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ARTICLE

Update on the geographical distribution of freshwater crabs of the Pseudothelphusidae family in the semi-arid region of northeastern Brazil

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Abstract. The humid forest zones of northeastern Brazil are recognized as endemic hotspots for pseudothelphusid crabs. In this study, we report new occurrence records of the pseudothelphusids, *Fredius ibiapaba* and *Kingsleya attenboroughi,* in humid soil and streams within humid forests of the semi-arid region of northeastern Brazil. These new records expand the geographical distribution of these crabs, highlighting their potential to inhabit humid forests throughout this region. Furthermore, this information indicates that these crabs, especially *K. attenboroughi,* are not confined to slopes and patches of humid forests in highland swamps but can also extend to springs in other areas of the Brazilian semi-arid region.

Keywords. Freshwater crabs; Endemic species; Humid forest Brazilian semi-arid; Neotropical crabs.

INTRODUCTION

Pseudothelphusidae Ortmann, 1893, comprises a family of freshwater crabs widely distributed throughout the Neotropical region, typically associated with mountainous environments ranging in altitude from 300 to 3,000 meters (Rodríguez & Magalhães, 2005; Acevedo-Alonso & Cumberlidge, 2021). With an estimated 290 species, these crabs inhabit a wide variety of habitats, such as rivers, streams, lakes, swamps, waterfalls, and caves (Magalhães & Türkay, 2010). In Brazil, the majority of pseudothelphusid species are concentrated in the northern region, primarily within the Amazon basin (Magalhães, 2003, 2016; Cumberlidge *et al.,* 2014).

However, recent studies conducted in northeastern Brazil have revealed that the Pseudothelphusidae fauna in this region is underestimated (Pinheiro & Santana, 2016; Pralon *et al.,* 2020; Santos *et al.,* 2020a). Additionally, geographic distribution studies and descriptions of new species have expanded the eastern limits of pseudothelphusid distribution into the states of Ceará (Magalhães *et al.,* 2005; Pinheiro & Santana, 2016; Santos *et al.,* 2020a) and Piauí (Pralon *et al.,* 2020).

Similar to other pseudothelphusid crabs, the species described from northeastern Brazil exhibit restricted distributions and a high degree of endemism. Currently, *Kingsleya attenboroughi* Pinheiro & Santana, 2016 and *Fredius ibiapaba* Santos, Tavares, Silva, Cervini, Pinheiro & Santana, 2020 are found in limited areas along the eastern portions of the Chapada do Araripe and Serra da Ibiapaba, respectively (Pinheiro & Santana, 2016; Santos *et al.,* 2020a, b; Araújo *et al.,* 2022), with the exception of a recent record suggesting the probable occurrence of *F. ibiapaba* in Bragança, Pará (Mantelatto *et al.,* 2022). Furthermore, *Kingsleya parnaiba* Pralon, Pinheiro & Santana, 2020 has been recorded only at its type locality (Pralon *et al.,* 2020).

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The restricted geographic distribution and anthropogenic pressures indicate a favorable scenario for the extinction of freshwater crab species (Vogt, 2013; Magalhães, 2016). Dalu *et al.* (2017) suggest that establishing the actual distribution area of a species is crucial for conservation actions. Therefore, the present study reports new occurrence records of Pseudothelphusidae freshwater crabs in the semi-arid region of northeastern Brazil, thereby expanding their distributional range.

MATERIAL AND METHODS

Sampling was carried out between June 2021 and November 2022 in poorly explored humid forest areas located in the states of Ceará and Piauí, in the semi-arid region of northeastern Brazil. These two states were explored due to previous records of pseudothelphusid species (Magalhães *et al.,* 2005; Pinheiro & Santana, 2016; Pralon *et al.,* 2020; Santos *et al.,* 2020a, b; Araújo *et al.,* 2022) and the presence of humid forest areas that have been under-explored for freshwater crabs.

During field sampling, crab specimens were collected during the day using the active search method, inspecting small streams on humid forest slopes, as well as soils with litter, characteristic environments where Pseudothelphusidae occur in northeastern Brazil (Magalhães *et al.,* 2005; Pinheiro & Santana, 2016; Pralon *et al.,* 2020; Santos *et al.,* 2020a, b). The sex was determined by the presence (males) or absence (females) of gonopods, according to Magalhães (2003). Subsequently, the crabs were individually placed in plastic containers and euthanized by cooling on crushed ice. Then, we packed the crabs in a thermal box and transported them to the Laboratório de Crustáceos do Semiárido (LACRUSE) at the Universidade Regional do Cariri (URCA), in the municipality of Crato, Ceará, Brazil.

In the laboratory, the specimens were identified as *Fredius ibiapaba* and *Kingsleya attenboroughi* according to Santos *et al.* (2020a) and Pinheiro & Santana (2016), respectively, based on the morphology of male gonopods (Figs. 1, 2). Subsequently, specimens were measured using a digital caliper (precision of 0.01 mm) for carapace width (CW = distance between the lateral margins of the carapace), pleon width (PW = width of the 4th pleon somite for females and the 3rd for males), and length of the larger propodus (LP = distance between the base and the distal portion of the larger propodus). Finally, specimens were preserved in 70% ethanol and deposited in the LACRUSE carcinological collection.

