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Pseudoscorpiones (Arachnida) of the Brazilian oceanic islands

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A B S T R A C T

Pseudoscorpiones are compose an ancient order of arachnids, occur in a wide variety of terrestrial habitats worldwide, with representatives of various genera occurring exclusively in insular habitats. The primary objective of this study was to determine the composition and distribution of Pseudoscorpiones within the Brazilian equatorial oceanic islands. To determine Pseudoscorpiones communities and distribution in coastal environmental habitats of the Brazilian equatorial oceanic islands (Fernando de Noronha archipelago, Rocas Atoll and St. Peter and St. Paul rocks), was defined three zones along the insular environmental gradient in the Brazilian equatorial oceanic islands. These zones include the Sand Beach (SB) closest to the intertidal zone, the Slope Forest (SF) with a sloping terrain and the Top Forest (TF) farthest from the beach. Collecting points were distributed in each zones (SB, SF, and TF) at distances greater than 1 km, with four samples collected at each point approximately 12.5 m apart from each other. The TF zone is observed only in Fernando de Noronha. In our study we found pseudoscorpions exclusively on the islands of the Fernando de Noronha archipelago. We collected 5 species from the Hesperolpiidae and Syarinidae families. The SF habitats exhibited greater species richness, while the Upper Forest habitats showed greater population abundance. Notably, we recorded pseudoscorpions (*Ideoblothrus amazonicus*) in bird nests (*Sula dactylatra*) on Rata Island, suggesting the use of nests as habitat, reproduction, and, possibly, occasional transport to and from other habitats. No pseudoscorpions were found in SB environments. Landscape changes and tourism can threaten this incredible newly discovered community, vital for monitoring environmental changes in this delicate ecosystem.

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1. Introduction

The order Pseudoscorpiones of arachnids currently comprises about 4197 described species and 474 genera (World Pseudoscorpiones Catalog, 2022). All pseudoscorpions are predators and occur in a wide variety of terrestrial habitats worldwide, with a preference for tropical and subtropical regions (Weygoldt, 1969; Muchmore, 1990). They are most commonly found in leaf litter, under tree bark, in desert zones, in nests of mammals and birds, and subterranean habitats (Mahnert and Adis, 1985; Aguiar and Bührnheim, 2003, 2011; Murienne et al., 2008; Von Schimonsky and Bichuette, 2019; Lira et al., 2020), and some restricted to coastal environments, with representatives of various genera occurring exclusively in halophilic and insular habitats (Harvey, 2009). The phoretic behavior allows Pseudoscorpions to reach habitats with potential adequate supply that would otherwise be unavailable (Poinar et al., 1998; Zeh et al., 2003; Harvey, 2002; Tizo-Pedroso and Del-Claro, 2007; Bedoya-Roqueme and Quirós-Rodríguez, 2018). Seas, high mountains, and large rivers are the main physical barriers for an arachnid to reach a new territory to survive and initiate a new speciation (Beron, 2018).

The transoceanic dispersal ability of some pseudoscorpions is crucial for colonization and subsequent diversification on islands (Harvey, 2002; Lomolino, 2010). Pseudoscorpions living on oceanic islands generally exhibit a unique diversity and a high incidence of endemism (Harvey, 2013; Cosgrove et al., 2016). The island's biogeographical history is a determining factor in the composition of pseudoscorpions diversity, which show different patterns around the world. For example, 174 species are currently Known to occur in the Caribbean islands, of which 120 species (69%) are endemic to the islands and 93 species (53%) are endemic to a single island (Beron, 2018; Harvey, 2013), Another example are the relatively close island assemblages such as Australia and New Zealand that share 10 genera but no species (Beron, 2018; Harvey, 2013).

Brazil has an insular region composed of 4 sets of islands. To the north, there are the equatorial islands (Figs. 1, 2), the Rocas Atoll (1), and the archipelagos of Fernando de Noronha (2), and St Pedro and St Paulo (3). To the south, there are archipelago Trindade (4), and Martin Vaz (5). So far there is a record for a single species of pseudoscorpion in the Brazilian insular region (*Diplotemnus insularis* Chamberlin, 1933), in the rocks of St. Peter and St. Paul (Harvey, 2013; Chamberlin, 1933; Edwards, 1979; Edwards and Lubbock, 1983; Turienzo et al., 2010) and a single species (*Iporangella* sp. indet. Andrade and Pinto-da-Rocha 2016) on mainland island Queimada Grande (Harvey et al., 2016). The biodiversity in the islands, which was once visited by the father of modern biology aboard the Beagle in 1832 (Darwin, 1845), sometimes still unknown, is suffering from processes of biodiversity erosion, degradation and climate change (Borges et al., 2018, 2020; Noronha official page, 2023). Therefore, this study aims to investigate the composition and distribution of Pseudoscorpiones in the Brazilian equatorial oceanic islands.

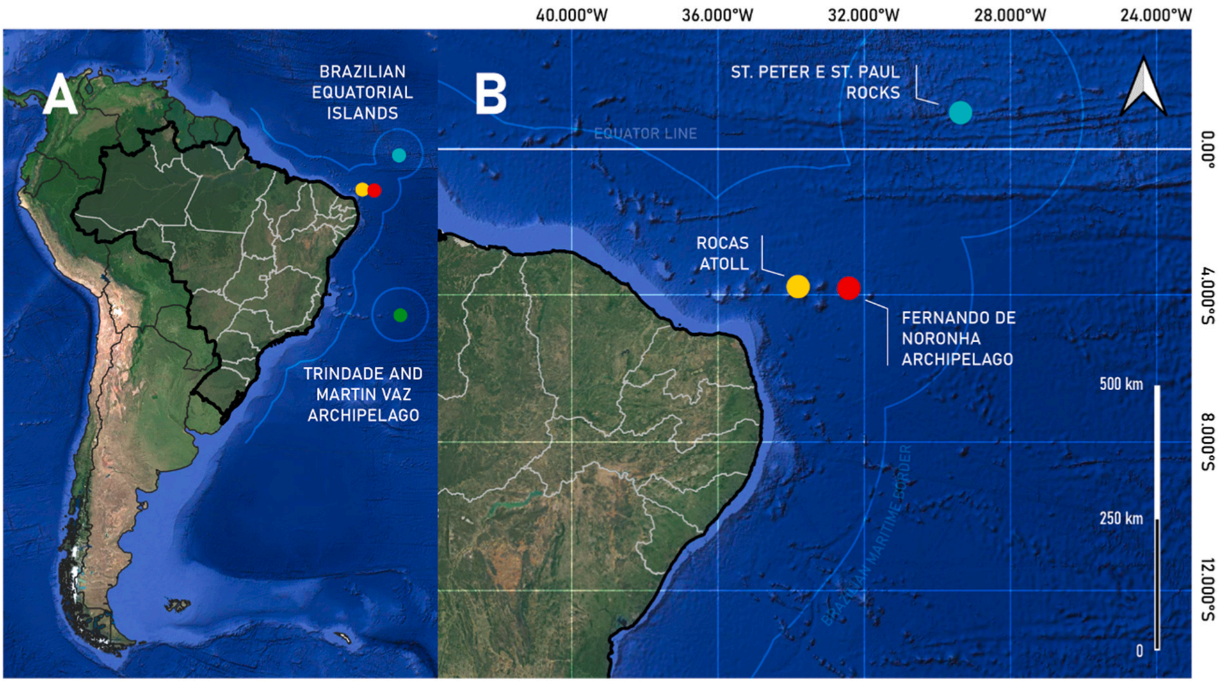

Fig. 1. Maritime territory and island sets of Brazil. A. Brazilian Oceanic Islands, the equatorial islands are located to the north, while the archipelagos of Trindade and Martin Vaz are situated to the south. B. Equatorial Brazilian Islands: Rocas Atoll, Fernando de Noronha Archipelago, and St. Peter and St. Paul rocks. This figure was produced using QGIS 3.16 software (QGIS Development Team 2020). Modified from Lima et al. (2021, 2022).

