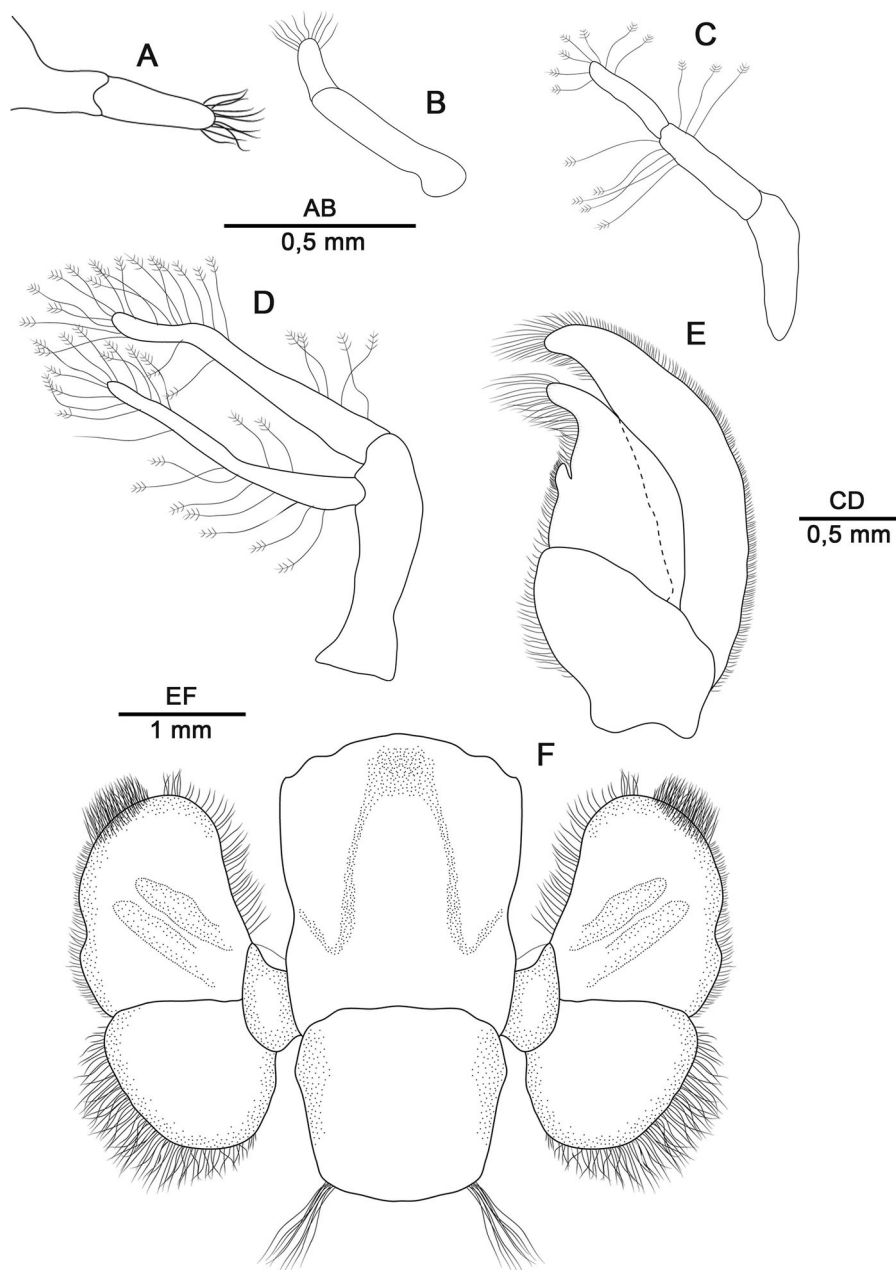
**Figure 2.** A–F, *Biffarius botterae* Hernáez, Miranda and Tavares, 2020. A, C, D, holotype, male, cl 4.6 mm, Tutóia, Brazil, MZUSP 39002; B, paratype, male, cl 5.6 mm, Icapuí, Brazil, MZUSP 40376; C, D, paratype, female, cl 4.1 mm, Tutóia, Brazil, MZUSP 40375. A, carapace front, eyestalks, and antennular and antennal peduncles, dorsal view; B, left maxilliped 3, external surface; C, D, major and minor chelipeds, respectively, lateral view; E, F, major and minor chelipeds, respectively, lateral view. G, H, *Biffarius delicatulus* Rodrigues & Manning, 1992. G, holotype, male, cl 6.8 mm, São Sebastião, Brazil, MZUSP 10582; H, male, cl 5.0 mm, Olinda, Brazil, CRUSTA 130001. G, H, male major cheliped, lateral view.

same locality data as holotype, MZUSP 40375; 1 male, cl 5.6 mm, 1 female, cl 5.0 mm, mangrove, 04°40'55"S, 37°21'30"W, lower intertidal, Icapuí, Ceará, P. Hernáez coll., 16 July 2016, MZUSP 40376.

**Comparative material examined** – *Biffarius bififormis* (Biffar, 1971a): holotype, male, tl 24 mm, mouth of Doboy Sound, lower intertidal, south end of Sapelo Island, McIntosh County, Georgia, USA, R.W. Heard coll., 1 June 1969, USNM 135052. Paratypes: 18 males, tl: 15–29 mm and 14 females, tl: 20–26.5 mm, same locality data as holotype, USNM 135053; 4 males, tl: 27–32 mm and ovigerous female, tl 26 mm, same locality as holotype, R.W. Heard coll., July 1969, USNM 135054. Other material: male, cl 3.6 mm, female, cl 3.2 mm, Praia da Pedra Rachada, 03°23'55"S, 39°00'48"W, Paracuru, Ceará, Brazil, P. Pachelles coll., 11

August 2014, MZUSP 33465; 3 females, cl: 3.1–3.5 mm, Praia de Tremembé, 04°44'05"S, 37°17'24"W, Icapuí, Ceará, Brasil, P. Pachelles coll., 12 February 2014, MZUSP 33463. *Biffarius delicatulus* Rodrigues and Manning, 1992a: holotype, male, cl 6.8 mm, Praia do Araçá, 23°40'S, 45°20'W, São Sebastião, São Paulo, Brazil, S.A. Rodrigues coll., 18 May 1985, MZUSP 10582; male, cl 3.1 mm, Praia do Tremembé, 04°44'05"S, 37°17'24"W, Icapuí, Ceará, P. Pachelles coll., 19 August 2012, MZUSP 27620; 3 males, cl: 4.5–5.0 mm and 2 females, cl: 4.4–4.7 mm, Praia da Casa Caiada, 07°58'59.8"S, 34°50'06"W, Olinda, Pernambuco, M. Botter-Carvalho coll., 27 February 2013, CRUSTA 130001.

**Diagnosis** (from Hernáez et al. 2020) – Carapace lateral margin emarginate on central part, rostrum short and



**Figure 3.** A–F, *Biffarius botterae* Hernandez, Miranda and Tavares, 2020. A, B, E, F, holotype, male, cl 4.6 mm, Tutodia, Brazil, MZUSP 39002; C, D, paratype, female, cl 4.1 mm, Tutodia, Brazil, MZUSP 40375. A, B, male pleopods 1–2, respectively, external surface; C, D, female pleopod 1–2, respectively, external surface; E, pleopods 3–5, external surface; F, abdominal somite 6, uropods, and telson, dorsal view.

triangular, without distinct lateral projection. Antennular peduncle shorter than antennal peduncle; penultimate antennal article 1.2 times longer than distal article. Third maxilliped without crista dentata. Male major cheliped massive, ischium with row of well-spaced acute teeth from midlength to articulation with basis. Male pleopod 2 present. Uropodal endopod widening distally, inner lateral margin convex. Anterodorsal plate of uropodal exopod absent. Posterior margin of telson convex.

**Distribution and habitat** – South-western Atlantic. Brazil: Maranhao (Tutodia) and Ceara (Icapui), north-eastern Brazil. This species builds its galleries in the intertidal zone of fine-grain size sandy beaches, among galleries of other burrowing shrimps where it is usually confused with juveniles of a sympatric species, *Neocallichirus maryae* Karasawa, 2004. Salinity and temperature average equal to  $36.1 \pm 1.2$  and  $35.1 \pm 0.3^\circ\text{C}$ , respectively.

**Remarks** – At present, three out of the four species of the genus *Biffarius* are known from Brazil, viz. *B. biformis*, *B. botterae* and *B. delicatulus*. *Biffarius biformis* is reported from Ceará (Pachelle et al. 2016) and Pernambuco (Botter-Carvalho et al. 2012), while *B. delicatulus* from São Paulo (Rodrigues and Manning 1992a) to Paraná (Souza and Borzone 1996) although neither species of this genus were found by us in the present study. *Biffarius botterae* is morphologically close to *B. delicatulus*, with which it shares a number of characteristics including vestigial male pleopods 2, absence of crista dentata in the third maxilliped, and uropodal endopod widening distally (cf. Rodrigues and Manning 1992a: figs 1d–i, r, w; see also Figures 2B, 3C, F). However, the two species can be easily separated from each other by the shape of the male major cheliped, much more massive in *B. botterae* (Figure 2C) than in *B. delicatulus* (cf. Rodrigues and Manning 1992a: fig. 1j, see also Figure 1G, H). *Biffarius botterae* can be distinguished from both *B. biformis* and *B. limosus* (Poore, 1975) in having vestigial male pleopods 2 (vs. male pleopods 2 absent in *B. biformis* and consisting of a minute papilla in *B. limosus*), and the uropodal endopods widening distally (vs. uropodal endopod subrectangular in *B. biformis* and subtriangular in *B. limosus*) (cf. Biffar 1971a: fig. 3l; Poore 1975: fig. 4b; see also Figures 3A, F).

#### **Family Callichiridae** Manning and Felder, 1991

**Genus *Audacallichirus*** Poore, Dworschak, Robles, Mantelatto & Felder, 2019

*Audacallichirus mirim* (Rodrigues, 1971)  
(Figures 4A–F, 5A–F)

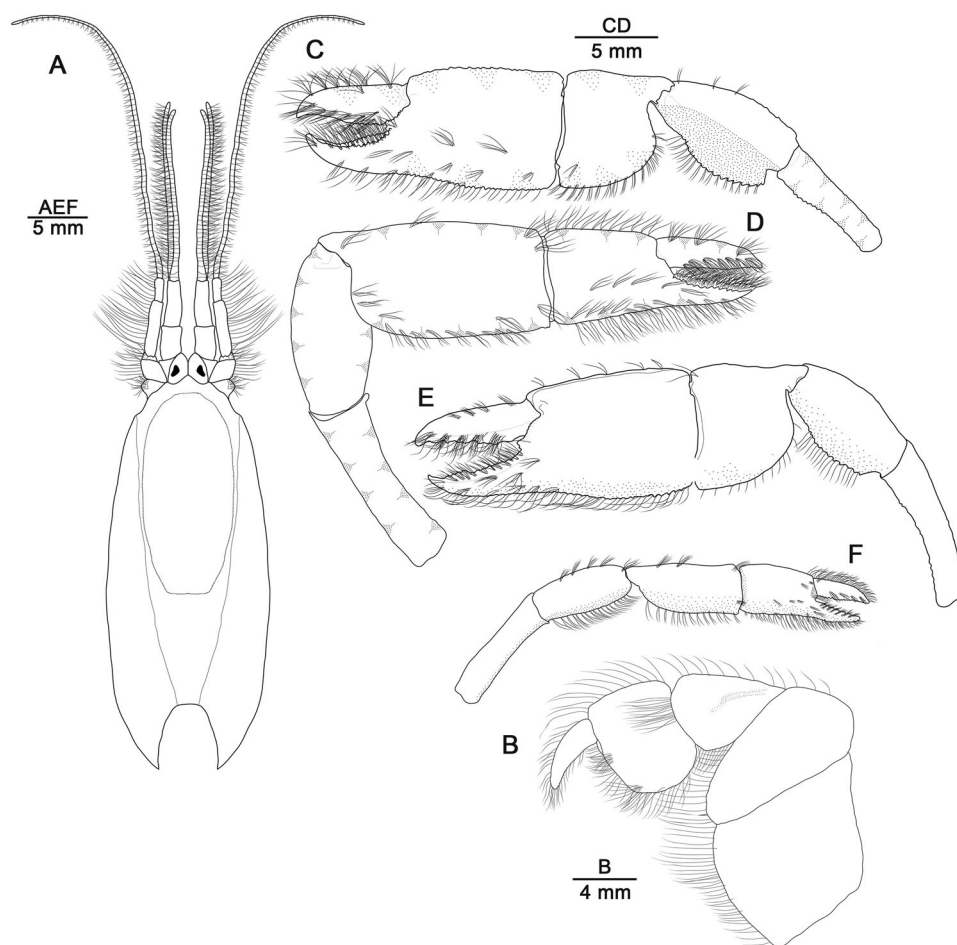
**Material examined** – Brazil: holotype, male, cl 20.5 mm, São Sebastião, lower intertidal, São Paulo, S. Rodrigues coll, March 1966, MZUSP 2730. Non type material: Brazil: male, cl 11.7 mm, mouth of the river Caravelas, 17°44'17"S, 39°11'16"W, Caravelas, Bahia, P. Hernáez coll., 5 June 2016, MZUSP 39019; 2 males, cl: 8.8–9.6 mm, female, cl 8.5 mm, Lagoa de Santo Antônio dos Anjos, Tesoura, 28°29'46"S, 48°45'51"W, Imbituba, Santa Catarina, P. Hernáez coll., 9 July 2016, MZUSP 39040; 2 males, cl: 8.8–9.6 mm, female, cl 8.5 mm, Praia de Tapera, 29°14'51"S, 49°39'10"W, lower intertidal, Passo de Torres, Santa Catarina, P. Hernáez coll., 5 July 2016, MZUSP 39041; 14 males, cl: 22.9–32.6 mm, 41 females, cl: 20.1–36.1 mm, Balneário Pinhal, 29°14'51"S, 49°39'10"W, Rio Grande do Sul, P. Hernáez coll., 6 July 2016, MZUSP 39042.

**Diagnosis** (modified from Sakai 2011; inclusions are in bold) – **Rostrum triangular, reaching the base of**

**cornea. Anterolateral margin of carapace with triangular protrusion on each side. A1 peduncle similar in length than A2 peduncle.** Mxp3 ischium-merus subrectangular; **ischium without crista dentata on inner surface**; propodus subquadrate, and dactylus digitiform. **Male major cheliped with strong denticulation on ventral margin of merus; in female major cheliped with fine denticulation.** Male Plp1 uniramous, bisegmented, and w-shaped distally; **female Plp1 uniramous and trisegmented**; male Plp2 bearing distally proximally-fused appendix masculina with setae, and proximally-fused appendix interna mesioproximally; **female Plp2 with digitiform appendix interna; Plp3-5 with embedded appendix interna.** Telson wider than long, convex laterally, and curving toward rounded posterior margin with median concavity with sharp spine. **Uropodal endopod acuminate distally.**

**Distribution and habitat** – South-western Atlantic. Brazil: Bahia (Caravelas) and Rio Grande do Sul (Cassino beach) (present study); northern coast of Argentina (Sakai 2011). This species builds galleries in the lower intertidal and shallow subtidal zone of sandy beaches. The salinity and temperature were, on average,  $28.8 \pm 2.5$  and  $19.9 \pm 7.7^\circ\text{C}$ , respectively.