RESULTS

Family Pseudothelphusidae Ortmann, 1893
Subfamily Kingsleyinae Bott, 1970
Genus *Fredius* Pretzmann, 1967

Fredius ibiapaba Santos, Tavares, Silva, Cervini, Pinheiro & Santana, 2020 (Fig. 1).

New records: BRAZIL – **Ceará:** Parque Estadual das Carnaúbas, municipality of Granja, district of Timonha; 03°18′14.11″S, 041°09′56.74″W; 760 m altitude; 19.VII.2021; J.G. Araújo, C.A.M. Martins, C.A. Nascimento & P.H.P. Nobre; 2 males e 1 female (LACRUSE 304).

Additional material: Fonte do caranguejo, in the city of Viçosa do Ceará; 03°33′39.35″S, 041°05′14.60″W; 600 m; 20.VII.2021; J.G. Araújo, C.A.M. Martins, C.A. Nascimento & P.H.P. Nobre; 1 male (LACRUSE 305).

Distribution: Brazil, state of Ceará.

Previous records: Planalto da Ibiapaba, municipality of Ipu, state of Ceará, in the following localities: sítio Gameleira (04°17′42.00″S, 040°44′48.00″W), sítio Gameleira Quintal (04°17′042.00″S, 040°44′43.00″W); cachoeira do sítio Ipuçaba (04°17′56.00″S, 040°44′35.00″W); olho d'água do sítio Ipuçaba (04°18′05.00″S, 040°44′43.00″W); olho d'água da Cinta (04°18′34.00″S, 040°44′48.00″W); sítio Caranguejo (04°18′51.00″S, 040°44′48.00″W); Santa Cruz I (04°19′40.00″S, 040°45′09.00″W); Santa Cruz II (04°19′40.00″S, 040°45′09.00″W); olho d'água da Taperinha (04°20′18.00″S, 040°45′23.00″W); riacho da Taperinha (04°20′33.00″S, 040°45′32.00″W); and Santa Luzia (04°22′11.00″S, 040°45′52.00″W) (Santos *et al.,* 2020a). Planalto da Ibiapaba, municipality of Viçosa do Ceará, state of Ceará, fonte do Caranguejo (03°33′43.20″S, 041°5′9.06″W) (Magalhães *et al.,* 2005; Santos *et al.,* 2020a). Municipality of Bragança, state of Pará (Mantelatto *et al.,* 2022).

Remarks: Three specimens of *F. ibiapaba* were found in Parque Estadual das Carnaúbas inside burrows approximately 50 centimeters deep (Fig. 3A, B), constructed in a small forested area with humid soil at approximately 760 m above sea level (Fig. 3C-E). This new occurrence area is approximately 29.9 km north of the nearest recorded occurrence point (Fig. 4B), located at Fonte do Caranguejo in the municipality of Viçosa do Ceará, and approximately 122.17 km north of the type locality at Sítio Santa Cruz, municipality of Ipu. Among the collected specimens, two are males (male 1: CW = 43.42 mm, PW = 13.20 mm, LP = 34.47 mm; male 2: CW = 46.12 mm, PW = 14.24 mm, and LP = 37.55 mm) and one female (CW = 39.66 mm, PW = 17.62 mm, and LP = 29.01 mm) LACRUSE 304 (Fig. 5C, D).

The new site showed few signs of anthropic intervention, with dense vegetation, humid soil rich in organic matter, and well shaded conditions, favoring the occurrence of the species. However, all these factors were present only in a small area, limiting the distribution of specimens around a headwater. Additionally, this area exhibits few signs of anthropic pressures.

At Fonte do Caranguejo, we found only one male specimen LACRUSE 305 (CW = 35.05 mm, AW = 11.34 mm, and LP = 26.64 mm) of *F. ibiapaba* (Fig. 5E) inside a burrow approximately 40 cm deep (Fig. 5B, C), constructed under rocks in the humid soil of a small forested area around the spring near the rocky wall (Fig. 6A). Due to