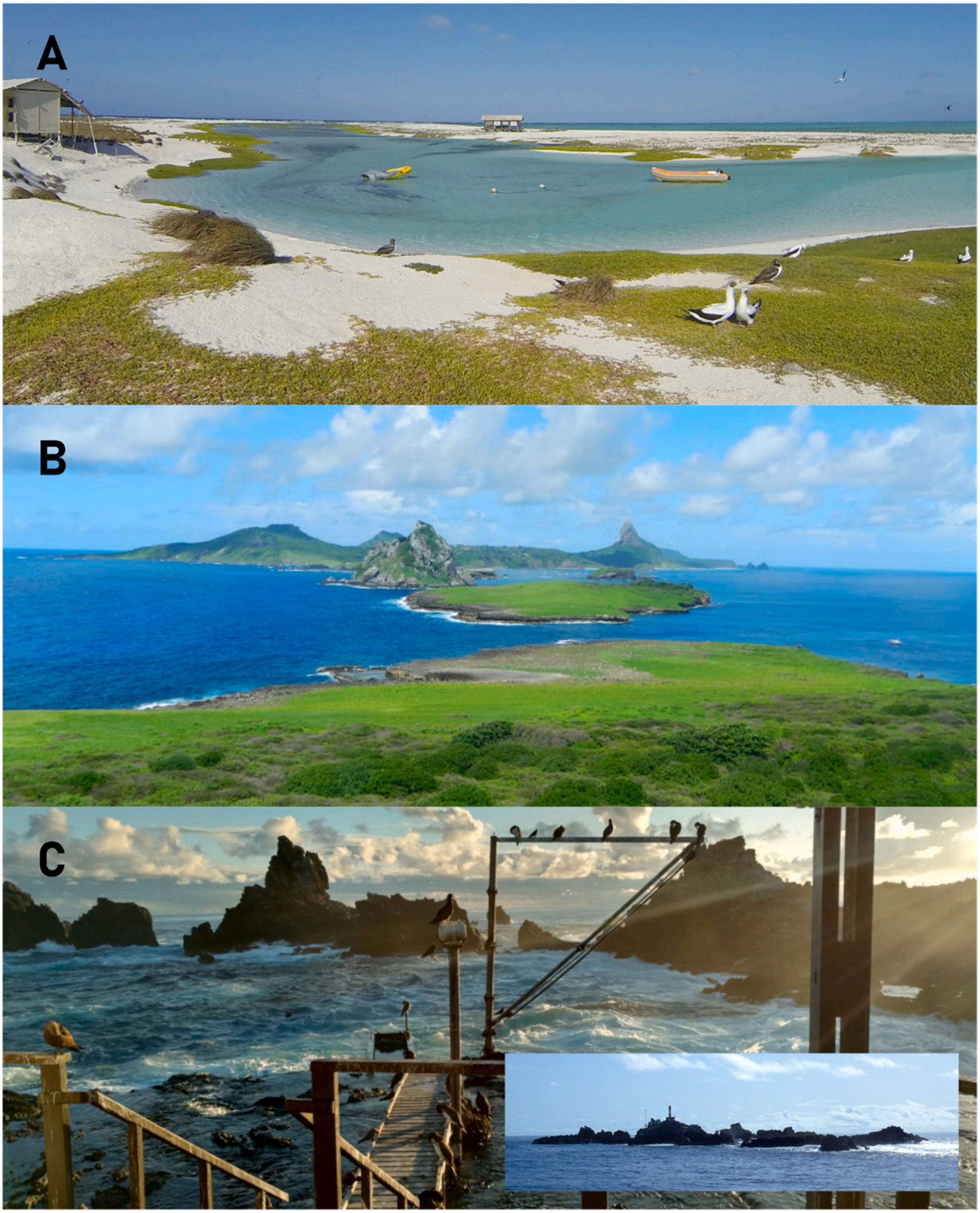

Fig. 2. Landscape of the Brazilian equatorial islands. A. Rocas Atoll. B. Fernando de Noronha Archipelago, photographed from Rata Island. C. St. Peter and St. Paul rocks, the smallest photo depicts the rocks of the archipelago viewed from the vessel.

2. Methods

2.1. Sampling design and study area

In this study, the methodology performed by de Lima et al. 2021, 2022, 2023 was applied, in which three zones of the insular environmental gradient were defined on the equatorial oceanic islands (Fig. 3A). The insular zone, called *Sand Beach* (SB), is the closest to the intertidal zone, the cliffs and sloping terrain are called *Slope Forest* (SF), and the zone characterized by the forested plain in the island, is called *Top Forest* (TF). In each zones (SB, SF, and TF) collecting points were distributed with distances greater than 1 km along