**Remarks** – *Callianassa mirim* (= *Audacallichirus mirim*) was described by Rodrigues (1971) based on 12 specimens from the south-east region of Brazil. From the visual material recorded by this author during the 1970s (Rodrigues and Höld 1989, 1990), it is possible to affirm that this species was very abundant in the low intertidal zone of Santos beaches. After an important collection effort carried out between 2015 and 2018 in the Bay of Santos (Hernáez et al. 2019; Rio et al. 2019; Laurino et al. 2020; João and Hernáez 2021), in which we didn't find any specimen of *A. mirim*, we have concluded that this species has been completely decimated in this place. Unfortunately, this conclusion extends to the entire coast of São Paulo where we have not found any specimen of *A. mirim* either. *Audacallichirus mirim* seems to be much better adapted to colder environmental conditions such as those of the south-east region of Brazil where we have found that *A. mirim* is very abundant. *Audacallichirus mirim* is morphologically closest to the south-eastern Atlantic *A. monodi*, sharing a number of characteristics including third maxilliped ischium without crista dentata on inner surface, female major cheliped with merus ventrally expanded, posterior margin of telson armed with sharp spine and uropodal endopod acuminate distally (cf. de Saint Laurent and Le Loeuff 1979, figs 17c, 18a, 22a; see



**Figure 4.** A–F, *Audacallichirus mirim* (Rodrigues, 1971). A–D, male, cl 20.4 mm, E, F, female, cl 17.2 mm, Balneário Pinhal, Brazil, MZUSP 39042. A, carapace front, eyestalk, and antennular and antennal peduncles, dorsal view; B, third maxilliped, external surface; C, D, major and minor chelipeds, respectively, lateral view; E, F, major and minor cheliped, respectively, lateral view.

also Figures 4E, 5F). On the other hand, the two species can be easily separated from each other by the relation between the length of the antennular and antennal peduncle, much shorter in *A. monodi* (de Saint Laurent and Le Loeuff 1979, fig. 16f) than in *A. mirim* (Figure 4A). *Audacallichirus mirim* can be distinguished from both *A. audax* (De Man, 1911) and *A. pentagonocephalus* (Rossignol, 1962) in having posterior margin of telson armed with sharp spine and uropodal endopod acuminate distally (vs. unarmed posterior margin of telson and uropodal endopods widening distally in *A. audax* and *A. pentagonocephalus* (cf. de Man 1911; not figured; Rossignol 1962, fig. 1b; see also Figure 5F).

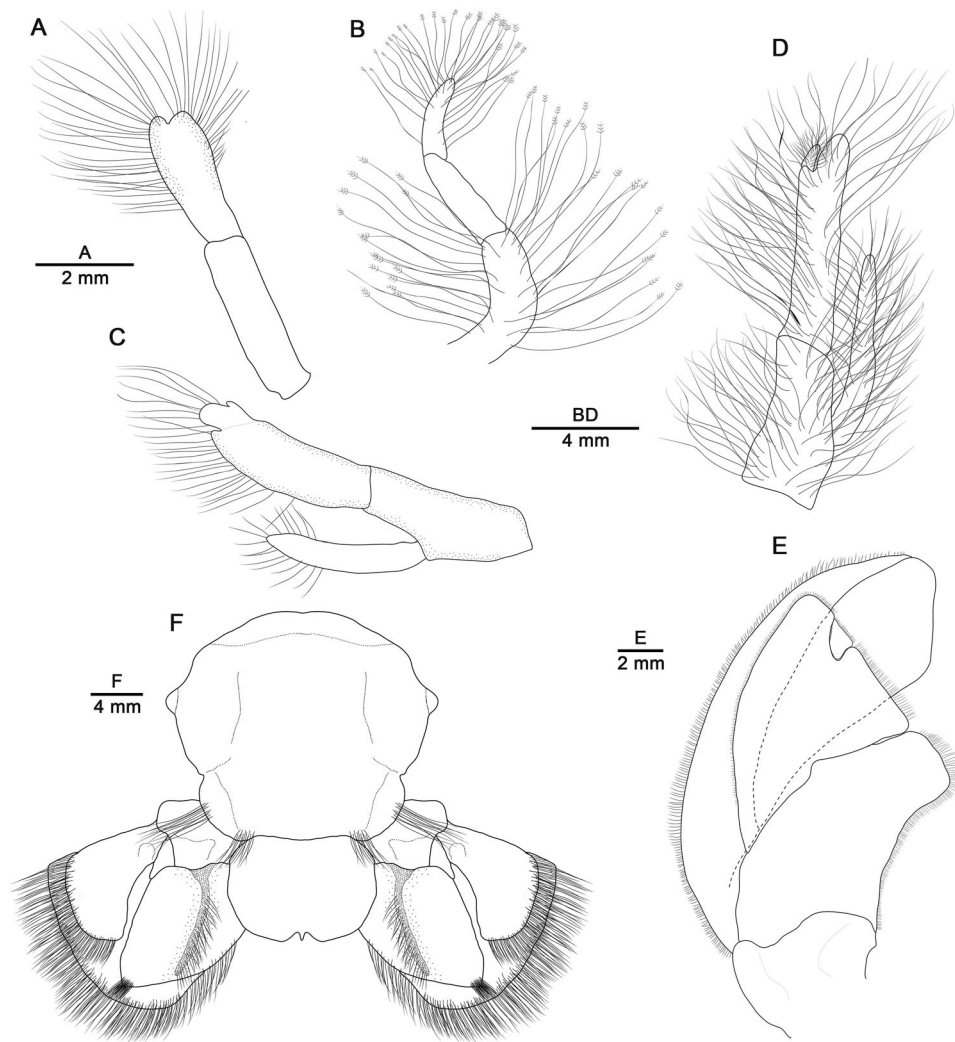
#### Genus *Callichirus* Stimpson, 1866

*Callichirus corruptus* Hernáez, Miranda, Rio and Pinheiro, 2022

(Figures 6A–F, 7A–F)

**Material examined** – Brazil: 8 males, cl: 10.1–18.3 mm, 15 females, cl: 10.4–19.2 mm, Praia do Crispim, 00°

34'58''S, 47°39'04''W, lower intertidal, Marapanim, Pará, P. Hernáez coll., 9 July 2017, MZUSP 38995; 8 males, cl: 13.7–19.6 mm, 11 females, cl: 10.5–21.2 mm, Praia de Ajuruteua, 00°49'40''S, 46°36'20''W, lower intertidal, Bragança, Pará, P. Hernáez coll., 7 July 2017, MZUSP 38993; 10 males, cl: 10.8–17.6 mm, 15 females, cl: 12.5–19.8 mm, Praia Olho d'água, 02°28'44''S, 44°13'51''W, lower intertidal, São Luis, Maranhão, P. Hernáez coll., 6 July 2017, MZUSP 38994; male, cl 12.4 mm, 2 females, cl: 15.6–18.7 mm, Praia de Tutoia, 02°45'40''S, 42°15'45''W, lower intertidal, Tutóia, Maranhão, P. Hernáez coll., 5 July 2017, MZUSP 39001; 9 males, cl: 9.6–15.6 mm, 14 females, cl: 10.2–17.7 mm, Praia da Atalaia, 02°53'22''S, 41°37'41''W, lower intertidal, Luís Correia, Piauí, P. Hernáez coll., 3 July 2017, MZUSP 38998; 2 females, cl: 5.8–10.4 mm, close to the marine lighthouse, 02°52'35''S, 40°55'24''W, lower intertidal, Camocim, Ceará, P. Hernáez coll., 3 July 2017, MZUSP 39006; 22 males, cl: 5.6–12.8 mm, 19 females, cl: 7.6–13.3 mm, Praia do Pirangi, 05°58'28''S, 35°07'28''W,

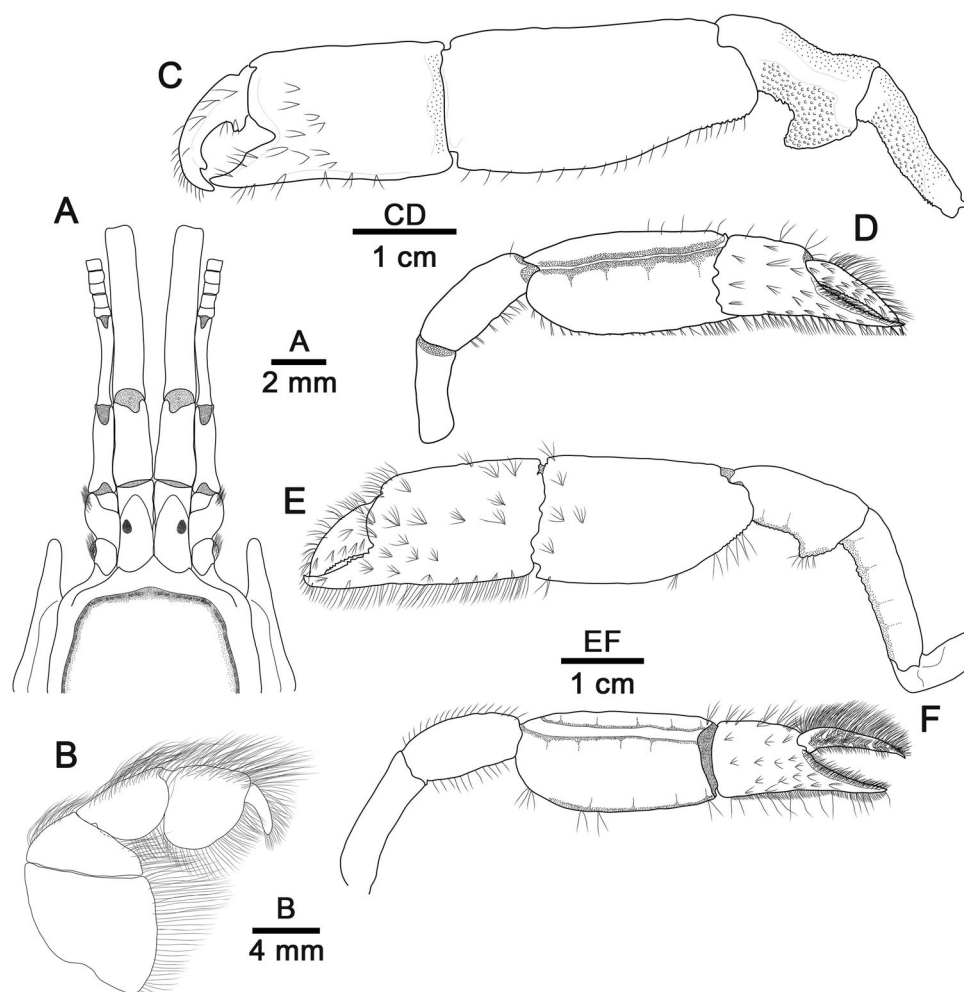


**Figure 5.** A–F, *Audacallichirus mirim* (Rodrigues, 1971). A, C, E, F, male, cl 20.4 mm, B, D, female, cl 17.2 mm, Balneário Pinhal, Brazil, MZUSP 39042. A, male first pleopod, external surface; B, female first pleopod, external surface; C, male second pleopod, external surface; D, female second pleopod, external surface; E, third-fifth pleopod, external surface; F, sixth abdominal somite, telson and uropods, dorsal view.

lower intertidal, Pirangi, Rio Grande do Norte, P. Hernáez coll., 11 June 2016, MZUSP 39011; male, cl 10.5 mm, 4 females, cl: 13.9–16.1 mm, Praia de Baixa Verde, 07°45'17"S, 34°49'28"W, lower intertidal, Ilha de Itamaracá, Pernambuco, P. Hernáez coll., 17 June 2016, MZUSP 39012; 6 males, cl: 7.9–15.9 mm, 5 females, cl: 7.8–15.3 mm, Praia Piedade, 08°10'01"S, 34°54'47"W, lower intertidal, Recife, Pernambuco, P. Hernáez coll., 10 June 2016, MZUSP 39013; 15 males, cl: 9.0–16.0 mm, 14 females, cl: 12.9–17.7 mm, Praia do Sobral, 09°40'22"S, 35°33'44"W, lower intertidal, Maceió, Alagoas, P. Hernáez coll., 9 June 2016, MZUSP 39014; 9 males, cl: 11.5–15.8 mm, 18 females, cl: 10.3–18.0 mm, Praia Aruana, 11°00'50"S, 37°03'50"W, lower intertidal, Aracajú, Sergipe, P. Hernáez coll., 8 June 2016, MZUSP 39016; 16 males, cl: 12.6–15.7 mm, 16 females, cl: 11.8–14.7 mm, Praia Malvinas,

18°04'48"S, 39°32'35"W, lower intertidal, Mucuri, Bahia, P. Hernáez coll., 20 June 2016, MZUSP 39022; 15 males, cl: 7.8–12.5 mm, 11 females, cl: 6.8–12.2 mm, Praia de Piúma, 20°50'37"S, 40°44'02"W, lower intertidal, Piúma, Espírito Santo, P. Hernáez coll., 3 June 2016, MZUSP 39023; 14 males, cl: 5.7–11.9 mm, 8 females, cl: 7.4–11.5 mm, Praia de Barequeçaba, 23°49'39"S, 45°26'04"W, lower intertidal, Barequeçaba, São Paulo, P. Hernáez coll., 2 June 2016, MZUSP 39028; holotype, male, cl: 18.8 mm, Praia do Gonzaga, 23.970°S, 46.334°W, lower intertidal, Santos, P. Hernáez coll., 1 September 2016, MZUSP 41251; paratypes: 1 female, cl: 20.4 mm, MZUSP 41252, 4 males (one dissected), cl: 15.4–19.4 mm, and 4 females, cl: 16.4–22.2 mm (2 ovigerous females), MZUSP 41253, same data as holotype; 3 males, cl: 8.6–15.5 mm, 3 females, cl: 7.9–8.3 mm, Cibratel, 24°12'04"S, 46°48'45"W, lower intertidal,