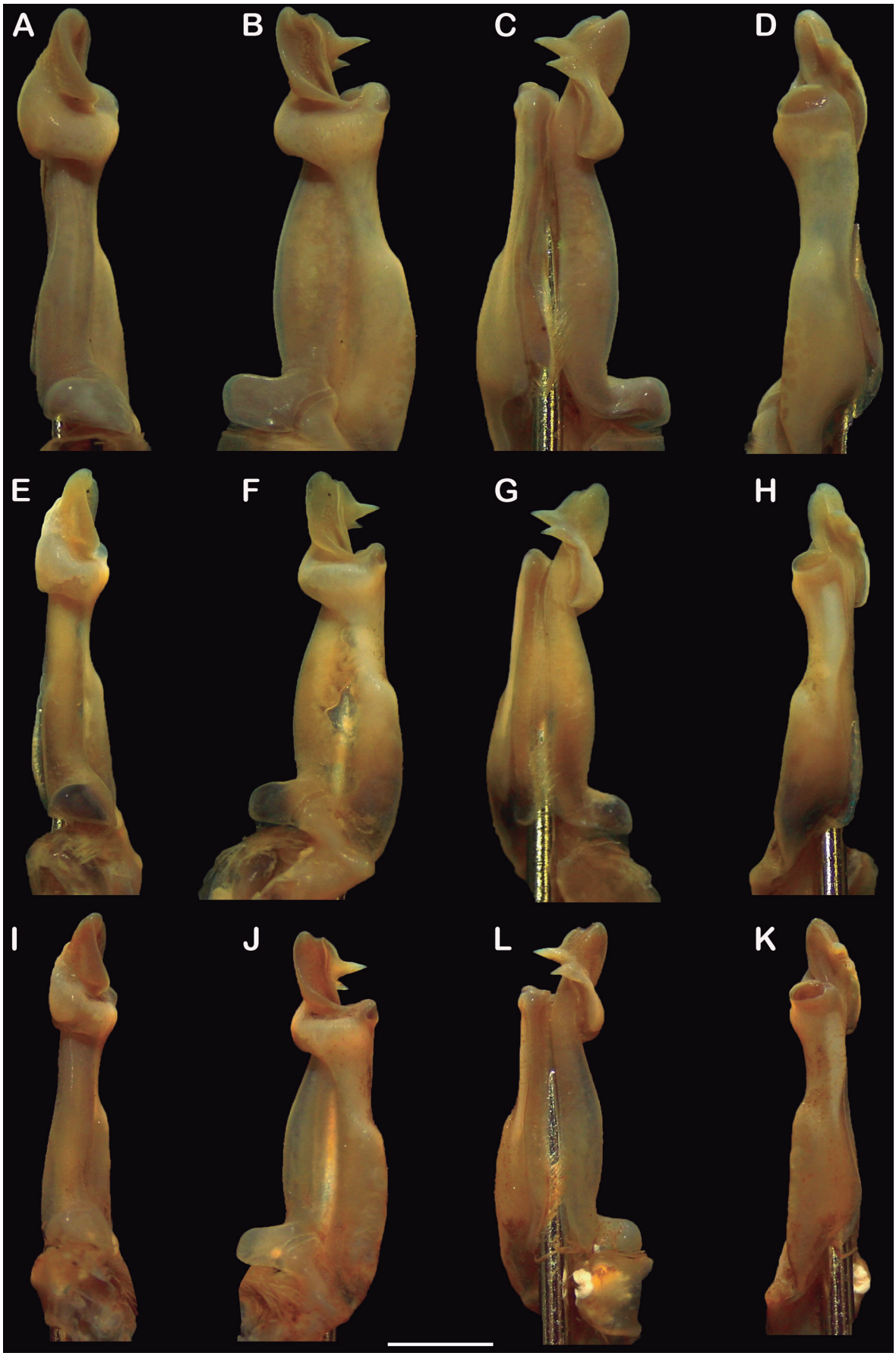

Figure 1. Right gonopod (G1) of *Fredius ibiapaba* Santos, Tavares, Silva, Cervini, Pinheiro & Santana (2020) in external, lateral, mesial and pleon views respectively. (A-D) Gonopod of *F. ibiapaba* collected in the Parque Estadual das Carnaúbas in the municipality of Granja (LACRUSE 304); (E-H) Gonopod of *F. ibiapaba* collected at Fonte do Caranguejo in the city of Viçosa do Ceará (LACRUSE 305); (I-K) Gonopod of *F. ibiapaba* collected at sítio Caranguejo in the municipality of Ipu (LACRUSE 151). Scale bar = 2 mm.

its proximity to the urban area, the site shows strong evidence of human presence, such as solid waste (Fig. 6D-F).

Despite the small number of specimens collected, we observed the presence of several burrows in the humid soil of the visited sites, with openings of various diameters, indicating the presence of other crabs. We also collected some juvenile specimens that were later released.

Genus *Kingsleya* Ortmann, 1897

Kingsleya attenboroughi Pinheiro & Santana, 2016 (Fig. 6).

New record: BRAZIL – **Piauí:** Riacho Jacaré, municipality of São João da Canabrava; 06°47′5.00″S, 041°22′25.00″W; 346 m altitude; 16.XI.2022; J.G. Araújo, C.A.M. Martins,