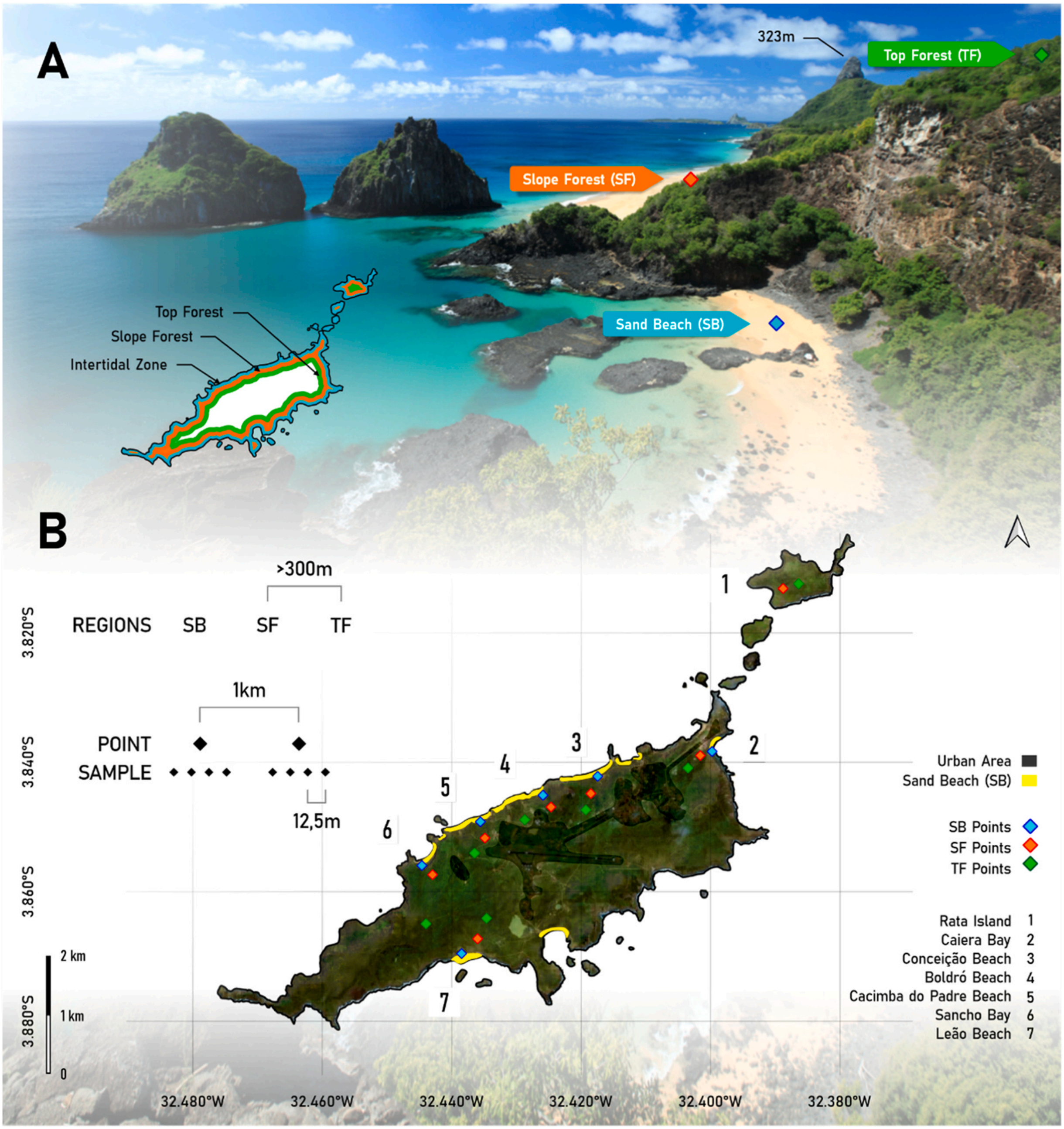

Fig. 3. Fernando de Noronha Archipelago. A. Profile of the selected coastal environmental gradient strips in the study: Sand Beach (SB), Slope Forest (SF), and Top Forest (TF). B. Sampling design and arrangement of points on the environmental gradients in seven locations on the Archipelago's two largest islands. This figure was produced using QGIS 3.16 software (QGIS Development Team 2020). Modified from Lima et al. (2021, 2022).

each island, and four samples were taken at each sampling location, approximately 12.5 m apart from earch other in a 50 m line chosen at random. The distance between the points in the each zones (SB, SF, and TF) was approximately 300 m. This methodology was applied to the three Brazilian equatorial oceanic islands, with the particularity that the Rocas Atoll only has the SB zone and St. Peter and St. Paul rocks do not have the TF zone. All specimens were captured with Berlese–Tullgren funnels. Pseudoscorpions have only been found in the two largest islands of the Fernando de Noronha Archipelago (Fernando de Noronha Island and Rata Island). In Fernando de Noronha, 21 collection points (Fig. 3B) and 84 samples collected, between June 15 and August 15, 2012, during the beginning of the dry season, with an average temperature of 28℃.

All these islands are relatively isolated from the coast and have volcanic origins, except for St. Peter and St. Paul rocks (Teixeira,

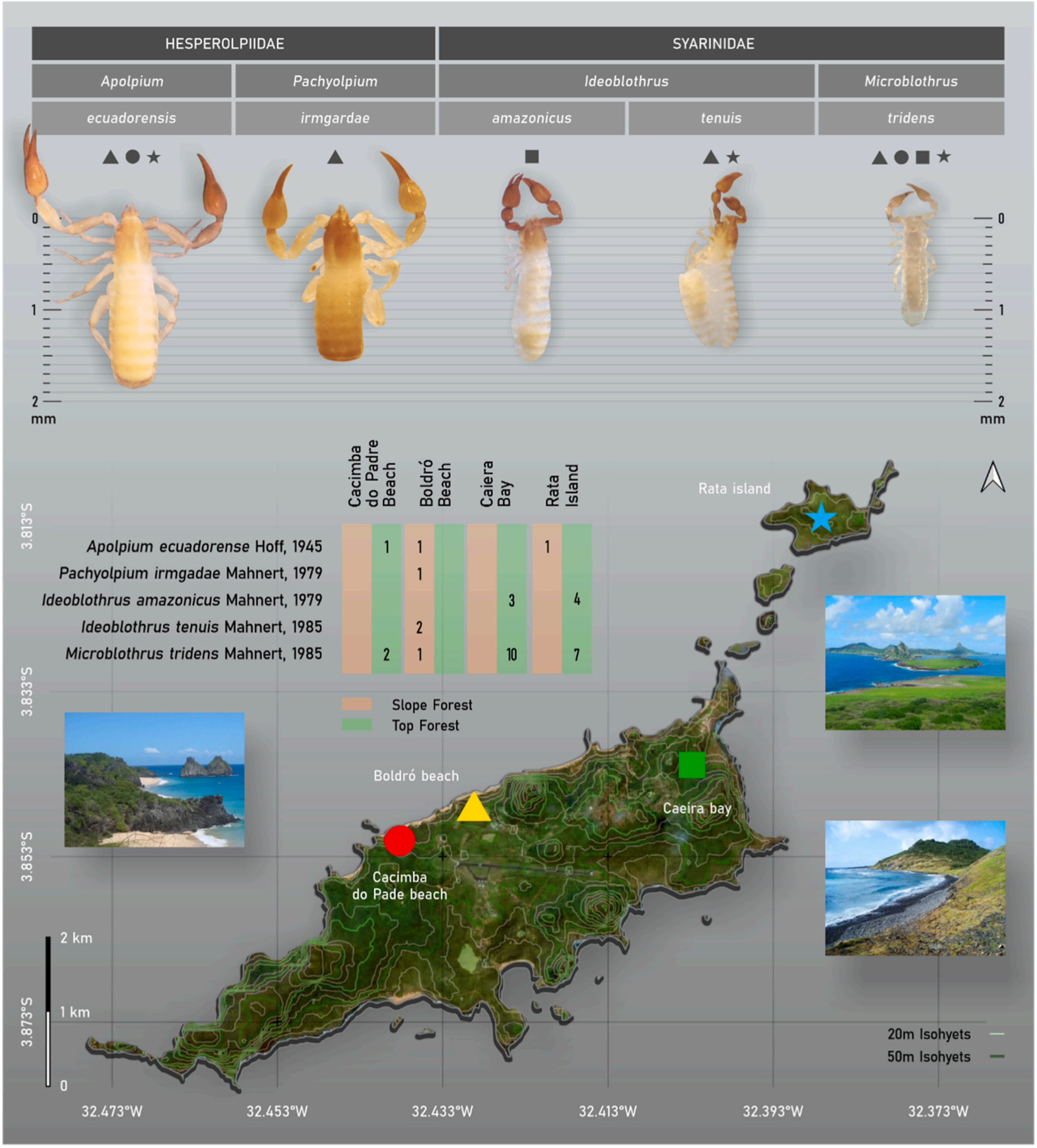

Fig. 4. Pseudoscorpions of Fernando de Noronha archipelago: Distribution of pseudoscorpions on the soil of different environmental gradients on the two main islands of the archipelago. This figure was produced using QGIS 3.16 software (QGIS Development Team 2020).