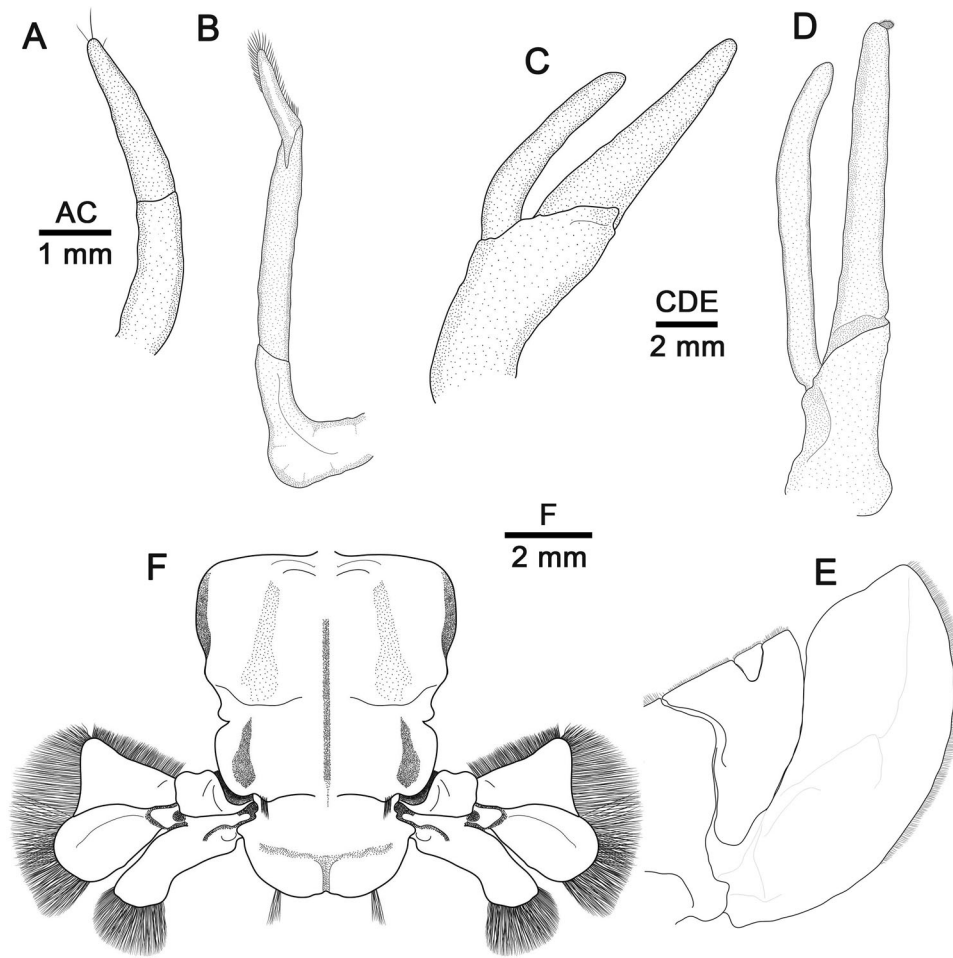


**Figure 6.** *Callichirus corruptus* Hernáez, Miranda, Rio and Pinheiro, 2022. A–D, holotype, male, cl 18.8 mm, Gonzaga, Brazil, MZUSP 41251; E, F, paratype, female, cl 20.4 mm, Gonzaga, Brazil, MZUSP 41252. A, carapace front, eyestalk, and antennular and antennal peduncles, dorsal view; B, third maxilliped, external surface; C, male major cheliped, lateral view; D, male minor cheliped, lateral view; E, female larger cheliped, lateral view; F, female minor cheliped, lateral view.

Itanhaém, São Paulo, P. Hernáez coll., 12 August 2016, MZUSP 39026; 3 males, cl: 7.3–10.8 mm, 3 females, cl: 7.4–14.4 mm, Rio Peruíbe, 24°19'47''S, 46°59'59''W, estuary, Peruíbe, São Paulo, P. Hernáez coll., 1 September 2016, MZUSP 39025; 8 males, cl: 6.4–18.7 mm, 4 females, cl: 12.6–15.9 mm, Praia Ilha Comprida, 24°45'22''S, 47°33'34''W, lower intertidal, Ilha Comprida, São Paulo, P. Hernáez & J. Rio coll., 1 July 2016, MZUSP 39029; 15 males, cl: 7.9–16.7 mm, 22 females, cl: 10.0–16.4 mm, Praia de Leste, 25°37'50''S, 48°25'16''W, lower intertidal, Pontal de Paraná, Paraná, P. Hernáez & J. Rio coll., 2 July 2016, MZUSP 39037; 10 males, cl: 11.0–16.7 mm, 27 females, cl: 8.9–22.3 mm, Balneário Camboriú, 26°59'20''S, 48°37'45''W, lower intertidal, Camboriú, Santa Catarina, P. Hernáez & J. Rio coll., 3 July 2016, MZUSP 39039.

**Comparative material examined** – *Callichirus garthi* (Retamal, 1975): Chile: 53 males, cl: 3.8–23.3 mm, 54

females, cl: 4.3–21.9 mm, Las Machas, 18°26'14''S, 70°18'15''W, Arica, P. Hernáez coll., 27 August 2011, MUAP-CD 0426/2011; holotype, male, cl 35 mm, Lenga, 36°45'S, 73°10'W, Concepción, M.A. Retamal coll., May 1975, MZUC-UCCC 7311; paratype, male, cl 30 mm, same site as holotype, March 1974, M.A. Retamal coll., MZUC-UCCC 7313; 66 males, cl: 7.6–21.3 mm, 68 females, cl: 8.6–20.0 mm, Lenga, 36°46'00''S, 73°10'18''W, Concepción, P. Hernáez coll., 9 March 2011, MUAPCD 0432/2011. *Callichirus islagrande* (Schmitt, 1935): USA: holotype, male, cl 19 mm, Grand Isle, Louisiana, Gulf of Mexico, W.W. Anderson coll., summer of 1930, USNM 69362. *Callichirus major* (Say, 1818): USA: male, cl 20.6 mm, Onslow Bay, 34°36'23''N, 77°12'35''W, New River, North Carolina, R.B. Manning & D.B. Bixler coll., 30 July 1989, USNM 266227; female, cl 11.9 mm, Onslow Bay, 34°36'23''N, 77°12'35''W, New River, North Carolina, R.B. Manning & D.B. Bixler coll., 7 August 1990, USNM 266232;



**Figure 7.** *Callichirus corruptus* Hernáez, Miranda, Rio and Pinheiro, 2022. A, B, D, F, holotype, male, cl 18.8 mm, Gonzaga, Brazil, MZUSP 41251; C, E, paratype, female, cl 20.4 mm, Gonzaga, Brazil, MZUSP 41252. A, male first pleopod, external surface; B, female first pleopod, external surface; C, male second pleopod, external surface; D, female second pleopod, external surface; E, third–fifth pleopod, external surface; F, sixth abdominal somite, telson and uropods, dorsal view.

male, cl 21.2 mm, Tybee Island, 31°59'58"N, 80°50'29"W, Georgia, G.A. Bishop coll., 1 April 1988, USNM 266247; 2 males, cl: 15.0–24.4 mm, Grand Island, 30°08'N, 89°25'W, Louisiana, Gulf of Mexico, E.R. Willis coll., 26 June 1939, USNM 79171; ovigerous female, cl 16.4 mm, Heald Bank, 29°43'36"N, 93°42'29"W, Sabine, Texas, W.G. Hewatt coll., 1967, USNM 97653; 2 ovigerous females, cl: 9.7–20.2 mm, Indian River, 27°52'48"N, 80°27'24"W, Florida, R.B. Manning, W. Lee, M. Schotte & C. King coll., 20 April 1988, USNM 266125; female, cl 21.0 mm, Indian River, 27°38'11"N, 80°21'50"W, North Hutchinson Island, Fort Pierce, Florida, D.L. Felder & W. Lee coll., 14 August 1987, USNM 266118; male, cl 11.1 mm, Fort Pierce area, 27°28'18"N, 80°17'48"W, Florida, R.B. Manning coll., 2 March 1987, USNM 266127; female, cl 15.4 mm, Indian River, 27°28'18"N, 87°17'48"W, North Hutchinson Island, Fort Pierce, Florida, R.B. Manning & W. Lee coll., 2 March 1987, USNM 266126; female, cl 16.3 mm, Indian River, 27°11'00"N, 80°

09'30"W, Seminole Shores, Florida, R.B. Manning & L.K. Manning coll., 7 July 1984, USNM 266111; female, cl 16.3 mm, Indian River, 27°10'30"N, 80°10'24"W, Flat Just Inside Saint Lucie Inlet, Florida, R.B. Manning coll., 11 February 1983, USNM 228087; topotypic, male, cl 13.2 mm, Indian River, 27°10'14"N, 80°10'24"W, Florida, R.B. Manning coll., 9 February 1983, USNM 228086; male, cl 18.6 mm, Lake Worth Inlet, 26°46'17"N, 80°02'14"W, Peanut Island, Florida, R.B. Manning & D.L. Felder coll., 11 August 1987, USNM 266114. *Callichirus* aff. *major*: Colombia: Caribbean coast: male, cl 22.2 mm, La Boquilla, 10°28'19"N, 75°29'59"W, Cartagena, R. Lemaitre coll., 10 August 1980, USNM 266208; male, cl 13.9 mm, ovigerous female, cl 13.7 mm, La Boquilla, 10°28'19"N, 75°29'59"W, Cartagena, R. Lemaitre coll., 10 August 1988, USNM 266225; female, cl 23.6 mm, Castillo Grande, 10°23'43"N, 75°33'02"W, Cartagena Bay, Cartagena, R. Lemaitre coll., 7 July 1988, USNM 266211. *Callichirus seilacheri* (Bott, 1955): El Salvador: topotypic,

male, cl 16.3 mm, female, cl 24.1 mm, Los Blancos, 13° 19'38"N, 88°58'10"W, P. Hernáez & A. Gamboa-González coll., 22 July 2013, MZUCR 3335-01; topotypic, male, cl 8.4 mm, 5 females, cl: 9.7–20.2 mm, Los Blancos, 13° 19'38"N, 88°58'10"W, P. Hernáez & A. Gamboa-González coll., 22 July 2013, MZUCR 3336-01. Costa Rica: Pacific coast: 15 males, cl: 8.2–14.5 mm, 16 females, cl: 8.6–14.9 mm, Mata de Limon, 09°55'12"N, 84°42'37"W, Puntarenas, P. Hernáez & A. Gamboa-González coll., 10 June 2012, MZUCR 3337-01.

**Diagnosis** (from Hernáez et al. 2022) – Carapace with small triangular rostrum and two rounded anterolateral projections. Ocular peduncles contiguous except for separated blunt apical portion, not reaching second article antennular peduncles. Antennular peduncle longer and stouter than antennal peduncle, second article of antennular peduncle slightly exceeding fourth article of antennal peduncle. Maxilliped 3 merus with distal and proximal margins not parallel, strongly oblique distally, not projecting beyond carpo-meral articulation. Male major cheliped merus with prominent hook on lower margin; fixed finger with small triangular tooth at mid length of cutting edge; dactylus strongly arcuate with tip curved downward, bifid, longer than fixed finger, cutting edge with large bifid tooth proximally, otherwise unarmed. Male pleopod 2 with endopod and exopod well developed. Telson slightly broader than long, tapering distally, emarginate posteriorly.

**Distribution and habitat** – Known from Praia do Crispim, Pará to Balneário Camboriú, Santa Catarina, Brazil (Hernáez et al. 2022). This species usually dominates the substrate in terms of other Brazilian burrowing shrimps, being the most common callinassid shrimp in the intertidal zone of medium-grain size sandy beaches of Brazil. The salinity and temperature were, on average,  $29.5 \pm 4.4$  and  $26.7 \pm 5.0^\circ\text{C}$ , respectively.

**Remarks** – Morphologically, *C. corruptus* differs from *C. major* s. str. by a combination of characters including: (1) the ocular peduncle reaches the distal one-third of the first article of the antennular peduncle (vs reaches to or slightly beyond the distal end of the first article of the antennular peduncle in *C. major*; Hernáez et al. 2022: fig. 1a, d); (2) the third article of the antennular peduncle is about 2.0 times as long as the second article (vs 2.4 times as long as the second article; Hernáez et al. 2022: fig. 1a, d), among others characters (for details see Hernáez et al. 2022).

*Callinectes corruptus* can be easily distinguished from the four other American congeners, viz. *C. garthi*, *C. islagrande* (Schmitt, 1935), *C. santarosaensis* (Sakai

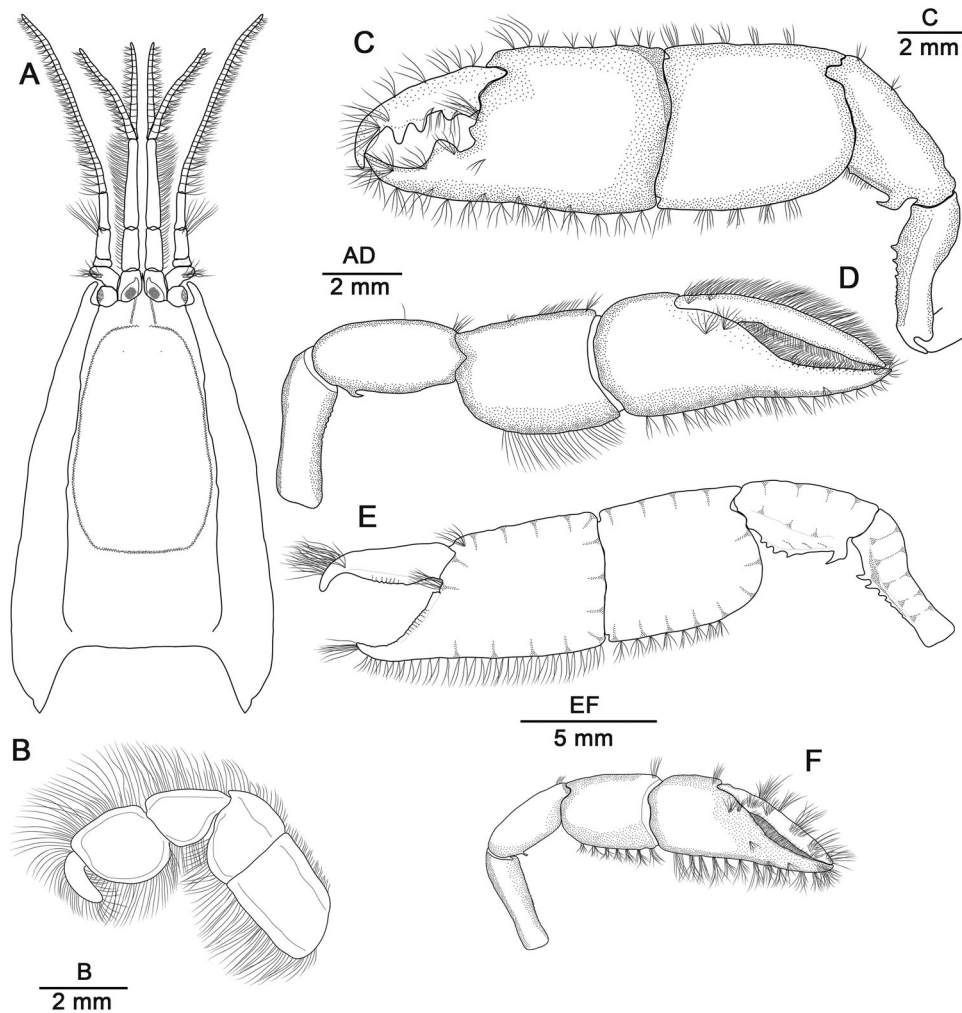
and Türkay, 2012), *C. seilacheri*, by the following combination of three characters: (i) eyestalks with obtuse tip (distomesial projection absent), not exceeding the second article of the antennular peduncle in the new species, whereas it is elongate with distomesial projections exceeding the second article of the antennular peduncle in *C. garthi*, *C. islagrande* and *C. seilacheri*; (ii) maxilliped 3 merus with distal margin strongly oblique in the new species, but slightly oblique in *C. garthi*, *C. islagrande* and *C. seilacheri*; and (iii) male pleopod 2 with the endopod well developed and exopod unsegmented in *C. aff. major* from Brazil, but with endopod reduced and exopod bisegmented in *C. santarosaensis* (cf. Manning and Felder 1991, fig. 2a–c; Hernáez et al. 2015, figs 2a, b, 3a, b; Sakai and Türkay 2012, fig. 10h; Hernáez et al. 2018, fig. 2b, c; Hernáez et al. 2022, figs 8a–f, 9a–h, 10a–e; see also Figures 6A, B, 7C).