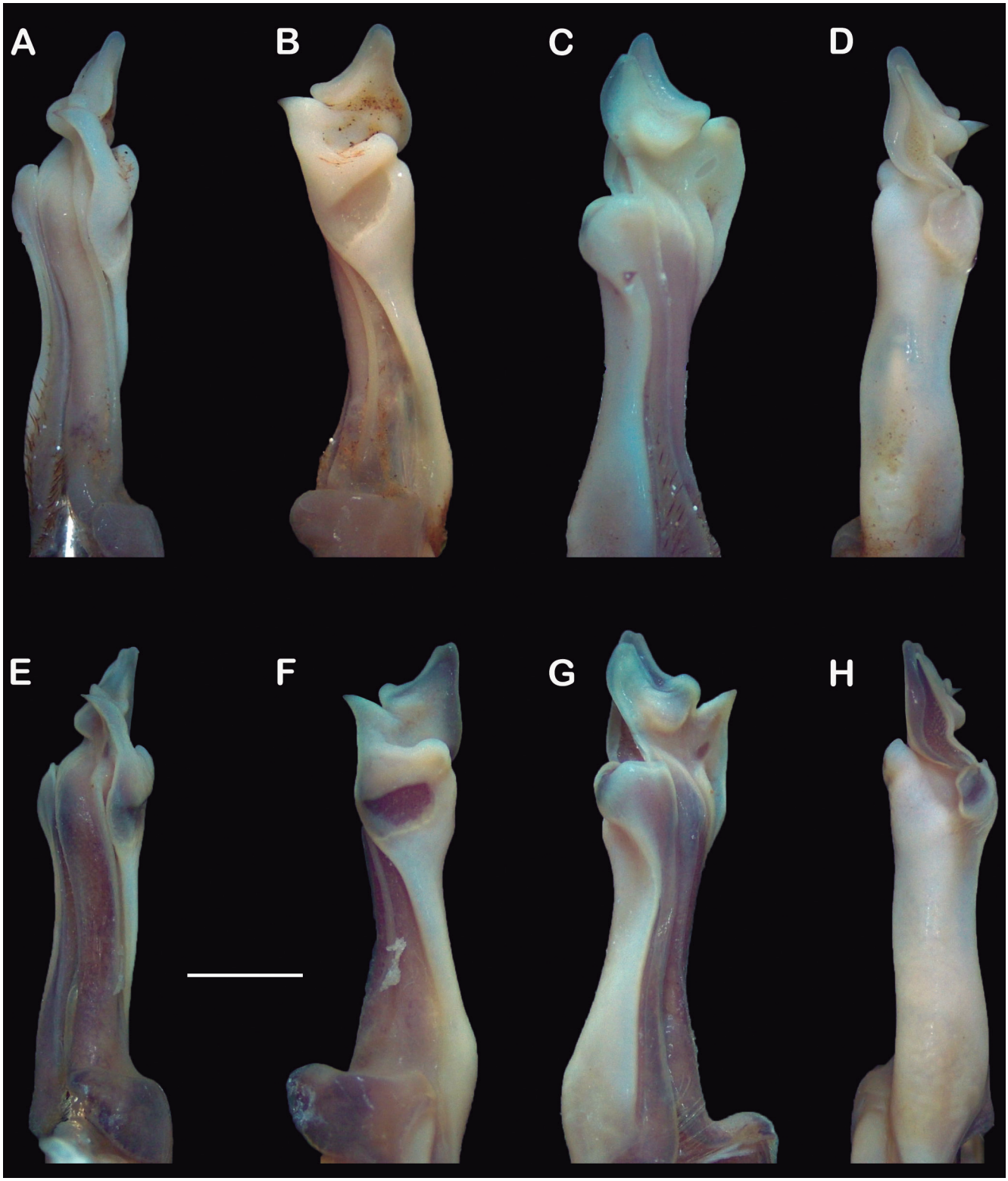

Figure 2. Right gonopod (G1) of *Kingsleya attenboroughi* Pinheiro & Santana (2016) (LACRUSE 306) in external, lateral, mesial and pleon views, respectively. (A-D) Gonopod of *K. attenboroughi* collected in the riacho Jacaré, municipality of São João da Canabrava, state of Piauí; (E-H) gonopod of *K. attenboroughi* collected in the district of Arajara, municipality of Barbalha, state of Ceará. Scale bar = 2 mm.