2003; Serafini et al., 2010). Accidentally discovered on April 20, 1511, the biodiversity of the of St. Peter and St. Paul rocks (Figs. 1B and 2C) was visited by Darwin aboard on the historical HMS Beagle in February 16, 1832 (Darwin, 1845). St. Peter and St. Paul rocks is made up of several rocks that rise abruptly from the sea, the islets are connected forming a single island, the largest rocks are between 16 and 18 m above mean sea level, the island is home to several species of vertebrates and invertebrates, however it has a low diversity (Edwards, 1979; Edwards and Lubbock, 1983; Darwin, 1845). The Rocas Atoll (Figs. 1B and 2A) is the only atoll in the South Atlantic (Garcia et al., 2022; Darwin, 1842). It was the first Brazilian marine conservation unit protected by law and entirely dedicated to species protection and research. The Rocas Atoll was established as a biological reserve in 1979 and became a World Heritage site in 2001. Rocas remains virtually untouched (Claudino-Sales, 2019). The Fernando de Noronha archipelago (Figs. 1B and 2B) is internationally recognized as a Biosphere Reserve of the Atlantic Forest and protected by two distinct Conservation Units (Fernando de Noronha Environmental Protection Area and Fernando de Noronha Marine National Park). Composed of a set of 21 islands, islets or rocks with a total area of 26 km^2, the Fernando de Noronha archipelago is located in the south equatorial Atlantic ocean, 360 kilometers from coast of northeastern Brazil (Teixeira, 2003; Freitas et al., 2013; Lucci Freitas et al., 2020). The archipelago is characterized by a harsh environment, with a shortage of freshwater, low vegetation diversity, and shallow soil with low water retention (Lucci Freitas et al., 2020). The native vegetation is mainly composed of shrubs and herbs, and there are several introduced species, in general, the island has low animal diversity (Noronha official page, 2023; Teixeira, 2003). Currently, tourism is considered the main economic activity in the Fernando de Noronha archipelago (Noronha official page, 2023).

2.2. *Treatment of specimens, measurement and terminology*

Studied material are deposited in the Reference Collection of Soil Fauna (CRFS) of the Institute of Soil Biology (IBS) on Paraíba State University (UEPB). The samples are stored in 96% ethanol. In some specimens pedipalps, chelicerae, carapace, opisthosome, first and fourth legs were dissected, clarified with Nesbitt's solution and mounted on glass microscope slides with Hoyer medium, for identification under phase contrast microscope. The morphometry of the examined specimens follows Beier (1963), and the terminology used for trichobothria and appendages follows Chamberlin (1931), modified by Harvey (1992), Judson (2007) and Harvey et al. (2012) (Beier, 1963; Chamberlin, 1931; Harvey, 1992a; Judson, 2007; Harvey et al., 2012) respectively.

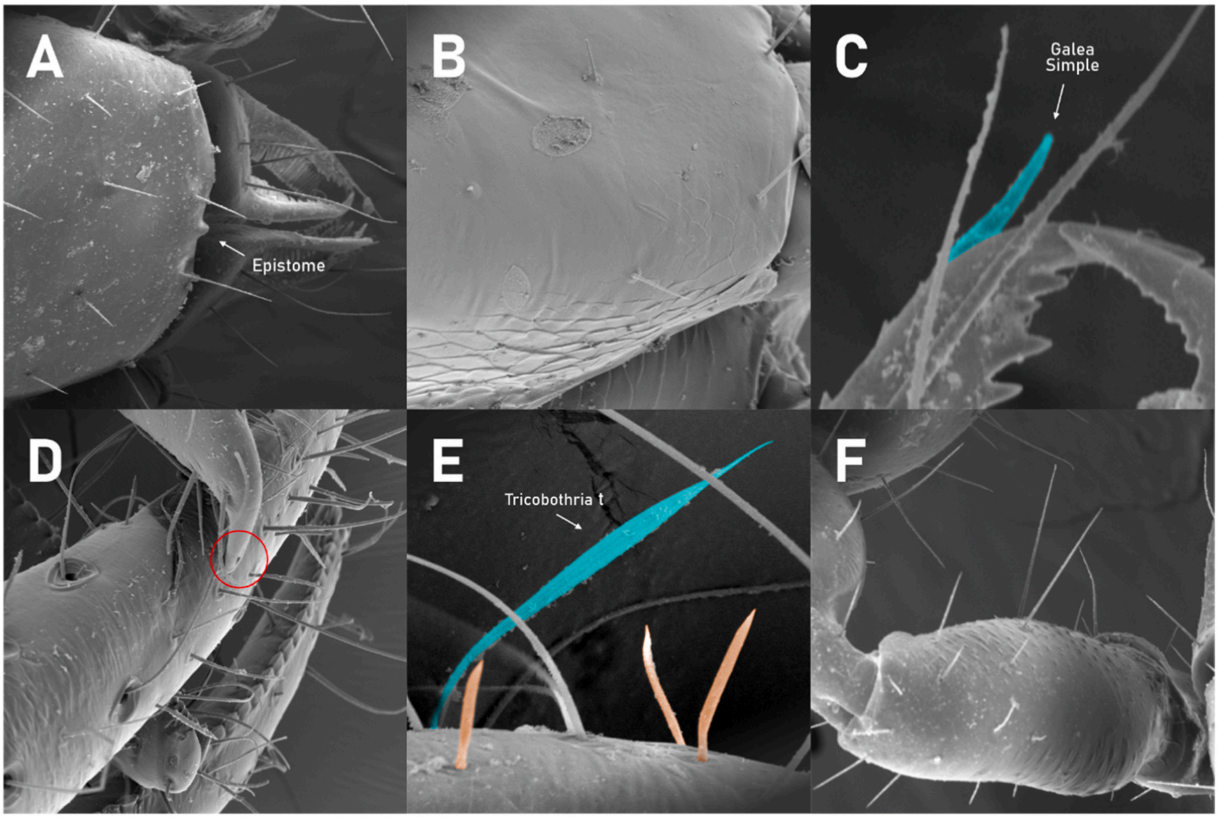

Fig. 5. Morphological characters for separation of Pseudoscorpiones Syariniidae family species in the soil of Fernando de Noronha archipelago. A. Anterior border of carapace, with epistome. B. Eyes absent. C. End region of chelicera, blue showing common Galea, without ramis. D. Apical tooth on fingers, red circle showing venom apparatum (VA), which indicates the presence of venom only on the fixed finger. E. Prolateral surface of palp, blue showing trichobothria t lanceolate and orange showing lanceolate microsetae. F. No trichobothria on the dorsum of the palp femur.

2.3. Electron microscopy, macro photography and illustrations

For scanning electron microscopy (SEM) study, specimens were dehydrated using a graded series of ethanol, dried in a Tousimis Autosamdri®-931 critical point dryer, coated with a Denton Vacuum HP Desk V system, and observed in a Tescan Vegas III scanning electron microscope. For macrophotography, a Carl Zeiss Stemi DV4 stereomicroscope with a camera adapter was used. Figures were generated and assembled using Affinity Photo (https://affinity.serif.com) and CorelDRAW Graphics Suite 2020 (https://www.coreldraw.com) software for Windows.

2.4. Distribution

The distribution of pseudoscorpions collected in the Fernando de Noronha Archipelago was mapped according to the data provided in this study. All maps were generated using the QGIS 3.16 geographic information software (http://qgis.osgeo.org).