#### **Genus *Lepidophthalmus* Holmes, 1904**

*Lepidophthalmus siriboia* Felder and Rodrigues, 1993 (Figures 8A–F, 9A–F)

**Material examined** – Brazil: 6 males, cl: 4.6–10.2 mm, 3 females, cl: 5.3–9.9 mm, Marudá, 00°37'31"S, 47° 37'53"W, Marapanim, Pará, P. Hernáez coll., 9 July 2017, MZUSP 38996; 5 males, cl: 3.5–7.1 mm, 4 females, cl: 3.0–8.3 mm, Praia de Ajuruteua, north side, 00°49'40"S, 46°36'20"W, Bragança, Pará, 7 July 2017, P. Hernáez coll., CRUSTA 170024; 9 males, cl: 7.7–10.2 mm, females, cl: 5.3–9.1 mm, Porto do Dadão, 02° 53'22"S, 41°37'41"W, Luís Correia, Piauí, P. Hernáez coll., 4 July 2017, MZUSP 38999; male, cl: 9.5 mm, 4 females, cl: 6.7–10.4 mm, close to fishing boats, 02° 53'03"S, 40°50'46"W, Camocim, Ceará, P. Hernáez coll., 3 July 2017, MZUSP 39005; male, cl: 8.4 mm, 11 females, cl: 8.4–11.3 mm, Praia Arpoeira, 02°49'56"S, 40°05'08"W, Acaraú, Ceará, P. Hernáez coll., 14 June 2016, MZUSP 39009; 4 males, cl: 9.2–11.3 mm, 8 females, cl: 8.3–11.2 mm, Boca da Barra, 09°42'13"S, 35°47'04"W, Maceió, Alagoas, P. Hernáez coll., 17 May 2017, MZUSP 39015; 2 males, cl: 9.3–10.8 mm, 7 females, cl: 7.5–12.4 mm, Saleiro port, 14°02'38"S, 38° 58'23"W, Península de Maraú, Bahia, P. Hernáez coll., 7 June 2016, MZUSP 39017; 7 males, cl: 6.9–11.7 mm, 5 females, cl: 5.3–11.7 mm, mouth of the river Caravelas, 17°44'16"S, 39°11'15"W, Caravelas, Bahia, P. Hernáez coll., 5 June 2016, MZUSP 39021; 10 males, cl: 8.2–9.7 mm, 10 females, cl: 5.8–12.1 mm, mouth of the river Mucuri, 18°05'34"S, 39°32'51"W, Mucuri, Bahia, P. Hernáez coll., 20 June 2016, MZUSP 39024.

**Diagnosis** – Rostrum spinose distally, overreaching eyestalks. Anterolateral margin of carapace with



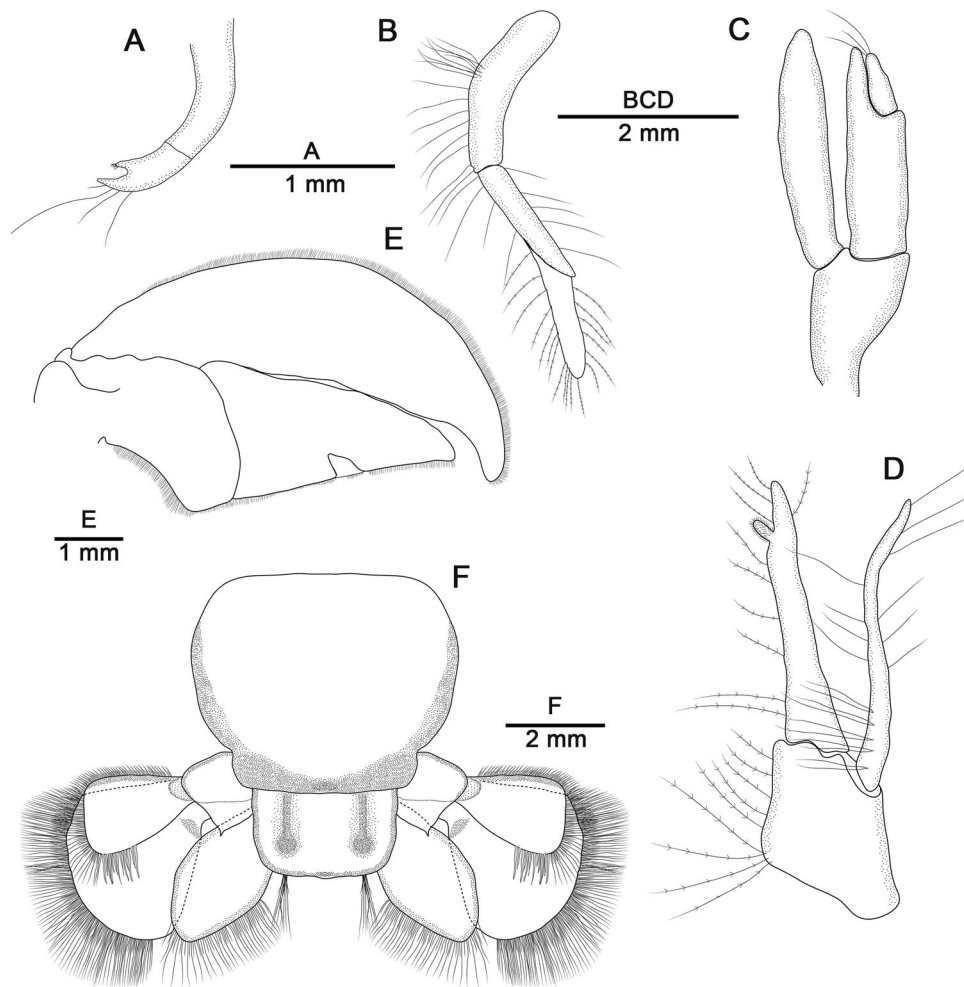
**Figure 8.** A–F, *Lepidophthalmus siriboia* Felder and Rodrigues, 1993. A–D, male, cl 10.3 mm, E, F, female, cl 10.5 mm, Boca da Barra, Brazil, MZUSP 39015. A, carapace front, eyestalk, and antennular and antennal peduncles, dorsal view; B, third maxilliped, external surface; C, male major cheliped, lateral view; D, male minor cheliped, lateral view; E, female major cheliped, lateral view; F, female minor cheliped, lateral view.

rounded projection on each side. A1 peduncle thicker and longer than A2 peduncle, A1 last article more than twice as long as penultimate article. Mxp3 propodus subsquare. P1 unequal in adults of both sexes. Male major cheliped with denticles on ventral margin, dorsal margin arched; small meral hook; also present in female larger cheliped merus; fixed finger with single triangular tooth on cutting edge; dactylus armed with two triangular teeth at middle and one sub-square proximal tooth. Plp1 uniramous in both sexes; bisegmented and chelate distally in male; trisegmented and spatulate distally in female; Plp2 biramous in both sexes; male Plp2 with appendix masculina, but without appendix interna; female Plp2 with small and slightly elongate appendix interna. Plp3–5 with embedded appendix interna. Telson subquadrate, slightly convex on middle

posterior margin. Uropodal protopod with spine on posterodistal corner; dorsal plate of exopod with posterodistal corner bearing dense field of long, stiff, spiniform setae.

**Distribution and habitat** – South-western Atlantic, Brazil: between Pará (Marapanim) and Bahia (Mucuri) (Felder and Rodrigues 1993; present study). This species builds their galleries in sand bars of coarse grain of the estuarine areas. *Lepidophthalmus siriboia* is a euryhaline species, forming populations in hypohaline habitats with salinities below 6 ppt. The salinity and temperature were, on average,  $25.8 \pm 12.1$  and  $30.0 \pm 0.9^\circ\text{C}$ , respectively.

**Remarks** – *Lepidophthalmus* is currently represented by six species in the western Atlantic, viz. *L. jamaicense* (Schmitt, 1935), *L. louisianensis*



**Figure 9.** A–F, *Lepidophthalmus siriboia* Felder and Rodrigues, 1993. A, C, E, F, male, cl 10.3 mm, B, D, female, cl 10.5 mm, Boca da Barra, Brazil, MZUSP 39015. A, male first pleopod, external surface; B, female first pleopod, external surface; C, male second pleopod, external surface; D, female second pleopod, external surface; E, third–fifth pleopod, external surface; F, sixth abdominal somite, telson and uropods, dorsal view.

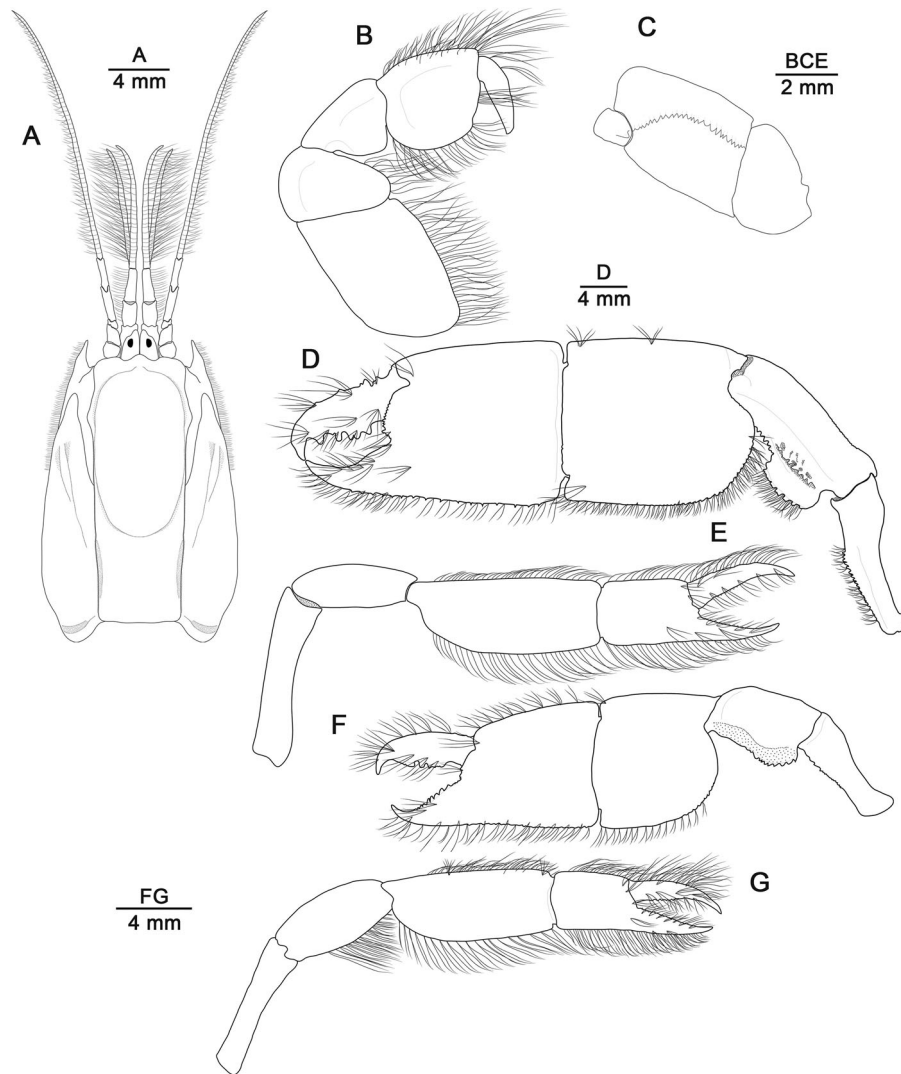
(Schmitt, 1935), *L. manningi* Felder and Staton, 2000; *L. richardi* Felder and Manning, 1997; *L. sinuensis* Lemaitre and Rodrigues, 1991, *L. siriboia* and *L. statoni* Felder, 2015. Endemic from Brazil, *L. siriboia* occurs in estuarine areas of the north-eastern region. In the present study, *L. siriboia* is reported for the first time from the coast of Piauí and Alagoas, spreading the northern-most limit of their distribution range along the Brazilian coastline. *Lepidophthalmus siriboia* can be easily separated from *L. jamaicense*, *L. manningi* and *L. richardi* by the absence of calcified plates on the first and second abdominal sternites (present in the other three species); and from *L. sinuensis* by the presence of rounded anterolateral projections of carapace (subsquare in *L. sinuensis*) (cf. Lemaitre and Rodrigues 1991, fig. 1a; Felder and Manning 1997, fig. 1d, e, 4i; Felder and Staton 2000, fig. 1i; Felder

2003, fig. 27). *Lepidophthalmus siriboia* also shares with *L. louisianensis* and *L. statoni* the presence of ventral abdominal not sclerotized (Felder and Rodrigues 1993; Felder 2015); however, this species can be distinguished from both *L. louisianensis* and *L. statoni* in having the terminal segments of the antennule and antenna with a parallel base (vs. non-parallel base of terminal segments of the antennule and antenna in *L. louisianensis* and *L. statoni*) (cf. Felder and Rodrigues 1993, fig. 1a, 4b; Felder 2015, fig. 1a; see also Figure 8A).