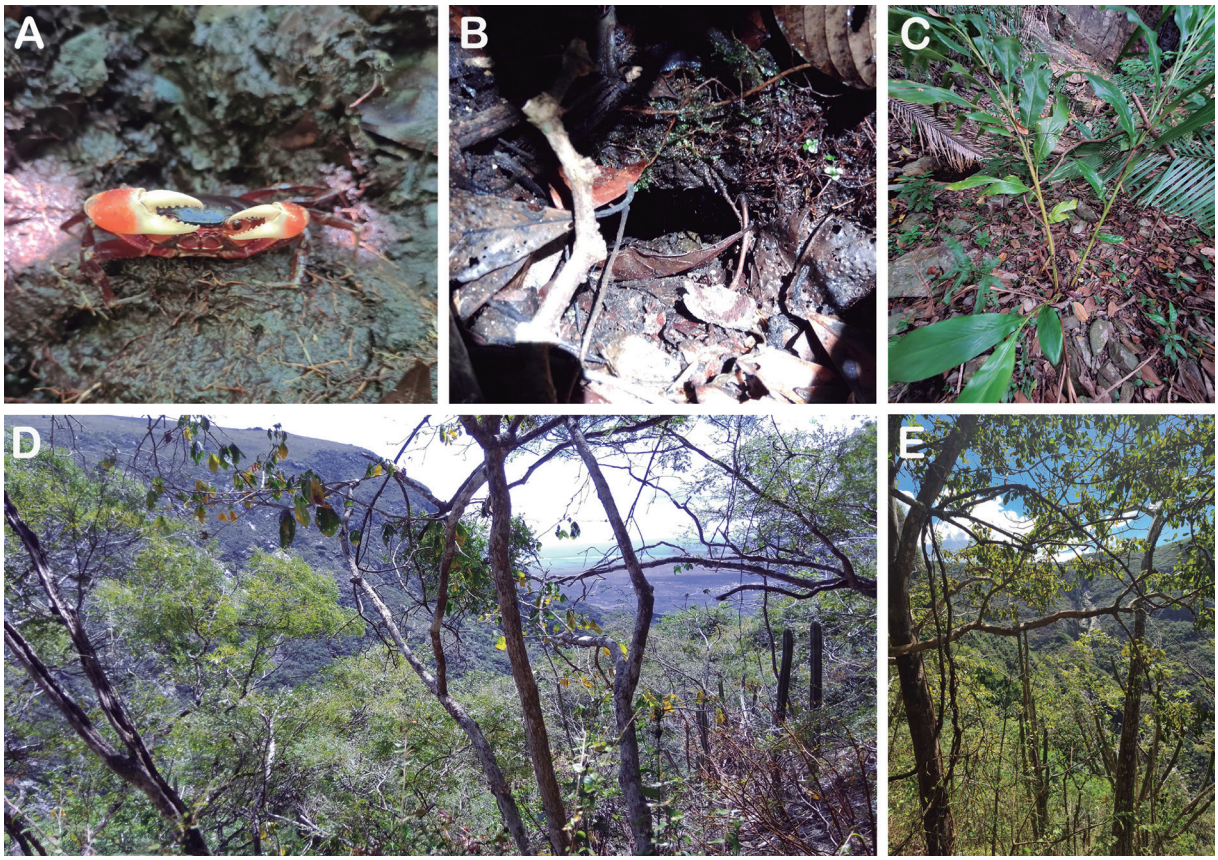

Figure 3. Habitat of *Fredius ibiapaba* in Parque Estadual das Carnaúbas. (A) Adult of *F. ibiapaba;* (B) burrow of *F. ibiapaba* built in moist soil; (C) litter in the soil at the place of occurrence; (D, E) panoramic view of the park.