3. Results

3.1. Composition and distribution

On our expedition to the Brazilian equatorial islands, more than 70.000 specimens of terrestrial invertebrates were collected from the ground. Of these, less than 0.04% are pseudoscorpions, they were only recorded in less than 10% of the samples, and were found exclusively on the two largest islands of the Fernando de Noronha archipelago (Fernando de Noronha Island and Rata Island). We collected a total of 32 pseudoscorpions (Fig. 4), belonging to 5 species from the families Hesperolpiidae and Syarinidae. The specimens included 3 individuals (1 adult female and 2 nymphs) of *Apolpium ecuadorense* Hoff 1945, 1 individual (1 adult male) of *Pachyolpium irmgadae* Mahnert, 1979, 6 individuals (2 adult male, 1 adult female and 3 nymphs) of *Ideoblothrus amazonicus* Mahnert, 1979, 2 individuals (2 adult female) of *Ideoblothrus tenuis* Mahnert, 1985, and 20 individuals (2 adult male, 7 adult female and 11 nymphs) of *Microblothrus tridens* Mahnert, 1985. The SF zone is the more diverse, containing four species of pseudoscorpions, *Apolpium ecuadorense*, *Pachyolpium irmgadae*, *Ideoblothrus tenuis*, and *Microblothrus tridens* collected in the slope of Boldró Beach. The TF zone had a greater number of Pseudoscorpiones, with their occurrence in the forest of three locations, Cacimba do Padre Beach, Caiera Cove, and Rata Island. The TF zone showed a predominance of the species *Microblothrus tridens*, being present in all forested areas. We recorded for the first time the presence of pseudoscorpions nymphs (*Ideoblothrus amazonicus*) in nests of *Sula dactylatra* on Rata Island, this data is a strong indication that Pseudoscorpiones use the nests as habitat, where they prey on small invertebrates, reproduce and are occasionally transported to and from other habitats by phoresy.

3.2. Identification key for Pseudoscorpions of the Fernando de Noronha

1- Presence of an epistoma on the anterior margin of the carapace (Fig. 5A). Eyes absent (Fig. 5B). Without poison apparatus on movable finger (Fig. 5C). Common Galea, without ramis (Fig. 5D). Trichobothria *t* lanceolate (Fig. 5E). No trichobothria on dorsal surface of palpal femur (Fig. 5F)……………………………………………………………………Syarinidae…2

1'- There is no epistoma on the anterior margin of the carapace (Fig. 4A). Four eyes present (Fig. 4B). poison apparatus present in both fingers of the palp (Fig. 4C). Galea with rami (Fig. 4D). Trichobothria *t* common (Fig. 4E), A trichobothria on the dorsal surface of the palpal femur (Fig. 4F) ……………………………………………………………………Hesperolpiidae…4

2- Four trichobothria on movable finger, trichobothria *sb* - *st* - *t* distal from *b* on fixed finger, trichobothria *sg* on chelicera of galea size or larger……………………………………………………………………*Ideoblothrus*…3

2'- Three tribobothria on movable finger, trichobothria *sb* absent and *st* - *t* distal from *b* on mobile finger, trichobothria *sg* on chelicera extends to mid-galea……………………………………………………*Microblothrus*….*Microblothrus tridens*

3- Trichobothria *ib* proximal to *esb* - *eb* on outer surface of fixed finger, trichobothria lanceolate *t* common……………………………………………………………………
……………………………………………*Ideoblothrus amazonicum*

3'- Trichobothria *ib* proximal to *isb* on dorsum of fixed finger, Trichobothria *t* slight lanceolate……………*Ideoblothrus tenuis*

4- Trichobothria *it* clearly distal from *est* on palpal fixed finger, trichobothria *st* located near medial region of movable finger, venom duct passes *st*, trichobothria *ist* distal to *ib* ……………………………………………………………*Apolpium*…*Apolpium ecuadorense*

4'- Trichobothria *it* proximal to *est* on palpal fixed finger, trichobothria *st* clearly proximal to *sb* - *b* in basal region of movable finger, venom duct does not extend beyond *et*, trichobothria *ist* proximal to *ib*………………………*Pachyolpium*…*Pachyolpium irmgardae*

3.3. New records

Family **Hesperolpiidae** Chamberlin, 1930
Genus ***Apolpium*** Chamberlin, 1930
Apolpium ecuadorensis Hoff, 1945
New records. BRAZIL, Pernambuco, Fernando de Noronha Archipelago (Atlantic Ocean), Boldró Beach, 03°50'52.93"S, 32°25'50.15"W, 39 m, August 2012, Seasonal Deciduous Forest, Slope zone. Estevam C. Araújo de Lima.

BRAZIL, Pernambuco, Fernando de Noronha Archipelago (Atlantic Ocean), Cacimba do Padre Beach, 03°51’7.52"S, 32°26’11.47"W, 30 m, August 2012, Seasonal Deciduous Forest, Forest zone, Col. Estevam C. Araújo de Lima.

BRAZIL, Pernambuco, Fernando de Noronha Archipelago (Atlantic Ocean), Rata island, 03°48’44.73"S, 32°23’19.69"W, 48 m, August 2012, Seasonal Deciduous Forest, Forest zone, Col. Estevam C. Araújo de Lima.

Material examined. 1 adult female and 2 nymphs.

Distribution. Brazil, Cayman Islands, St Vincent and the Grenadines, US Virgin Islands and Venezuela.

Family **Hesperolpiidae** Chamberlin, 1930

Genus ***Pachyolpium*** Beier, 1931

Pachyolpium irmgardae Mahnert, 1979

New records. BRAZIL, Pernambuco, Fernando de Noronha Archipelago (Atlantic Ocean), Boldró Beach, 03°50’52.93"S, 32°25’50.15"W, 39 m, August 2012, Seasonal Deciduous Forest, Slope zone, Col. Estevam C. Araújo de Lima.

Material examined. 1 adult male.

Distribution. Brazil.

Family **Syarinidae** Chamberlin, 1930

Genus ***Ideoblothrus*** Balzan, 1891

Ideoblothrus amazonicus Mahnert, 1979

New records. BRAZIL, Pernambuco, Fernando de Noronha Archipelago (Atlantic Ocean), Caeira Bay, 03°50’24.92"S, 32°24’6.90"W, 48 m, August 2012, Seasonal Deciduous Forest, Forest zone, Col. Estevam C. Araújo de Lima.

BRAZIL, Pernambuco, Fernando de Noronha Archipelago (Atlantic Ocean), Rata island, Nests of birds 03°48’44.73"S, 32°23’19.69"W, 48 m, August 2012, Seasonal Deciduous Forest, Forest zone, Col. Estevam C. Araújo de Lima.

Material examined. 2 adult male, 1 adult female and 3 nymphs.

Distribution. Brazil.

Family **Syarinidae** Chamberlin, 1930

Genus ***Ideoblothrus*** Balzan, 1891

Ideblothrus tenuis Mahnert, 1985

New records. BRAZIL, Pernambuco, Fernando de Noronha Archipelago (Atlantic Ocean), Boldró Beach, 03°50’52.93"S, 32°25’50.15"W, 39 m, August 2012, Seasonal Deciduous Forest, Slope zone, Col. Estevam C. Araújo de Lima.

Material examined. 2 adult females.

Distribution. Brazil.

Family **Syarinidae** Chamberlin, 1930

Genus ***Microblothrus*** Mahnert, 1985

Microblothrus tridens Mahnert, 1985

New records. BRAZIL, Pernambuco, Fernando de Noronha Archipelago (Atlantic Ocean), Boldró Beach, 03°50’52.93"S, 32°25’50.15"W, 39 m, August 2012, Seasonal Deciduous Forest, Slope zone, Col. Estevam C. Araújo de Lima.