#### Genus *Neocallichirus* Sakai, 1988

*Neocallichirus guara* (Rodrigues, 1971)  
(Figures 10A–G, 11A–F)

**Material examined** – Brazil: 7 males, cl: 9.3–20.4 mm, 3 females, cl: 10.1–17.8 mm, Praia Tutóia, 02°45'40"S,



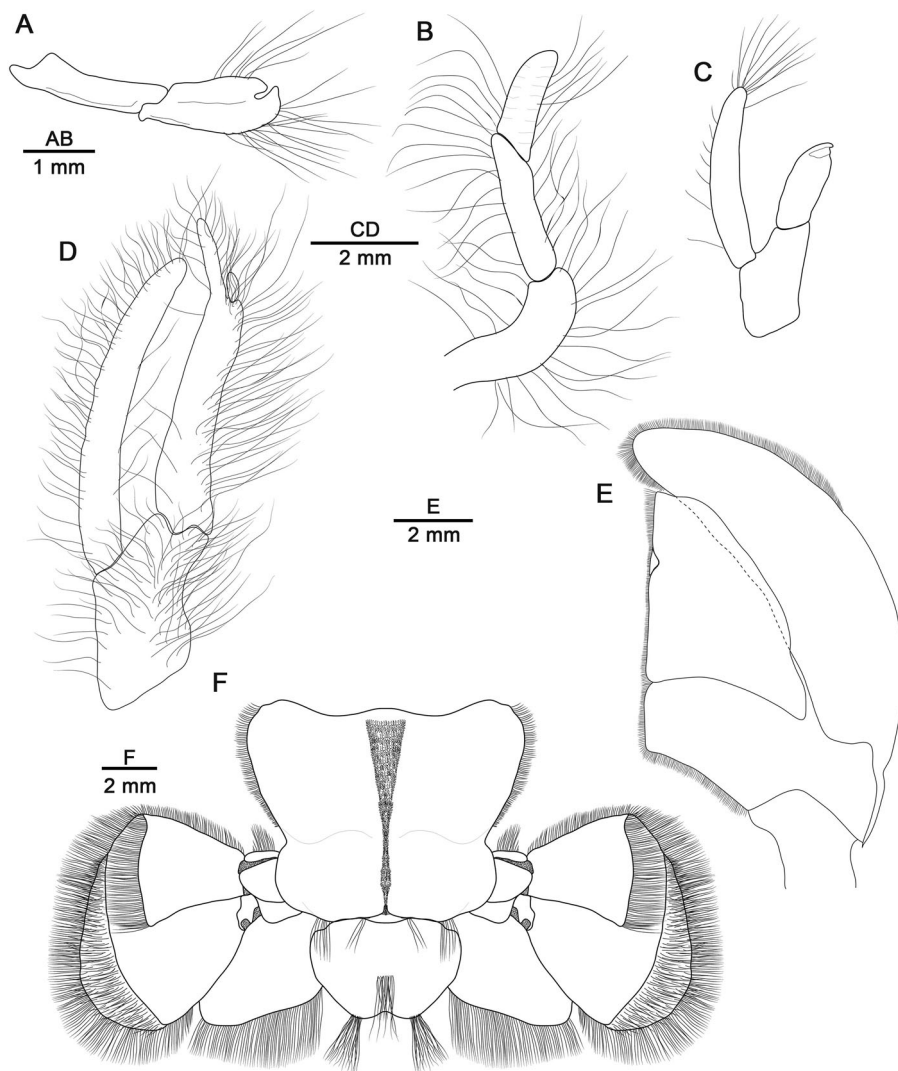
**Figure 10.** A–G, *Neocallichirus guara* (Rodrigues, 1971). A–E, male, cl 20.4 mm, F, G, female, cl 17.2 mm, Tutóia, Brazil, MZUSP 38997. A, carapace front, eyestalk, and antennular and antennal peduncles, dorsal view; B, third maxilliped, external surface; C, same, detail of crista dentata, dorsomesial view; D, male major cheliped, lateral view; E, male minor cheliped, lateral view; F, female larger cheliped, lateral view; G, female minor cheliped, lateral view.

42°15'45"W, Tutóia, Maranhão, P. Hernáez coll., 5 July 2017, MZUSP 38997.

**Comparative material examined** – *Neocallichirus cacahuete* Felder and Manning, 1995: Brazil: male, cl: 8.8 mm, Tremembé beach, 04°44'05"S, 37°17'24"W, Icapuí, Ceará, P. Pachelle coll., 10 February 2014, MZUSP 32615. *Neocallichirus grandimana* (Gibbes, 1850): male, cl: 12.4 mm, 3 females, cl: 8.3–17.8 mm, Potengi river, 05°45'53"S, 35°12'14.61"W, Natal, Rio Grande do Norte, S. Rodrigues coll., 25 March 1984, MZUSP 26417; female, cl: 10.2 mm, Ilha Santa Bárbara, 18°02'01.35"S, 38°40'00.46"W, Bahia, S. Rodrigues coll., 15 February 1967, MZUSP 26418. *Neocallichirus lemaitrei* Manning, 1993: Colombia: holotype, male, cl 11.6 mm, Islas de Rosario, 10°10'N, 75°46'W, Caribbean coast,

R. Lemaitrei & R. Manning coll., 17 July 1988, USNM 256876; paratype, female, cl 18.5 mm, Isla de Barú, 10° 10'N, 75°36'W, Caribbean coast, R. Lemaitrei & R. Manning coll., August 1986, USNM 256875; paratype, female, cl 18.4, same sampling location, R. Lemaitrei & R. Manning coll., 7 August 1986, USNM 256877. *Neocallichirus nickellae* Manning, 1993: Republic of Trinidad and Tobago: holotype, male, cl 15.2, Buccoo Reef, 11° 11'N, 60°49'W, Coral Garden, R. Lemaitrei & R. Manning coll., 28 July 1989, USNM 256879.

**Diagnosis** (modified from Sakai 2011; inclusions are in bold) – **Rostrum short and rounded, tip not reaching cornea. Anterolateral margin of carapace unarmed and subquadrate. A1 peduncle thicker and shorter than A2 peduncle.** Mxp3 ischium-



**Figure 11.** A–G, *Neocallichirus guara* (Rodrigues, 1971). A, C, E, F, male, cl 20.4 mm, F, G, female, cl 17.2 mm, Tutóia, Brazil, MZUSP 38997. A, male first pleopod, external surface; B, female first pleopod, external surface; C, male second pleopod, external surface; D, female second pleopod, external surface; E, third–fifth pleopod, external surface; F, sixth abdominal somite, telson and uropods, dorsal view.

merus subrectangular; **ischium with dentate crest on inner surface**; merus subtriangular; propodus subquadrate, and dactylus digitiform. **P1 unequal in adults of both sexes. Male major cheliped with meral crest ventroproximally, armed with subquadrate teeth; fixed finger unarmed on cutting edge; dactylus armed with three teeth of cutting edge, two rounded on distal half and one tricuspid on proximal half.** Male Plp1 uniramous and bisegmented, distal segment subchelate distally; **female Plp1 uniramous and trisegmented**; male Plp2 biramous, endopod bearing distally proximally-fused appendix masculina with proximally-fused appendix interna distolaterally; **female Plp2 biramous, subterminal appendix interna on endopod**; **Plp3–5 with embedded appendix interna.** Telson wider than

long and trapezoid, and concave medially on posterior margin, without median spine. Uropodal endopod broadly lanceolate.

**Distribution and habitat** – South-western Atlantic, Brazil: Pará, Maranhão, Ceará, Pernambuco (Coelho 1997; Pachelle et al. 2017; present study); São Paulo (Guarujá) (Rodrigues 1971). This species builds galleries in the lower intertidal zone of sand-mud beaches, co-occurring with other burrowing shrimps such as *Neocallichirus maryae* and *B. delicatulus*. The salinity and temperature were, on average,  $35.5 \pm 0.4$  and  $35.1 \pm 0.3^\circ\text{C}$ , respectively.

**Remarks** – The genus *Neocallichirus* currently comprises 33 species (WoRMS 2021) occurring mainly in

tropical shores of the world (Hernández et al. 2020), of which 11 are known from the Americas: ten from the western Atlantic, viz. *N. cacahuete*, *N. grandimana*, *N. guaiqueri* (Blanco Rambla, Liñero Arana and Beltán Lares, 1995), *N. guara* (Rodrigues 1971), *N. guassutinga* (Rodrigues, 1971), *N. lemaitrei*, *N. maryae*, *N. nickellae*, *N. pinheiroi* Hernández, Windsor, Paula and Santana, 2020; *N. raymannigi* Blanco-Rambla and Lemaitre, 1999, and two from the eastern Pacific, viz. *N. grandimana* and *N. mortenseni* Sakai, 2005.

*Callianassa guara* (= *Neocallichirus guara*) was described based on two male specimens from the south-east region of Brasil and first transferred to the genus *Sergio* Manning and Lemaitre, 1994 by Manning and Lemaitre (1994), and later transferred to *Neocallichirus* by Poore et al. (2019). After its description, *N. guara* was never recorded again in the south-eastern region of Brazil, being only later reported by Coelho (1997) in the north-east region of the country. Recently Pachellet et al. (2017), when re-examining the material collected on the coast of Ceará, reported one specimen of *N. guara*. The scarcity of Brazilian records of *N. guara* suggests that this species may be less common in the south-western Atlantic, at least along the continental coast of Brazil. In fact, we have found *N. guara* in only one of all visited sites (see examined material).

*Neocallichirus guara* is morphologically similar to *N. guaiqueri*, which is found along the north-eastern coast of Venezuela (Blanco Rambla et al. 1995). According to these authors, *N. guaiqueri* differs from *N. guara* in having larger, more inflated cornea; in the shape of margins of merus and carpus of the major cheliped, and in dentition of the dactyl of the major cheliped (cf. Blanco Rambla et al. 1995, figs a–d). The Tutoia material examined here includes a significant number of specimens, three mature females (10.1–17.8 mm cl) and seven males (9.3–20.4 mm cl), which is one of the largest collections of this species so far.

*Neocallichirus maryae* Karasawa, 2004 (Figures 12A–G, 13A–F)

**Material examined** – Brazil: male, cl: 10.8 mm, 4 females, cl: 9.0–14.2 mm, Praia Tutóia, 02°45'40"S, 42°15'45"W, Tutóia, Maranhão, P. Hernández coll., 5 July 2017, MZUSP 39000; 6 males, cl: 6.8–14.5 mm, 4 females, cl: 8.3–14.3 mm, Praia Barrinhã, 02°55'03"S, 41°22'28"W, Barra Grande, Piauí, P. Hernández coll., 13 July 2017, MZUSP 39003; 4 males, cl: 6.2–8.5 mm, 3 females, cl: 8.0–9.7 mm, Cajueiro da Praia, in front of

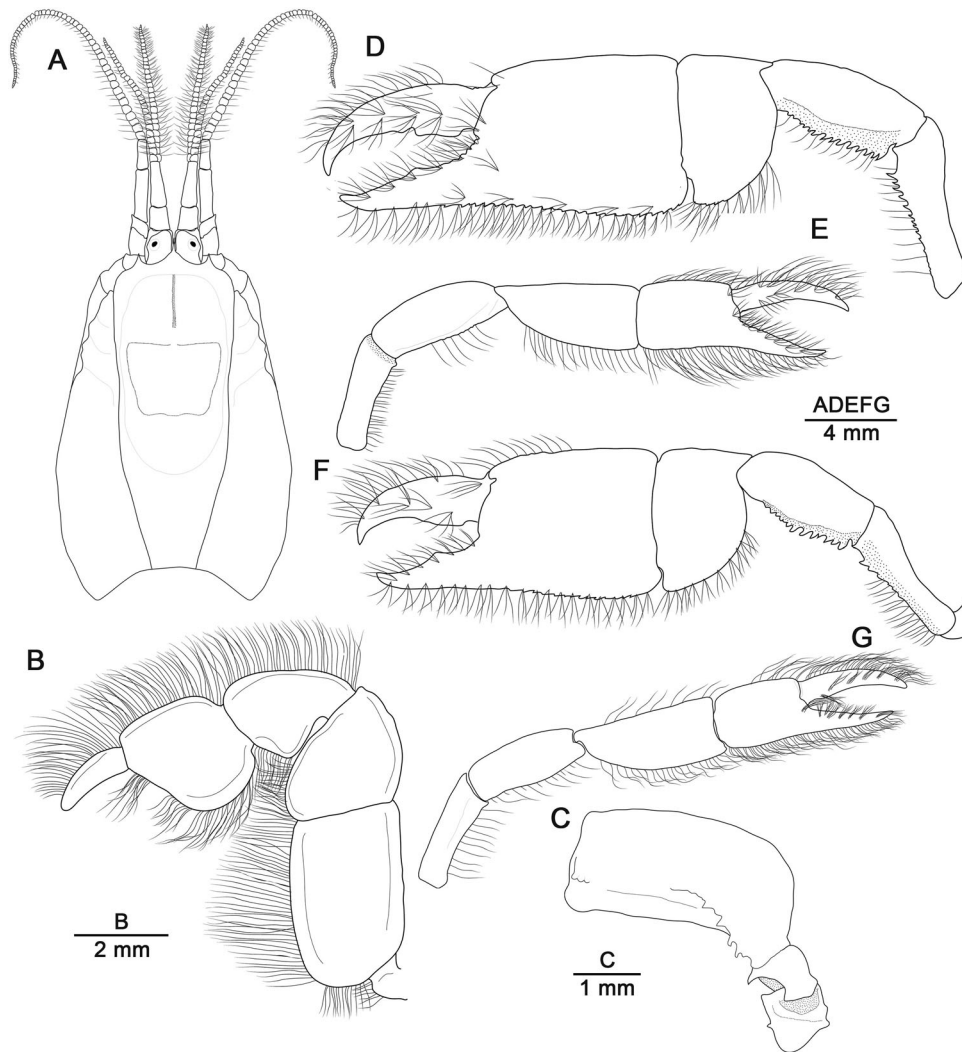
Peixe Boi reserve, 02°55'34"S, 41°20'11"W, Barra Grande, Piauí, P. Hernández coll., 13 July 2017, CRUSTA 170020; 7 males, cl: 9.4–13.5 mm, 16 females, cl: 9.3–17.5 mm, mangrove flats, 04°40'55"S, 37°21'30"W, Icapuí, Ceará, P. Hernández coll., 16 June 2016, MZUSP 39010.

**Diagnosis** (modified from Botter-Carvalho et al. 1995; inclusions are in bold) – **Rostrum spinose distally, not extending beyond the eyestalks. Anterolateral margin of carapace with acute and well-developed projection on each side.** Dorsal region with tuberculi-form bump on anterior third of carapace. **A1 peduncle shorter than A2 peduncle, A1 last article more than twice as long as penultimate article. Mxp3 expanded ventrally; basis with acute spine on inner face; ischium armed with crista dentata on inner face. P1 unequal in adults of both sexes.** Major cheliped with ischium-merus spinose ventrally **in both sexes. Plp1 uniramous in both sexes; bi-segmented in males, distal segment hooked; tri-segmented in females, distal segment spatulate; Plp2 biramous in both sexes; male Plp2 with appendix masculina, but without appendix interna; female Plp2 with digitiform appendix interna; Plp3–5 with projecting, finger-like appendix interna.** Telson trapezoid, convex on posterior margin. Uropodal endopod rhombic; **uropodal exopod with longitudinal carina.**

**Distribution and habitat** – western Atlantic: Key Biscayne, Miami, Florida, USA (Biffar 1971b); Bluefields, Jamaica (Schmitt 1935); St. Croix, Virgin Islands (Sakai 2011); Twin Cays and Cassiopeia Cove, Belize (Sakai 2011); Santa Marta, Caribbean coast of Colômbia (Sakai 2011); Gulf of Cariaco, Venezuela (Blanco-Rambla 2000); Brazil, between Tutóia, Maranhão and Icapuí, Ceará (Pachellet et al. 2016; present study); Forte Orange, Ilha de Itamaracá (Botter-Carvalho et al. 1995). *Neocallichirus maryae* is far more abundant on sea grass with sand flats and in tidal flats dominated by gravel and rubble of shallow subtidal habitats, e.g. in Barra Grande and Cajueiro da Praia, Piauí. The salinity and temperature were, on average,  $35.4 \pm 1.3$  and  $35.1 \pm 0.3^\circ\text{C}$ , respectively.