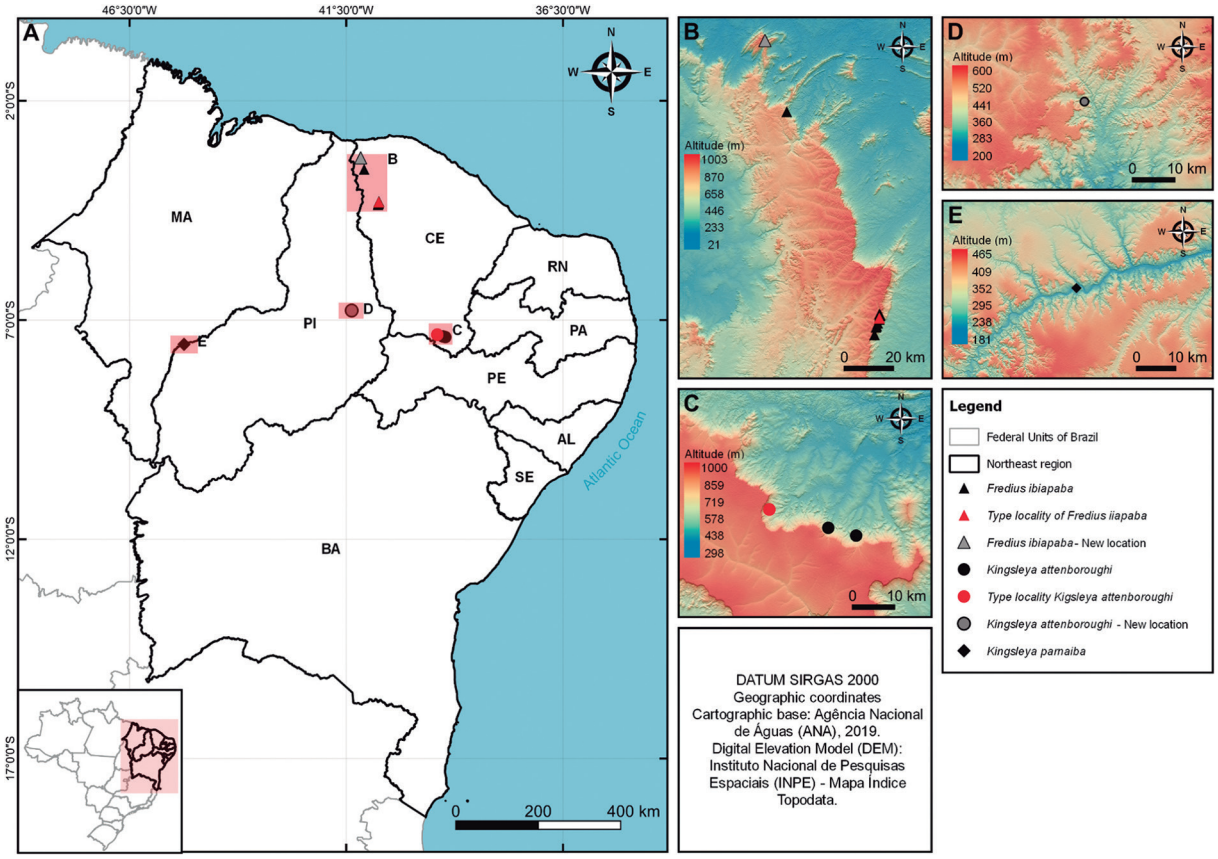

Figure 4. (A) Distribution of Pseudothelphusidae in northeastern Brazil; (B) previous records and new occurrences of *Fredius ibiapaba;* (C) previous occurrence of *Kingsleya attenboroughi;* (D) new occurrence of *K. attenboroughi;* (E) previous occurrence of *Kingsleya parnaiba.* (B-E) Digital Elevation Model (DEM) showing the altimetry of the Pseldothelphusidae areas of northeastern Brazil (warm colors indicate higher elevations). Map created in Qgis free software 3.16.14.

C.A. Nascimento, W.M. Nascimento, P.H.P. Nobre; 1 male 1 female (LACRUSE 306).

Distribution: Brazil, states of Ceará and Piauí.

Previous records: Chapada do Araripe, municipality of Barbalha, state of Ceará, in the following localities: district of Arajara (07°20′07.60″S, 39°23′58.80″W) and sítio Cocos (07°22′28.30″S, 39°16′21.90″W) (Pinheiro & Santana,