BRAZIL, Pernambuco, Fernando de Noronha Archipelago, Cacimba do Padre Beach, 03°51’7.52"S, 32°26’11.47"W, 30 m, August 2012, Seasonal Deciduous Forest, Forest zone, Col. Estevam C. Araújo de Lima.

BRAZIL, Pernambuco, Fernando de Noronha Archipelago, Caeira Bay. 03°50’52.93"S, 32°25’50.15"W, 39 m, August 2012, Seasonal Deciduous Forest, Forest zone, Col. Estevam C. Araújo de Lima.

BRAZIL, Pernambuco, Fernando de Noronha Archipelago (Atlantic Ocean), Rata island, 03°48’44.73"S, 32°23’19.69"W, 48 m, August 2012, Seasonal Deciduous Forest, Forest zone, Col. Estevam C. Araújo de Lima.

Material examined. 2 adult male, 7 adult female and 11 nymphs.

Distribution. Brazil.

4. Discussion

4.1. Pseudoscorpiones on Rocas Atoll

In the year 2000, a checklist of the entomofauna of Rocas Atoll was carried out, which found 112 specimens of arachnids, but no Pseudoscorpiones (de Almeida et al., 2000). Twelve one years later, during our expedition, we also did not find Pseudoscorpions at Rocas Atoll. We believe that, even when some occasional transoceanic dispersion may occur to Rocas Atoll in phoretic hosts (Poinar et al., 1998; Zeh et al., 2003; Harvey, 2002; Tizo-Pedroso and Del-Claro, 2007; Bedoya-Roqueme and Quirós-Rodríguez, 2018; Cosgrove et al., 2016), pseudoscorpions cannot establish permanent population due to the adversities of colonizing a habitat with low overall diversity (Claudino-Sales, 2019), as well as the challenging islands abiotic conditions (Costa and Siegle, 2022), for arachnids in general, and especially for pseudoscorpions (Beron, 2018).

4.2. Pseudoscorpiones on Fernando de Noronha islands

Pseudoscorpions were only registered in less than 10% of the samples in the two largest islands of the archipelago (Fernando de Noronha Island and Rata Island), where their proportion in relation to the others invertebrates collected in the soil is 0.06%, The total number of Pseudoscorpions in Fernando de Noronha is more than 10 times lower than the proportion found in the soil of northeastern Brazil, in the semi-arid Caatinga region (Bezerra and Andrade, 2022). The low number of pseudoscorpions found in Fernando de

Noronha may be an effect of the age and geology of the archipelago, which is relatively recent and originated by volcanic formation (Teixeira, 2003; Serafini et al., 2010; Lucci Freitas et al., 2020), but it also reflects the past of occupation and deterioration of habitat and decline of biodiversity, and more recently the impacts caused by tourism on the islands of the archipelago, especially Fernando de Noronha (Borges et al., 2018, 2020; Noronha official page, 2023).

All species found in the archipelago are distributed in continental Brazil, most species occur from Amazon to the northeastern Brazilian coast [Unpublished Data], crossing over the semi-arid Caatinga (Mahnert and Adis, 1985; Lira et al., 2020; Hoff, 1945a; Mahnert, 1979). The distribution of the species in the mainland, the observation of a nymph of *Ideoblothrus amazonicus* in birds nests of Rata Island, and the general models for dispersion and colonization of insular environments (e.g. rafting, phoresis and introduction), suggest phoresy as the main responsible for the dispersal from the northeastern coast to the archipelago of Fernando de Noronha (Table 1) (Poinar et al., 1998; Bedoya-Roqueme and Quirós-Rodríguez, 2018; Benavides et al., 2019). This conclusion is reinforced by the fact that the Rata Island is the most preserved in the whole archipelago.

In stable environments, the pseudoscorpion community was observed to maintains a consistent pattern of abundance and diversity over the years (Aguiar et al., 2006). The presence of pseudoscorpions is an indication of stability in the trophic chain, the simple community found in Fernando de Noronha archipelago can play an important role in the detection of environmental changes for monitoring programs (Borges et al., 2018, 2020; Noronha official page, 2023; Aguiar et al., 2006).

4.3. Pseudoscorpiones on St. Peter and St. Paul rocks

The St. Peter and St. Paul rocks was visited by the historic HMS Beagle in 1832, forty-one years later, the HMS Challenger expedition in 1873 which collected two specimens of the first Brazilian pseudoscorpion with occurrence on oceanic islands, the *Diplotemnus insularis* Chamberlin, 1933, lives associated with the nests of birds from the families Sulidae (*Sula leucogaster*) and Laridae, especially *Anous minutus*. That species was initially identified as being of the genus *Chelifer* and *Atemnus* by Ellingsen in 1908 and 1931, later in 1933, Chamberlin reviewed this species and described the genus *Diplotemnu* for this very special Brazilian insular arachnid and two more species. Currently, holotype of this specie (code: JC-559.01001) is deposited in the Natural History Museum in London (NHMUK) (Harvey, 2013; Chamberlin, 1933; Edwards, 1979; Edwards and Lubbock, 1983; Turienzo et al., 2010). In addition to St. Peter and St. Paul rocks, *D. insularis* has been recorded in French Southern Territories and Antarctica, these specimens are deposited (code: CASTYPE17496) in the California Academy of Sciences (CAS) (GBif, Diplotemnus insularis Chamberlin, 2022). In this study, no pseudoscorpions were found on St. Peter and St. Paul rocks. However, the presence of *D. insularis* on the archipelago cannot be ruled out since the island has numerous rocky microhabitats (Fig. 2C), occupied by birds, completely inaccessible to researchers through the rocks and further rocky islets, where landing is not possible due to the hostility of the environment. Described by Darwin 1845 as "*this small point rises abruptly cut of the depths of the ocean*" and still highlighted the adversity of this island "*one of the few persons who have landed here, informs me that he saw the crabs dragging even the young birds out of their nests, and devouring them. Not a single plant, not even a lichen, grows on this islet…*". Therefore, it is essential to carry out detailed investigations of these microhabitats and other Brazilian islands (Fig. 1), considering the distribution, ecology, and habitat complexity of *D. insularis* in future expeditions.

The *D. insularis* is not included in the latest list of Brazilian species, with the inclusion of *D. insularis* in the species count, the current number of valid Brazilian pseudoescorpion is 194. Currently, there are 193 Brazilian species recorded and distributed in the continental Brazilian territory (World Pseudoscorpiones Catalog, 2022; Lira et al., 2020; Bedoya-Roqueme et al., 2023), 6 species are found on oceanic islands (Table 1), among which 5 species are found on the continent and Fernando de Noronha (This Study), and one species, associated with bird nests, inhabits St. Peter and St. Paul rocks, French Southern islands (Chamberlin, 1933; Turienzo et al., 2010; GBif, Diplotemnus insularis Chamberlin, 2022) and possibly also occurs in the Brazilian archipelago of Trindade and Martin Vaz and a dozen other islands in the South Atlantic, between the Brazilian equatorial islands and the Antarctic lands.,

4.4. Distribution of Pseudoscorpiones on South Atlantic oceanic islands

The data of Pseudoscorpiones for the South Atlantic islands is quite fragmented, there are few studies and information about the species. In total, the South Atlantic has a record of occurrence for 26 species (Table 3), 22 genus and 11 families (Atemnidae, Cheiridiinae, Chernetidae, Chthoniidae, Garypidae, Garypinidae, Gymnobisiidae, Hesperolpiidae, Syariniidae, Tridenchthoniidae and Withiidae), more than half of the species are endemic to a single island or archipelago, however, pseudoscorpions are present in most of the main island groups in the South Atlantic (Fig. 7), Ascension (Beier, 1960; Mahnert, 1993), Falkland Islands (Vitali-di Castri,

Table 1
Pseudoscorpions on Brazilian equatorial islands List of Pseudoscorpions recorded on Brazilian equatorial islands, bird nests on the islands, previous phoresy record in the literature or island record or phoresy record in This Study. ●– species previously recorded in bird nests on Brazilian islands or recorded in nests on This Study. ○ – cosmopolitan species occurring on other islands or with previous record of phoresy. *– This Study.