**Remarks** – *Neocallichirus maryae* was originally described as *Callianassa rathbunae* by Schmitt (1935) based on male specimens from Jamaica and then renamed by Karasawa (2004) as *N. maryae* in a revision of the name assigned to this taxon. This species is widely distributed along the western Atlantic, including an isolated record in the Caribbean region. In





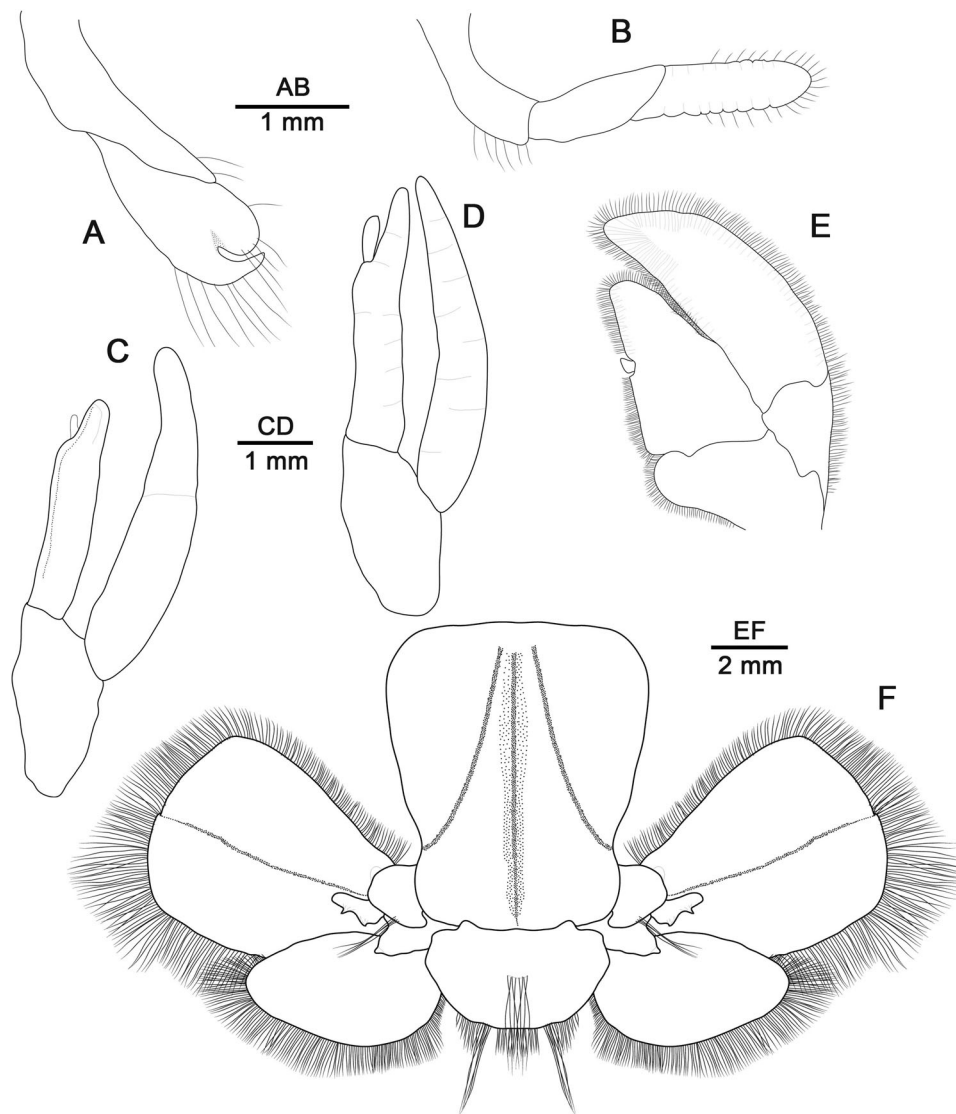
**Figure 12.** A–G, *Neocallichirus maryae* Karasawa, 2004. A–E, male, cl 13.5 mm, F, G, female, cl 12.4 mm, Icapui, Brazil, MZUSP 39010. A, carapace front, eyestalk, and antennular and antennal peduncles, dorsal view; B, third maxilliped, external surface; C, same, detail of crista dentata, dorsomesial view; D, male major cheliped, lateral view; E, male minor cheliped, lateral view; F, female larger cheliped, lateral view; G, female minor cheliped, lateral view.

Brazil, *N. maryae* has been recorded in the north-eastern region (i.e. Ceará, Pernambuco and Alagoas) by Botter-Carvalho et al. (1995), Calado et al. (1998) and Pachellet et al. (2016). In the present study, *N. maryae* is also reported for the first time from Maranhão and Piauí, extending the northern limit of its distribution by ~600 km.

The shape of the anterior region of carapace, male major cheliped, uropodal endopod, and telson, as well as the third maxilliped as described by Manning and Heard (1986, figs 1a–d) for *N. maryae* fit with the examined material of this species in Brazilian coast (see Figures 12A–D, 13F).

*Neocallichirus maryae* is morphologically closest to the western Atlantic species *N. raymannigi*. However, the two species differs from each other by

the shape of the rostrum, which is acute in *N. maryae* but rounded in *N. raymannigi* (cf. Manning and Heard 1986, fig. 1a; Blanco-Rambla and Lemaitre 1999, fig. 1a, b; see also Figure 12A). Furthermore, *N. maryae* can be separated from *N. raymannigi* by the relation between the size of carpus and palm of the male major cheliped, which is about half as long as palm in *N. maryae* but noticeably shorter than half palm in *N. raymannigi* (cf. Manning and Heard 1986, fig. 1c; Blanco-Rambla and Lemaitre 1999, fig. 1c; see also Figure 12D). *Neocallichirus maryae* can be easily separated from the remaining western Atlantic species of the genus *Neocallichirus* because it is the only species with the rostrum subtriangular, terminating in a spine (see Hernández et al. 2020).



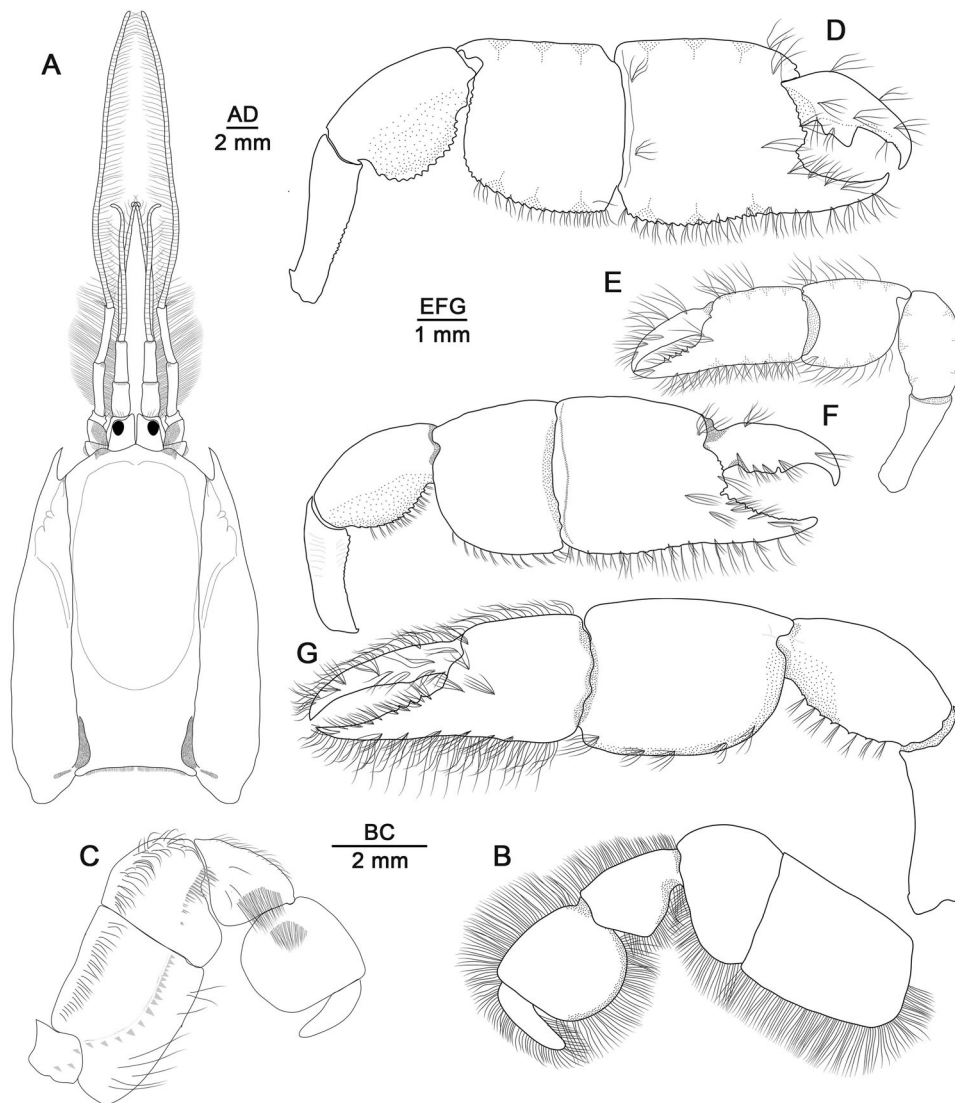
**Figure 13.** A–F, *Neocallichirus maryae* Karasawa, 2004. A, C, E, F, male, cl 13.5 mm, B, D, female, cl 12.4 mm, Icapui, Brazil, MZUSP 39010. A, male first pleopod, external surface; B, female first pleopod, external surface; C, male second pleopod, external surface; D, female second pleopod, external surface; E, third–fifth pleopod, external surface; F, sixth abdominal somite, telson and uropods, dorsal view.

*Neocallichirus pinheiroi* Hernandez, Windsor, Paula and Santana, 2020  
(Figures 14A–G, 15A–F)

**Material examined** – Brasil: holotype, male, cl 20.7 mm, Saquaira beach, 14°02'38"S, 38°56'55"W, in medium size sediment, depth about 1 m, Peninsula de Marau, Bahia, P. Hernandez coll., 6 June 2016, MZUSP 40097. Paratype, female, cl 20.6 mm, same collection site and data, MZUSP 40098. Additional paratypes, 5 males, cl: 7.0–11.8 mm, 6 females, cl: 11.2–16.4 mm, same collection site and data, MZUSP 39018.

**Diagnosis** (from Hernandez et al. 2020) – Carapace frontal margin with rounded lateral projections not

exceeding rostrum distal margin, each with short marginal setae, rostrum broadly rounded, obtuse. Third maxilliped with propodus subquadrate, expanded ventrally; merus subtriangular, internal surface with median row of sclerotized setae; basis subtriangular, internal surface with three spines. Major cheliped with dactylus distinctly longer than fixed finger; dactylus cutting edge with large subtriangular tooth proximally and row of small rounded teeth distally, triangular small tooth near base directed obliquely; cutting edge of fixed finger smooth. Minor cheliped with cutting edge of dactylus microscopically pectinate. First pleopod with distal segment shorter than proximal, bilobed and hooked, with one rounded and one acute tip.



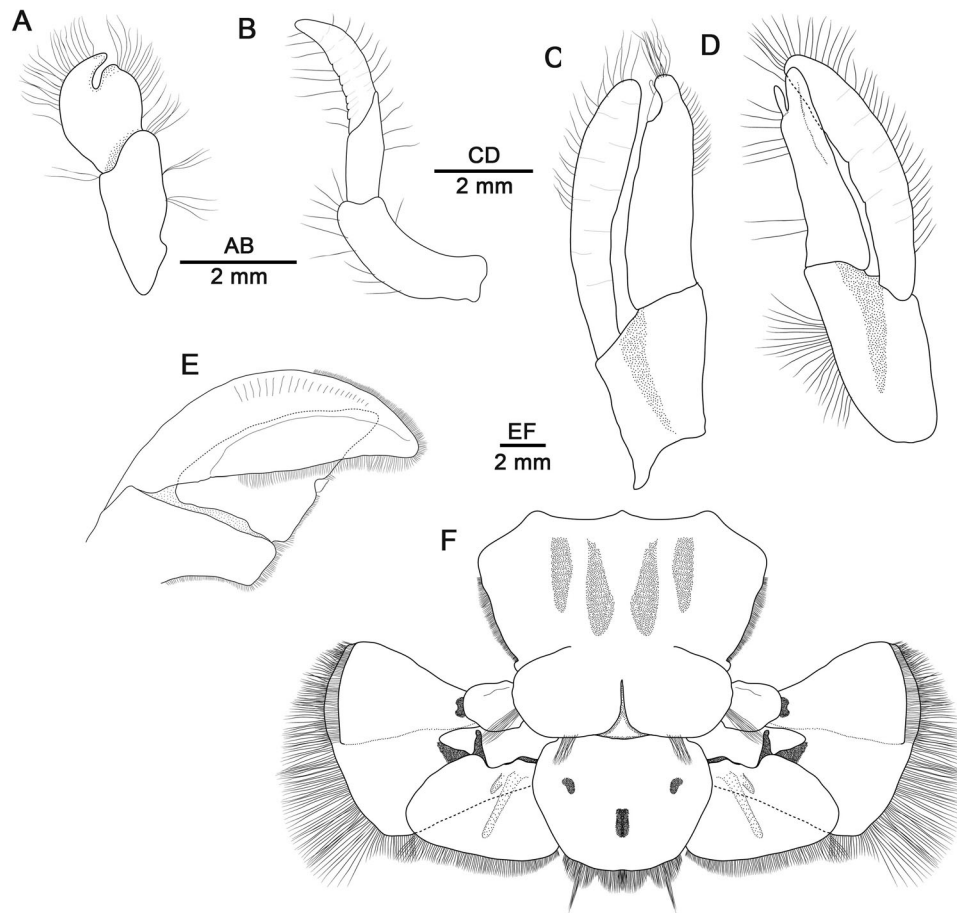
**Figure 14.** A–G, *Neocallichirus pinheiroi* Hernáez, Windsor, Paula and Santana, 2020. A, D, E, male, holotype, cl 20.7 mm, Saquaira, Brazil, MZUSP 40097; B, C, female, paratype, cl 16.4 mm, same site as holotype, MZUSP 39018; F, G, female, paratype, cl 20.6 mm, same site as holotype, MZUSP 40098. A, carapace front, eyestalks, and antennular and antennal peduncles, dorsal view; B, third maxilliped, external surface; C, third maxilliped, internal surface; D, male major cheliped, lateral view; E, male minor cheliped, lateral view; F, female major cheliped, lateral view; G, female minor cheliped, lateral view.

Endopod of second pleopod with appendix masculina demarcated by weak transverse suture, appendix interna digitiform. Posterior margin of telson exceeding the posterior margin of the uropodal endopod.

**Distribution and habitat** – Presently known only from the type locality in Saquaira, Península de Maraú, Bahia, north-eastern Brazil. This species inhabits shallow subtidal habitats at about 1 m in depth, on medium-grain sand substrate. The salinity and temperature were, on average,  $30.9 \pm 0.4$  and  $28.9 \pm 0.2^\circ\text{C}$ , respectively.