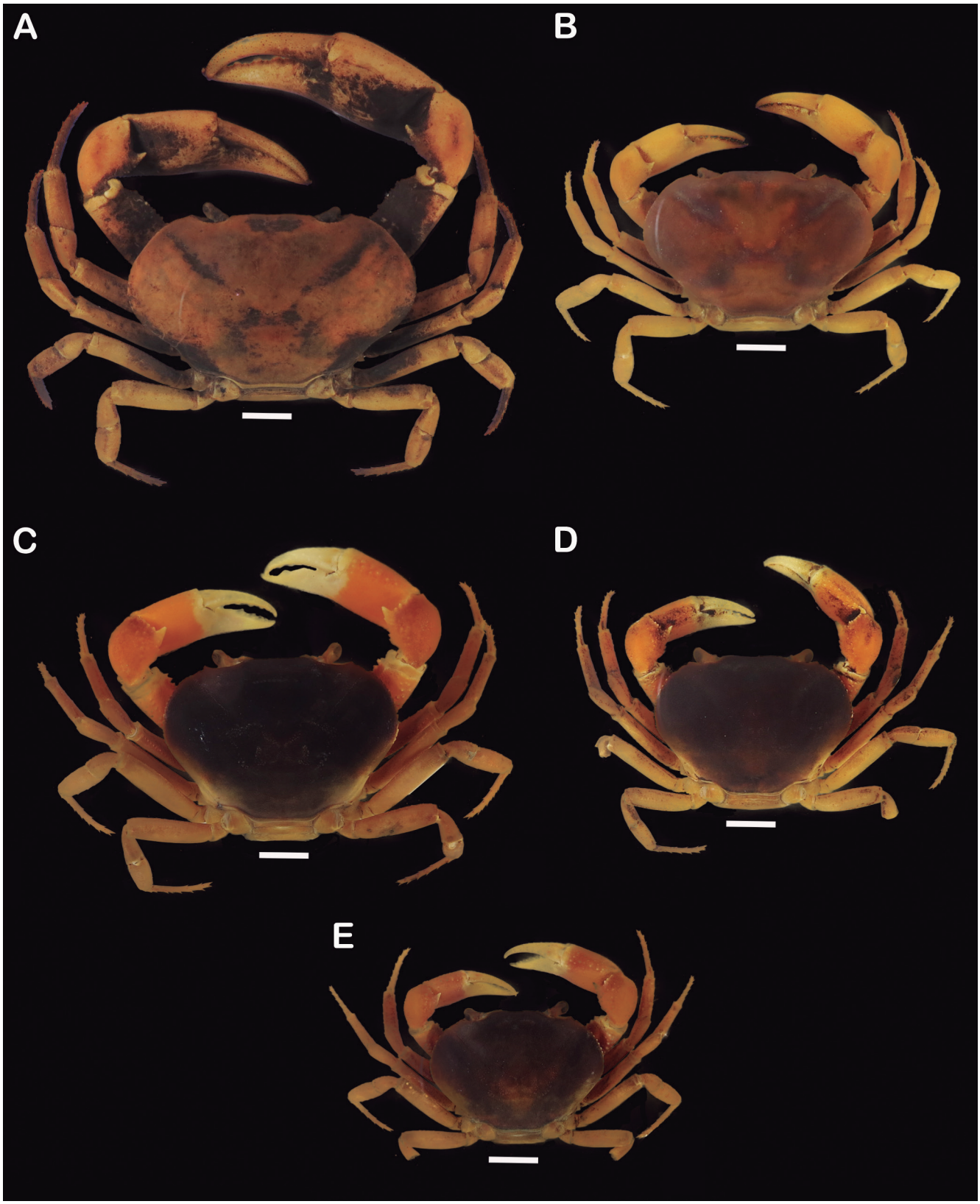

Figure 5. Dorsal view of specimens of *Fredius ibiapaba* and *Kingsleya attenboroughi.* (A) Adult male of *K. attenboroughi* from riacho Jacaré (LACRUSE 306); (B) adult female *K. attenboroughi* from riacho Jacaré (LACRUSE 306); (C) adult male of *F. ibiapaba* from Parque Estadual das Carnaúbas (LACRUSE 304); (D) adult female of *F. ibiapaba* from Parque Estadual das Carnaúbas (LACRUSE 304); (E) adult male of *F. ibiapaba* da Fonte do Caranguejo in the municipality of Viçosa do Ceará (LACRUSE 305). Scale bar = 1 cm.

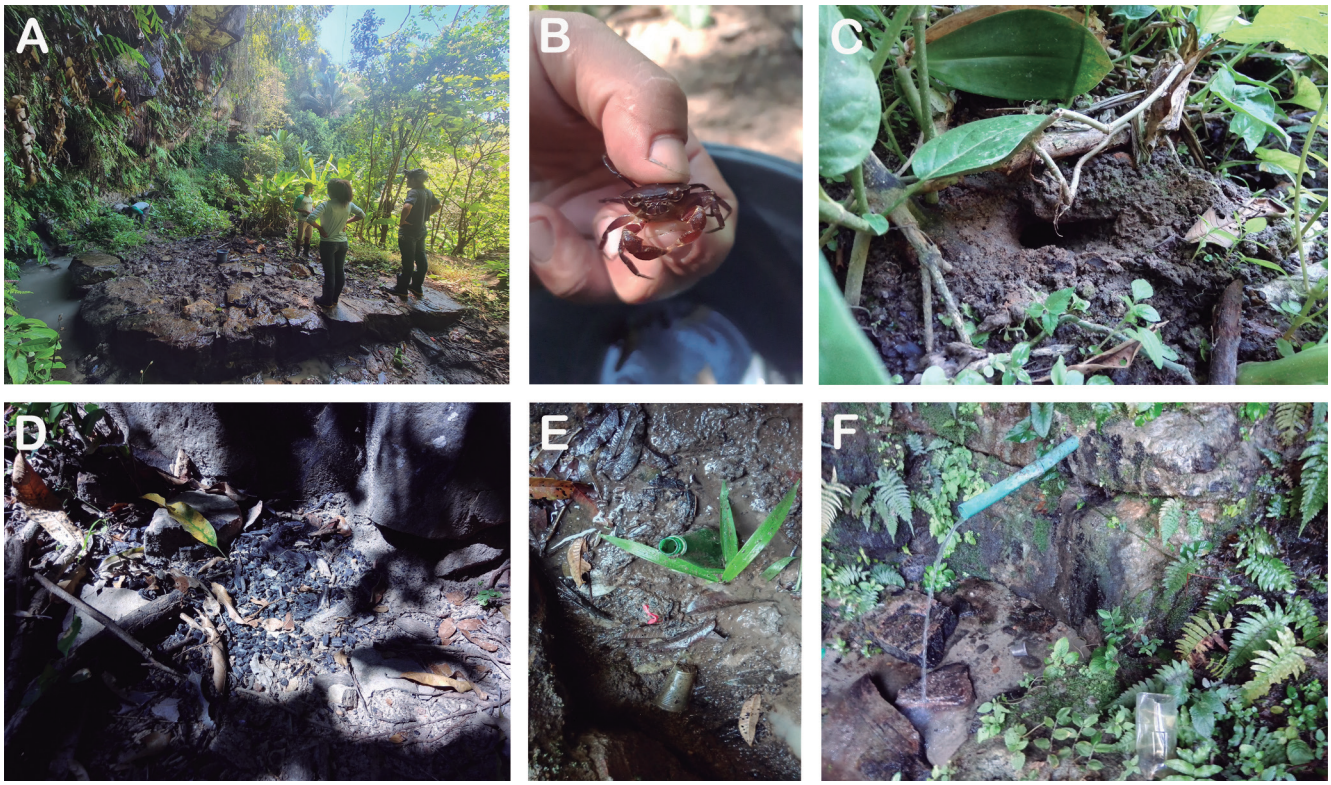

Figure 6. Habitat of *Fredius ibiapaba* at Fonte do Caranguejo in the municipality of Viçosa do Ceará. (A) Panoramic view of the place of occurrence; (B) juvenile by *F. ibiapaba;* (C) burrow of *F. ibiapaba* built in damp soil; (D, F) traces of strong human presence at Fonte do Caranguejo.