Species	Fernando de Noronha	Rocas atoll	St. Peter and St. Paul	Bird nests or phoresy	Record
Diplotemnus insularis Chamberlin, 1933			2	●	1873
Ideoblothrus amazonicus Mahnert, 1979	6*			●	2012
Ideoblothrus tenuis Mahnert, 1985	2*				2012
Microblothrus tridens Mahnert, 1985	20*				2012
Apolpium ecuadorensis Hoff, 1945	3*			○	2012
Pachyolpium irmgardae Mahnert, 1979	1*			○	2012

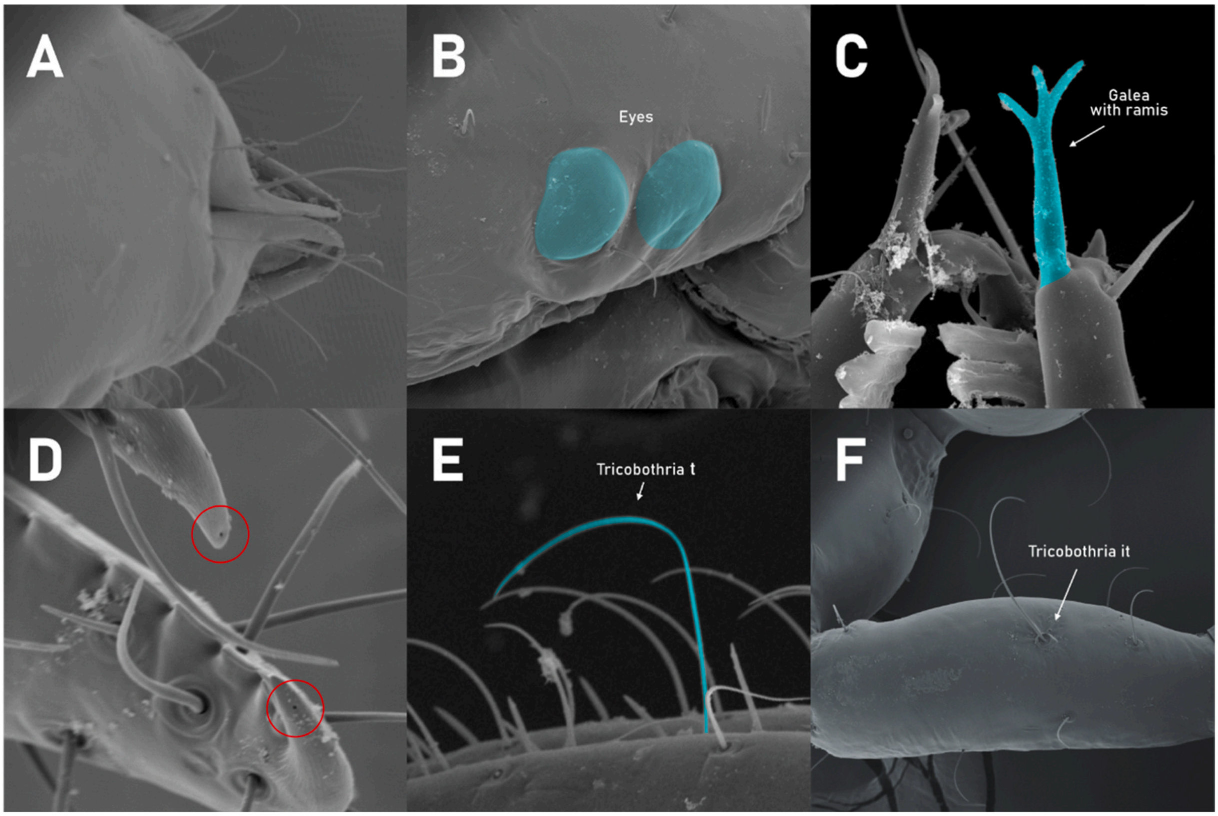

Fig. 6. Morphological characters of Pseudoscorpiones Hesperolpiidae family species in the soil of Fernando de Noronha archipelago. A. Anterior border of carapace, without epistome. B. Eyes present. C. End region of chelicera, blue showing Galea with ramis. D. Apical tooth on fingers, red circle showing venom apparatum (VA), which indicates the presence of venom in both fingers. E. Prolateral surface of palp, blue showing trichobothria t common. F. Tricobothria *it* located on the dorsum of the palpal femur.

1970), Fernando de Noronha (This Study), Gough Island and Tristan da Cunha (Holgate, 1960), St. Helena (Beier, 1977), St. Peter and St. Paul (Chamberlin, 1933) and St. Tome and Principe (Ellingsen, 1906).

The diversity of Pseudoscorpions on the oceanic islands of the South Atlantic presents pattern where, the islands relatively closer to the continents share a large part of their fauna, or all of it, with the mainland (*e.g.* Fernando de Noronha and St. Tome and Principe), while islands more distant present predominantly endemic species (Ascension, Falkland Islands, Gough Island and Tristan da Cunha and St. Helena).

Concerning those oceanic islands in the South Atlantic that do not have records for pseudoscorpions, the Brazilian archipelago of Trindade and Martin Vaz (Figs. 1 and 7) is the one with the highest probability of presenting endemic fauna, the archipelago above water land masses are large in size, have water availability, suitable climatic conditions and considerable distance from the mainland. Investigating the archipelago of Trindade and Martin Vaz is essential to expand knowledge about the Pseudoscorpiones on the South Atlantic. As well as monitoring known endemic species and investigating others island that have not yet been sampled.

4.5. Conservation of Pseudoscorpiones insular

Islands constitute only about 5% of terrestrial environment all over the globe (Olson et al., 2001). A total of 6.89% (289 species) of all pseudoscorpion species belong to genera which are confined to insular environments (Table 3 and Supplementary Material 1), however, the diversity found in islands in much higher than this, with high rate of endemism in general, as an instance, on the island of New Caledonia, 86% of pseudoscorpions species is endemic (Beron, 2018) and on Ascension Island 100% is endemic (Beier, 1960), but not related genera restricted to islands.

Conservation of island pseudoscorpions is crucial to the maintenance of soil micro and mesofauna health, plays a top predator role in the trophic chain (Weygoldt, 1969; Chamberlin, 1931). Current data concerning Island pseudoscorpions are derived from only a minute fraction of the total number of insular environments worldwide (approximately 700,000). These species are often directly impacted by human occupation and tourism.