**Remarks** – *Neocallichirus pinheiroi* resembles *N. lemaitrei*, but differs from it primarily in having a

third maxilliped propodus expanded ventrally, and in the case of males, a large subtriangular tooth on the cutting edge of the major cheliped dactylus (cf. Manning 1993, fig. 1d, e; see also Figure 14B, D). This species can be easily distinguished from the other nine western Atlantic congeners, viz. *N. cacahuete*, *N. grandimana*, *N. guaiqueri*, *N. guara*, *N. guassutinga*, *N. lemaitrei*, *N. maryae*, *N. nickellae*, *N. raymanningi*, by a combination of characters, including: (i) frontal margin of the carapace having obtuse rounded anterolateral projections (vs. sharp anterolateral projections in *N. maryae* and *N. raymanningi*); (ii) propodus of the third maxilliped with the ventral margin rounded and expanded ventrally (vs. emarginated in *N. lemaitrei*); (iii) male major cheliped having the



**Figure 15.** A–F, *Neocallichirus pinheiroi* Hernandez, Windsor, Paula and Santana, 2020. A, C, E, F, male, holotype, cl 20.7 mm, Saquaira, Brazil, MZUSP 40097; B, D, female, paratype, cl 20.6 mm, same site as holotype, MZUSP 40098. A, male first pleopod, external surface; B, female first pleopod, external surface; C, male second pleopod, external surface; D, female second pleopod, external surface; E, third–fifth pleopod, external surface; sixth abdominal somite, telson and uropods, dorsal view.

carpus about as long as palm (*vs.* carpus notably shorter than palm in *N. cacahuate*, *N. grandimana* and *N. raymanningi*); (iv) posterior margin of the telson exceeding the posterior margin of the uropodal endopod (*vs.* posterior margin of the telson not exceeding the posterior margin of the uropodal endopod in the other nine species); (v) the setation on the internal surface of the third maxilliped (setation absent in *N. lemaitrei* and *N. maryae*); (vi) crista dentata consisting of 15–19 spines (*vs.* 22–24 spines in *N. lemaitrei*); (vii) a large subtriangular tooth on the cutting edge of the major cheliped dactylus (*vs.* subrectangular or rectangular tooth in *N. cacahuate*, *N. grandimana*, *N. lemaitrei*, *N. maryae* and *N. raymanningi*); and (viii) absence of a longitudinal furrow subdividing the distal article of the male first pleopod (present in *N. cacahuate* and *N. lemaitrei*) (*cf.* Rodrigues 1971; Manning and Heard 1986; Manning 1993; Felder and Manning 1995; Blanco-Rambla and Lemaitre 1999; Sakai 2011; Hernandez et al. 2020; see also Figures 11F, 13F, 14A–D, 15AF).

**Infraorder Gebiidea** de Saint Laurent, 1979

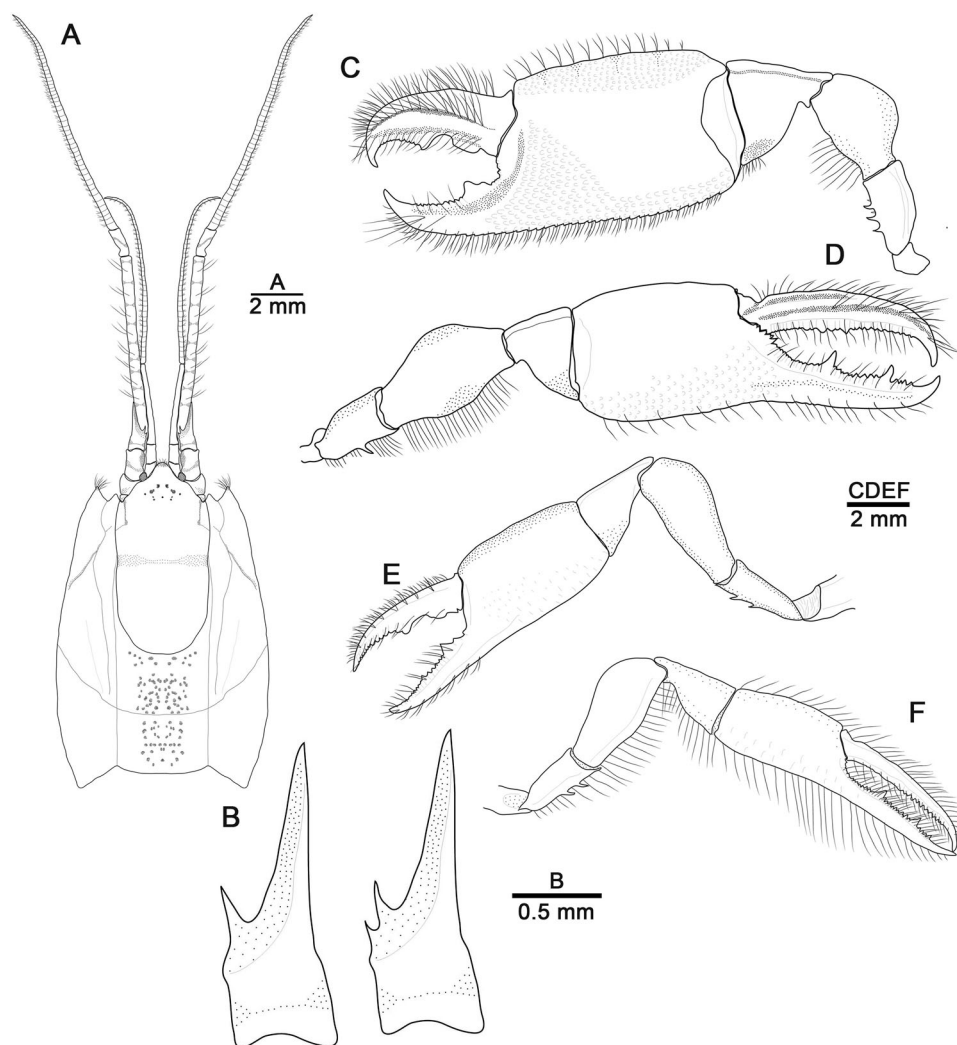
**Family Axianassidae** Schmitt, 1924

**Genus *Axianassa*** Schmitt, 1924

*Axianassa australis* Rodrigues and Shimizu, 1992  
(Figures 16A–F, 17A–C)

**Material examined** – Brazil: 10 males, cl: 6.9–11.7 mm, 19 females, cl: 5.7–11.4 mm, Lago da Santana, 02° 55'03"S, 41°22'28"W, Barra Grande, Piauí, P. Hernandez coll., 13 July 2017, MZUSP 39004; 2 males, cl: 6.9–8.2 mm, 9 females, cl: 4.9–8.1 mm, Praia Arpoeira, 02° 49'56"S, 40°05'08"W, Acaraú, Ceara, P. Hernandez coll., 14 June 2016, MZUSP 39008.

**Comparative material examined** – *Axianassa linda* Anker and Pachel, 2016, Costa Rica: male, cl 7.9 mm, Mata de Limon, 09°55'12"N, 84°42'37"W, Puntarenas, central Pacific coast, P. Hernandez coll., 10 June 2012, MZUCR-3393-01; 2 males, cl: 5.5–8.6 mm, same site and data collection, P. Hernandez coll.,



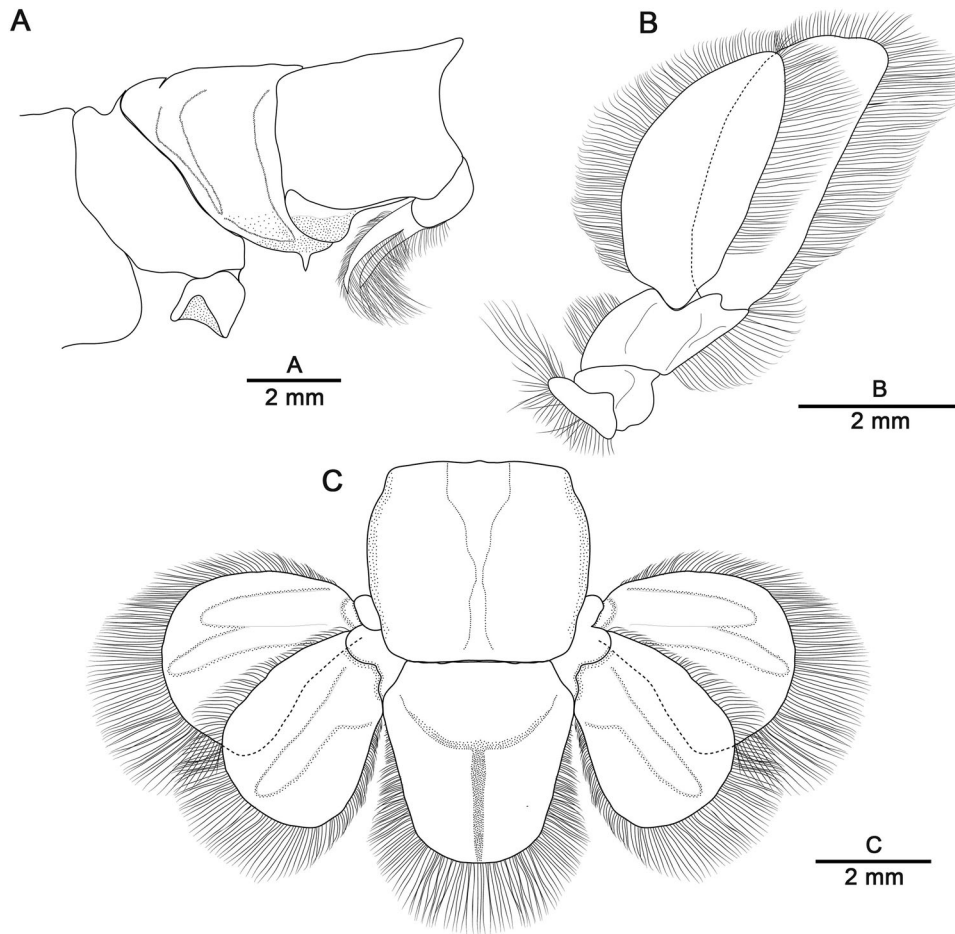
**Figure 16.** A–F, *Axianassa australis* Rodrigues and Shimizu, 1992. A–D, male, cl 10.3 mm, E, F, female, cl 9.7 mm, Lago da Santana, Brazil, MZUSP 39004. A, carapace front, eyestalk, and antennular and antennal peduncles, dorsal view; B, two forms of antennal acicle, dorsal view same; C, male major cheliped, lateral view; D, male minor cheliped, lateral view; E, female larger cheliped, lateral view; F, female minor cheliped, lateral view.

MZUCR-3391-01; 2 males, cl: 3.4–4.3 mm, same site collection, P. Hernáez coll., 21 December 2012, MZUCR-3393-02.

**Diagnosis** (modified from Graça-Melo et al. 2006; inclusions are in bold) – Carapace with well-defined linea thalassinica and cervical groove. **Rostrum well developed and rounded, reaching the end of first antennular segment.** Ventral flagellum of antennule a little bit longer than 1/3 of the dorsal flagellum's length. **A2 peduncle segment 2** with thin aciculae, bearing a sharp **tooth, sometimes two teeth**, on the inner margin. Mxp3 protopod with 1–2 small teeth at the lateral surface; **ischium-merus not fused**; ischium with a fringe bearing 14 teeth. Asymmetric and sexually dimorphic chelipeds; **male major cheliped ischium with five teeth on ventral margin, three bigger and two minute; ventral margin of**

**merus with minute teeth on proximal half.** Abdomen with thin walls. Pleura from the first abdominal somite, ventrally elongate, ending as a spine-like process, not reaching the middle line. Pleura from somites 3, 4 and 5 bearing a thick fringe of plumose setae. Pleura from somite 6 bearing a few hair-like structures and a sinuous ventral margin. **Male Plp1 absent; female Plp1 uniramous and bisegmented. Plp2-5 foliaceous, appendix interna absent.** Telson **acuminate; uropodal exopod and endopod foliaceous.**

**Distribution and habitat** – Western Atlantic: USA, between Florida and south-western Gulf of Mexico (Felder 2001); Golfo de México (México); Brazil, between Ceará and Paraná (Rodrigues and Shimizu 1992; Graça-Melo et al. 2006; Rosa and Almeida 2012;



**Figure 17.** A–C, *Axianassa australis* Rodrigues and Shimizu, 1992. A–C, male, cl 10.3 mm, Lago da Santana, Brazil, MZUSP 39004. A, first and second pleonites, lateral view; B, second–fifth pleopod, external surface; F, sixth abdominal somite, telson and uropods, dorsal view.

Botter-Carvalho et al. 2015; Pachelles et al. 2016; present study). This species builds galleries in mud-flat sediments close to estuarine areas. The salinity average was, on average,  $35.4 \pm 0.10$ .

**Remarks** – *Axianassa* currently comprises 15 species occurring mainly in the intertidal zone of tropical habitats (Anker and Pachelles, 2016), of which 11 are known from the Americas: six from the western Atlantic, viz. *A. arenaria* Kensley and Heard, 1990; *A. australis* Rodrigues and Shimizu, 1992; *A. ferrazae* Blanco-Rambla and Kensley, 1998; *A. intermedia* Schmitt, 1924; *A. jamaicensis* Kensley and Heard, 1990; *A. ovis* Blanco-Rambla and Kensley, 1998; and five from the eastern Pacific, viz. *A. canalis* Kensley and Heard, 1990; *A. christyi* Anker and Pachelles, 2016; *A. darrylfelderi* Anker and Lazarus, 2015; *A. linda* and *A. mineri* Boone, 1931.

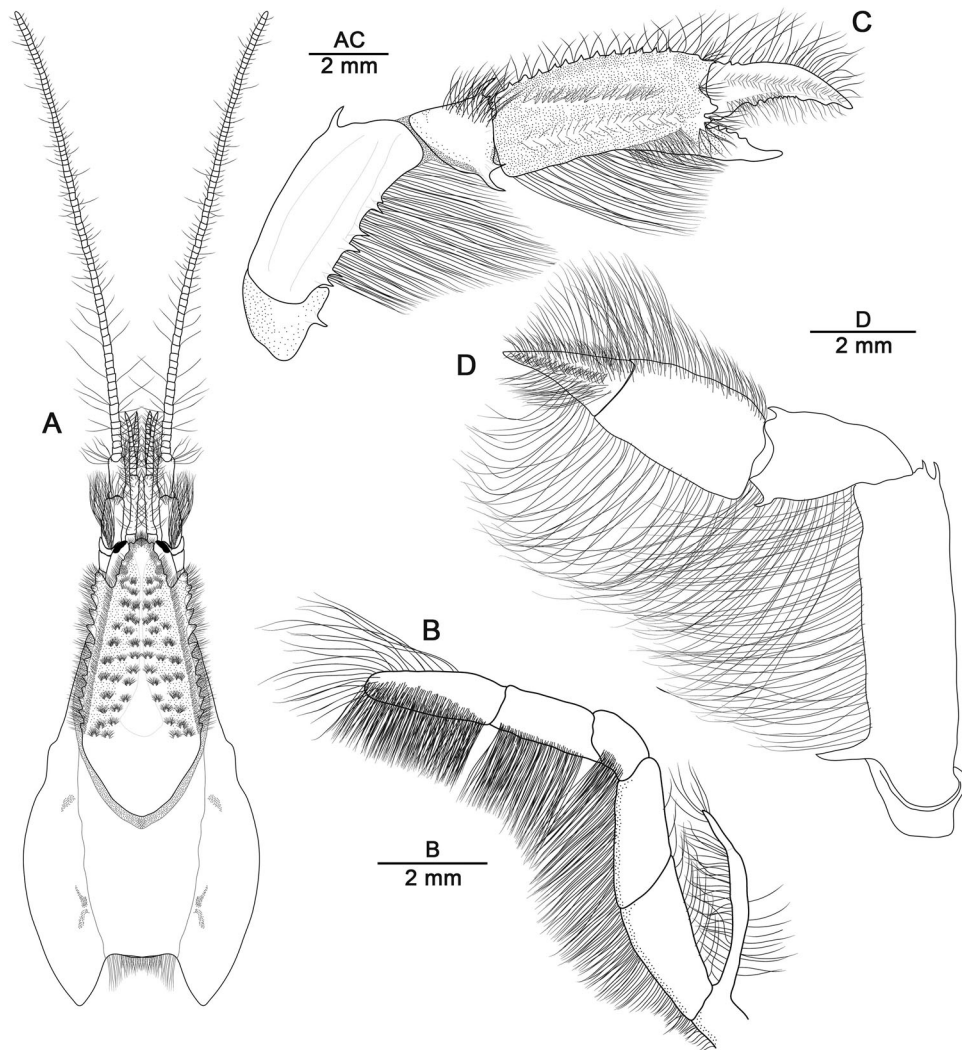
*Axianassa australis* is the only species of *Axianassa* from the Brazilian coast. In Brazil, this species has been recorded in the states of Pernambuco, Bahia,

São Paulo and Paraná (Graça-Melo et al. 2006). In the present study, *A. australis* is also reported for the first time from Piauí and Ceará, extending the northern limit of its distribution by ~800 km.