Figure 7. Habitat of *Kingsleya attenboroughi* in the riacho Jacaré. (A) Stony creek bed; (B, C) vegetation on the banks of the creek; (D, E) small puddles of standing water; (F) panoramic view of the site of occurrence of the *K. attenboroughi.*

2016). Chapada do Araripe, municipality of Missão Velha, state of Ceará, district of Missão Nova (07°23′27.71″S, 39°12′45.80″W) (Araújo *et al.,* 2022).

Remarks: Two specimens of *Kingsleya attenboroughi* were found in Riacho Jacaré. The specimens were hidden among leaves and rocks, within water puddles in a small spring area (Fig. 7). This new occurrence area is approximately 227.17 km east of the nearest recorded occurrence point (Fig. 4D), located in the Arajara district, municipality of Barbalha, state of Ceará (Fig. 4C) (Pinheiro & Santana, 2016; Araújo *et al.,* 2022). A male (CW = 56.94 mm, AW = 15.41 mm, LP = 54.25 mm) and a female (CW = 46.09 mm, PW = 24.24 mm, and LP = 31.16 mm; LACRUSE 306) were collected (Fig. 5A, B).

Riacho Jacaré has tall and dense riparian vegetation, making the creek well shaded and rich in organic matter, important factors for the presence of the species. However, the occurrence of *K. attenboroughi* in Piauí is restricted to a small area of stream sources in the midst of the caatinga, an environmental characteristic of the Brazilian semi-arid region, with several shrubs, twisted trees, and medium-sized trees. This likely contributes to the small population of *K. attenboroughi* present in this area as it presents a situation sensitive to anthropic pressures.

DISCUSSION

The new records of *Fredius ibiapaba* and *Kingsleya attenboroughi* in the semi-arid region of northeastern Brazil presented in this study expand their distributional range. *Fredius ibiapaba* is found in humid forest enclaves of the Serra da Ibiapaba, in patches of humid soil where they can construct their burrows (Santos *et al.,* 2020a). This type of environment is present in other unexplored locations in the Brazilian semi-arid region, known as humid forests (Ab'Sáber, 1999; Tabarelli & Santos, 2004).

The new occurrence record of *F. ibiapaba* in Parque Estadual das Carnaúbas, on the northern limit of Serra da Ibiapaba, shares similar characteristics with the previously reported occurrence area by Santos *et al.* (2020b). Therefore, our results emphasize the importance of forest zones with humid soil for this species. We believe that the actual geographical distribution of *F. ibiapaba* may be wider than currently known, as such environments are abundant along the eastern slope of Serra da Ibiapaba (Souza & Oliveira, 2006). Additionally, the new occurrence area of *F. ibiapaba* is highly restricted, indicating a likely small population, making it vulnerable to any environmental disturbance. Thus, the importance and necessity for the conservation of Parque Estadual das Carnaúbas are underscored, as other populations, including the population of Sítio Caranguejo in the municipality of Ipu, occur in areas with significant environmental disturbances (Santos *et al.,* 2020b). Therefore, as well as in other successful examples highlighted by Dalu *et al.* (2016), the preservation of Parque Estadual das Carnaúbas is crucial for the conservation of the population of *F. ibiapaba* in the municipality of Granja.

Prior to this study, *K. attenboroughi* was considered an endemic species of the state of Ceará, occurring only in the narrow strip of humid forest on the slopes of Chapada do Araripe (Pinheiro & Santana, 2016; Araújo *et al.,* 2022), with a strong association with areas near springs, always found in shaded streams with clear water, rich in organic matter and rocks (Pinheiro & Santana, 2016; Lima, 2018; Araújo *et al.,* 2022). However, the records presented here reveal a new occurrence of *K. attenboroughi* in a small stream near the headwaters of riacho Jacaré, municipality of São João da Canabrava, in the state of Piauí. This area is not located on slopes of elevations with humid forests, implying new and important aspects for the species. Therefore, *K. attenboroughi* can no longer be considered endemic to the state of Ceará or to the slopes of highland swamps. This might represent a substantial increase in the potential area of occurrence of *K. attenboroughi,* making its geographic distribution likely underestimated. Another significant aspect of this new occurrence area is its environmental characteristics, similar to the environments present in already known occurrence points (Araújo *et al.,* 2022), reinforcing the idea that such environmental characteristics are essential resources for the presence of these crabs, as well as consolidating the type of environment of the species.

The present results underscore the importance of biological surveys for freshwater crabs in northeastern Brazil. However, they also reveal that the population of *K. attenboroughi* from riacho Jacaré, as well as those of *F. ibiapaba* from Ceará, face significant anthropic pressures. The main issues encountered by Pseudothelphusidae crabs in northeastern Brazil include deforestation in areas adjacent to springs and streams, the presence of domestic animals such as pigs inside the rivers where the species occurs, and the presence of garbage and other pollutants in the areas where crabs are found, exerting strong anthropic pressure.

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