*Axianassa australis* can be differentiated from other western Atlantic species of *Axianassa* in having an antennal acicle slender, dagger-like, armed with one tooth on mesial margin (which is absent in *A. arenaria*), the presence of a ventral spiniform process on first abdominal somite (vs. spiniform process in *A. jamaicensis* and *A. intermedia*) and distolateral margin of uropodal exopod smooth (vs. with two to three teeth in *A. darrylfelderi*). Regarding *A. ferrazae* and *A. ovis*, both species from Venezuela, it is important to highlight that these species were not formally described. Indeed, the existence of both species is reported through a not illustrated abstract submitted in a Venezuelan meeting, being nomen nudum.

**Family Upogebiidae** Borradaile, 1903

**Genus Upogebia** Leach, 1814



**Figure 18.** A–D, *Upogebia omissa* Gomes Corrêa, 1968. A–D, male, cl 11.9 mm, Arpoeira, Brazil, CRUSTA 160024. A, carapace front, eyestalk, and antennular and antennal peduncles, dorsal view; B, third maxilliped, mesial view; C, male right cheliped, dorsal view; D, male second pereopod, lateral view.

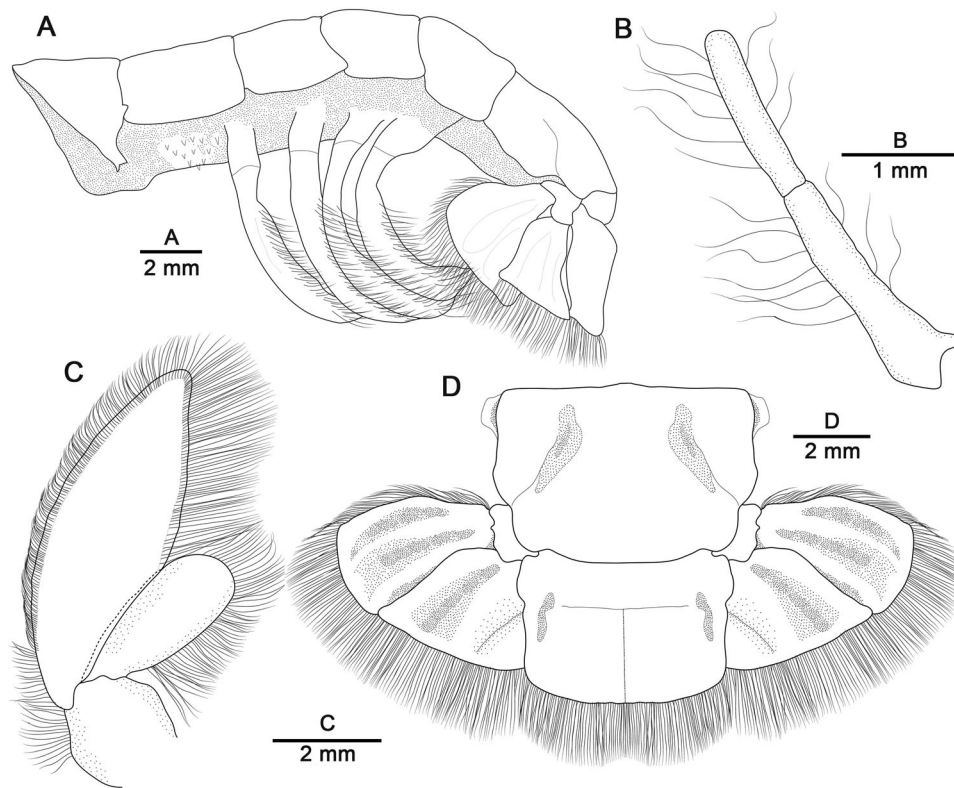
*Upogebia omissa* Gomes Corrêa, 1968  
(Figures 18A–D, 19A–D)

**Material examined** – Brazil: 6 males, cl: 5.1–11.9 mm, 5 females, cl: 10.2–14.7 mm, Praia Arpoeira, 02°49'56"S, 40°05'08"W, Acaraú, Ceará, P. Hernández coll., 14 June 2016, CRUSTA 160024.

**Diagnosis** (modified from Melo 1999; inclusions are in bold) – Rostrum triangular and short, straight or slightly curved downward and unarmed ventrally; anterolateral border of carapace with strong tooth beside eyestalk. **A1 peduncle thinner and shorter than A2 peduncle. Mxp3 digitiform**, epipod present and **exopod well developed**. P1 dactylus longer than polex in both sexes. P2 merus with two dorsal spines and one strong proximal spine.

**Male abdominal sternite 2 with calcified plate armed with acute spines; female abdominal sternites 1–2 with calcified plates armed with acute spines. Male Plp1 absent; female Plp1 uniramous and bisegmented; Plp2–5 foliaceous, appendix interna absent. Sixth abdominal somite with anterolateral subquadrate process. Telson subquadrate, transverse and lateral carinae, convex posterior margin. Uropodal protopod with acute spine.**

**Distribution and habitat** – western Atlantic: between Florida, USA and Santa Catarina, Brazil, including Caribbean islands and Caribbean coast of Colombia (Sakai 2006 and references therein). This species builds galleries in mud-flat sediments close to estuarine and mangrove areas.



**Figure 19.** A–D, *Upogebia omissa* Gomes Corrêa 1968. A, C, D, male, cl 11.9 mm, B, female, cl 12.2 mm, Arpoeira, Brazil, CRUSTA 160024. A, male pleon, lateral view; B, female first pleopod; C, second-fifth pleopod, external surface; D, sixth abdominal somite, telson and uropods, dorsal view.

**Table I.** Burrowing shrimp species of the infraorder Axiidea and Gebiidea reported in literature for Brazilian coast. The habitat of each species, intertidal or subtidal, is represented by 'I' and 'S', respectively.

Taxon	Habitat	Reference
<b>Infraorder Axiidea de Saint Laurent, 1979</b>		
<b>Family Anacalliidae Manning and Felder, 1991</b>		
<i>Anacalliax argentinensis</i> (Biffar, 1971a)	S	Ferreira and Pachelle 2019
<b>Family Axiidae Huxley, 1879</b>		
<i>Axiopsis brasiliensis</i> Coelho and Ramos-Porto, 1991	S	Coelho 1997
<i>Axiorygma nethertoni</i> Kensley and Simmons, 1988	S	Coelho 1997
<i>Calaxius spinosus</i> (Coelho, 1973a)	S	Coelho 1973a
<i>Coralaxius nodulosus</i> (Meinert, 1877)		
<i>Manaxius angulatus</i> (Coelho, 1973a)	S	Coelho 1973a
<i>Paraxiopsis defensus</i> (Rathbun, 1901)	S	Coelho 1997
<i>Paraxiopsis pindatyba</i> (Rodrigues and Kensley, 1991)	I	Rodrigues and Kensley 1991
<i>Paraxiopsis vicina</i> (Coelho and Ramos-Porto, 1991)	S	Coelho 1997
<b>Family Callianassidae Dana, 1852</b>		
<i>Biffarius biformis</i> (Biffar, 1971a)	I	Botter-Carvalho et al. 2012
<i>Biffarius botterae</i> Hernáez, Miranda and Tavares, 2020	I	Hernáez et al. 2020
<i>Biffarius delicatulus</i> Rodrigues and Manning, 1992a	I	Rodrigues and Manning 1992a
<i>Cheramoides marginatus</i> (Rathbun, 1901)	S	Coelho 1997
<i>Cheramus profundus</i> (Biffar, 1973)	S	Coelho 1997
<i>Fragillianassa fragilis</i> (Biffar, 1970)	I	Botter-Carvalho et al. 2012
<i>Poti gaucha</i> Rodrigues and Manning, 1992b	S	Rodrigues and Manning 1992b
<b>Family Callichiridae Manning and Felder, 1991</b>		
<i>Audacallichirus mirim</i> (Rodrigues, 1971)	I	Rodrigues 1971
<i>Callichirus corruptus</i> Hernáez, Miranda, Rio and Pinheiro, 2022	I	Melo 1999
<i>Corallianassa hartmeyer</i> (Schmitt, 1935)	I	Coelho 1997
<i>Corallianassa longiventris</i> (A. Milne-Edwards, 1870)	I	Coelho 1997
<i>Lepidophthalmus siriboia</i> Felder and de Rodrigues, 1993	I	Felder and Rodrigues 1993
<i>Neocallichirus cacahuete</i> Felder and Manning, 1995	I	Felder and Manning 1995
<i>Neocallichirus grandimana</i> (Gibbes, 1850)	I	Melo 1999
<i>Neocallichirus guara</i> (Rodrigues, 1971)	I	Rodrigues 1971
<i>Neocallichirus guassutinga</i> (Rodrigues, 1971)	I	Rodrigues 1971

(Continued)



Table I. Continued.

Taxon	Habitat	Reference
<i>Neocallichirus maryae</i> Karasawa, 2004	I	Pachelle et al. 2016
<i>Neocallichirus pinheiroi</i> Hernáez, Windsor, Paula and Santana, 2020	I	Hernáez et al. 2020
<b>Family Ctenocheilidae Manning and Felder, 1991</b>		
<i>Ctenocheilus holthuisi</i> Rodrigues, 1978	S	Rodrigues 1978
<i>Ctenocheiloides almeidai</i> Anker and Pachelle, 2013	I	Anker and Pachelle 2013
<i>Dawsonius latispinus</i> (Dawson, 1967)	S	Coelho 1997
<i>Gourettia laresi</i> Blanco Rambla and Liñero Arana, 1994	S	Pachelle et al. 2013
<b>Family Eucalliaciidae Manning and Felder, 1991</b>		
<i>Eucalliaxiopsis cearaensis</i> (Rodrigues and Manning, 1992a)	I	Rodrigues and Manning 1992a
<b>Family Micheleidae Sakai, 1992</b>		
<i>Marcusiaxius lemoscastroi</i> Rodrigues and Carvalho, 1972	S	Rodrigues and Carvalho 1972
<i>Marcusiaxius minutus</i> (Coelho, 1973b)	S	Coelho 1997
<i>Meticonaxius capricorni</i> Coelho, 1987	S	Coelho 1997
<b>Infraorder Gebiidea de Saint Laurent, 1979</b>		
<b>Family Axianassidae Schmitt, 1924</b>		
<i>Axianassa australis</i> Rodrigues and Shimizu, 1992	I	Rodrigues and Shimizu 1992
<b>Family Upogebiidae Borradaile, 1903</b>		
<i>Potamogebia operculata</i> (Schmitt, 1924)	S	Coelho 1997
<i>Upogebia acanthura</i> Coelho, 1973c	S	Coelho 1997
<i>Upogebia brasiliensis</i> Holthuis, 1956	I	Coelho 1997
<i>Upogebia careospina</i> Williams, 1993	S	Melo 1999
<i>Upogebia marina</i> Coelho, 1973c	S	Coelho 1997
<i>Upogebia noronhensis</i> Fausto-Filho, 1969	S	Melo 1999
<i>Upogebia omisa</i> Gomes-Corrêa, 1968	I	Coelho 1997
<i>Upogebia omisago</i> Williams, 1993	I	Williams 1993
<i>Upogebia paraffinis</i> Williams, 1993	I	Melo 1999
<i>Upogebia vasquezi</i> Ngoc-Ho, 1989	I	Coelho 1997

**Remarks** – *Upogebia omisa* is widely distributed along the western Atlantic (for details see Sakai 2006). In Brazil, this species has been recorded in the states of Maranhão, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Bahia, Espírito santo, Rio de Janeiro, São Paulo, Paraná, Santa Catarina. *Upogebia omisa* can be separated from other *Upogebia* species recorded in Brazil by having ventral plates calcified on abdominal somites 1 and 2 (only females) armed with acute teeth, and by one distodorsal spine on pereopods 2–3 and by numerous spined ventrally on pereopod 4 merus (Melo 1999).

## Discussion

A review of the literature shows us that so far, a total of 46 species of burrowing shrimps have been reported from Brazil: 35 Axiidea and 11 Gebiidea (Table I). From these, 24 out of 46 recorded species are distributed in intertidal habitats. This number is much higher than the total of the species found by us during our intense sampling activities along the Brazilian coast; our results show only 11 species found. This could be a result of poor identification of previous records or local extinctions of some populations. Nevertheless, the distribution of six out of 11 were modified, with new distributional ranges for *A. mirim*, *L. siriboia*, *N. guara*, *N. maryae* and *A. australis*. It is important to note that a sampling effort comprising

most of the Brazilian coast (Figure 1) directed to this specific group has never been done. Extensive sampling efforts are essential to construct a larger picture about the biology of such an important group of bioturbators and construct the underlying causes of the latitudinal gradient of species diversity of this group along the western Atlantic (for details on this theme see Hernáez et al. 2020). In particular, this information has also historical significance as a temporal picture of the burrowing shrimps in Brazil to date, which can be very useful for conservation purposes.

## Acknowledgements

The lead author is grateful to Juliana Rio for her help during some sampling activities. The material described herein was collected during the project entitled 'Diversidade e distribuição geográfica de camarões corruptos (Infraordens Axiidea e Gebiidea), ao longo do litoral brasileiro: uma aproximação ecológica aos padrões biogeográficos de distribuição'. We thank in particular Mrs Carolin Löscher, Editor in Chief, for the vital work she has done during the revision process of our article. Finally, we also thank the anonymous referees, who helped to improve the content of this article.

## Disclosure statement

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## Authors contributions

P.H. and M.A.A.P. conceived the idea for this study; P.H. collected the data; P.H., M.A.A.P. and W.S. examined the material; P.H., M.A.A.P., F.A.A.J. and W.S. wrote the paper.

## Sampling and field studies

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