We propose to evaluate the threat of extinction of the species listed in Table 3 under the IUCN criteria B and D, related to restricted distribution and isolated populations. The inclusion of insular endemic species in the IUCN “red list” may help to driver attention from governmental agencies to establish some conservation policies.

Table 2
Pseudoscorpions recoded on South Atlantic oceanic islands.

Island fauna	Distribution	Refs
Ascension		
Apocheiridium cavicola Mahnert, 1993	Ascension	(Mahnert, 1993)
Garypus titanius Beier, 1961	Ascension	(Beier, 1960)
Withius ascensionis (Beier, 1961)	Ascension	(Beier, 1960)
Stenowithius duffeyi Beier, 1961	Ascension	(Beier, 1960)
Falkland Islands (Malvines)		
Beierobisium oppositum Vitali-di Castri, 1970	Falkland Islands (Malvines)	(Vitali-di Castri, 1970)
Fernando de Noronha		
Apolpium ecuadorense Hoff 1945	Mainland South America, Cayman Islands, Fernando de Noronha, St. Vincent and the Grenadines, US Virgin Islands	This Study
Pachyolpium irmgadae Mahnert, 1979	Brazil, Fernando de Noronha	This Study
Ideoblothrus amazonicus Mahnert, 1979	Brazil, Fernando de Noronha	This Study
Ideoblothrus tenuis Mahnert, 1985	Brazil, Fernando de Noronha	This Study
Microblothrus tridens Mahnert, 1985	Brazil, Fernando de Noronha	This Study
Gough Island		
Chelanops atlanticus Beier, 1955	Gough Island and Tristan da Cunha	(Holgate, 1960)
St. Helena		
Tyrannochthonius helenae (Beier, 1977)	St. Helena	(Beier, 1977)
Hemisolinus helenae Beier, 1977	St. Helena	(Beier, 1977)
Scotowithius helenae Beier, 1977	St. Helena	(Beier, 1977)
Sphallowithius excelsus Beier, 1977	St. Helena	(Beier, 1977)
Sphallowithius inhonestus Beier, 1977	St. Helena	(Beier, 1977)
St. Peter and St. Paul		
Diplotemnus insularis Chamberlin, 1933	St. Peter and St. Paul, French Southern Territories and Antarctica	(Chamberlin, 1933; GBif, Diplotemnus insularis Chamberlin, 2022)
St. Tome and Principe		
Cyclatemnus equestroides (Ellingsen, 1906)	Guinea-Bissau, Equatorial Guinea (Isla de Bioko) and St. Tome and Principe	(Ellingsen, 1906)
Paratemnoides pallidus (Balzan, 1892)	Mainland Africa, Equatorial Guinea (Isla de Bioko), Malaysia, St. Tome and Principe and Sri Lanka	(Harvey, 2013)
Micratemnus pusillus (Ellingsen, 1906)	St. Tome and Principe	(Ellingsen, 1906)
Titanatemnus thomeensis (Ellingsen, 1906)	St. Tome	(Ellingsen, 1906)
Parachernes (Parachernes) rubidus (Ellingsen, 1906)	Guinea-Bissau and St. Tome and Principe	(Ellingsen, 1906)
Tridenchthonius addititius Hoff, 1950	St. Tome and Principe (St. Thomas Island)	(Hoff and New, 1950)
Ditha (Paraditha) sinuata (Tullgren, 1901)	Mainland Africa and St. Tome and Principe	(Harvey, 2013)
Stenowithius angulatus (Ellingsen, 1906)	Principe	(Ellingsen, 1906)
Withius simoni (Balzan, 1892)	Mainland Africa, Cape Verde and St. Tome and Principe	(Harvey, 2013)
Tristan da Cunha		
Chelanops atlanticus Beier, 1955	Gough Island and Tristan da Cunha	(Holgate, 1960)

This urgency stems from the fact that a significant portion of these genera, primarily restricted to islands worldwide, have evolved under highly specific situation, most of its individuals are found in small or relatively isolated subpopulations, these small subpopulations can become extinct, with little chance of recolonization (IUCN, 2023), therefore it is essential monitor.

5. Conclusion

We present the first survey of the fauna of pseudoscorpion in the Brazilian equatorial oceanic islands, 90 years after the description of the first Brazilian insular pseudoscorpion. The research revealed the presence of the genera *Apolpium*, *Pachyolpium*, *Ideoblothrus*, and *Microblotrus*. The survey indicated a rather low number of pseudoescorpion species in Brazilian equatorial oceanic islands. This result is not surprising, as processes of biodiversity erosion and habitat degradation may be related to human occupation and tourism, posing a threat to local diversity. A more comprehensive understanding of the insular pseudoescorpion fauna, will be achieved by increasing samplings to include islands and microhabitats still not investigated. The newly discovered community of mesofauna predators could play a crucial role in detecting environmental changes in Fernando de Noronha archipelago and similar environments around the world.

Table 3
Pseudoscorpions genera endemic to islands, oceanic and continental, around the world.

Genus	Islands	Refs
Fam. Chthoniidae		
Maorichthonius	New Zealand	(Chamberlin, 1925)
Sathrochthoniella	New Zealand	(Beier, 1967)
Tyrannochthoniella	New Zealand	(Beier, 1966a)
Vulcanochthonius	Hawaii	(Muchmore, 2000)
Fam. Tridenchthoniidae		
Dithella	Indonesia (Java), Philippines	(Harvey, 2013; Chamberlin, 1945)
Fam. Pseudogarypidae		
Neopseudogarypus	Australia (Tasmania)	(Morris, 1947)
Fam. Feaellidae		
Antsirananaella	Madagascar (Antsiranana)	(Lorenz et al., 2022)
Mahajanganella	Madagascar (Mahajanga, Toliara)	(Lorenz et al., 2022)
Toliaranella	Madagascar (Toliara)	(Lorenz et al., 2022)
Fam. Ideoroncidae		
Shravana	Thailand (Koh Chang)	(Chamberlin, 1930a)
Fam. Bochicidae		
Antillobisium	Cuba	(Dumitresco and Orghidan, 1977; Díaz et al., 2018)
Bochica	Grenada, Trinidad	(Harvey, 2013)
Troglobochica	Jamaica	(Muchmore, 1984a)
Fam. Syariniidae		
Anysrius	Australia (Tasmania)	(Harvey, 1998)
Microcreagrella	Azores, Madeira	(Simon, 1883)
Fam. Parahyidae		
Parahya	Australia, Indonesia, Micronesia, Singapura	(Bristowe, 1931)
Fam. Gymnobisiidae		
Beierobisium	Falkland Islands (Malvines)	(Vitali-di Castri, 1970)
Fam. Garypidae		
Anagarypus	Australia, British Indian Ocean Territory	(Muchmore, 1982)
Paragarypus	Madagascar	(Vachon, 1937)
Synsphyronus	Australia, New Caledonia, New Zealand	(Chamberlin, 1943, 1930b; Hoff, 1947; Harvey, 2021a, 1987, 2011, 2020; Beier, 1966b, 1954, 1996; With, 1908, 1971a, 2012; Harvey et al., 2015)
Fam. Menthidae		
Thenmus	Australia	(Harvey, 2006)
Fam. Olpiidae		
Antillolpium	Cayman Islands, Cuba	(Muchmore, 1991)
Austrohorus	Australia	(Beier, 1966a)
Heterohorus	Islas Los Frailes	(Van Den Tooren, 2011)
Hoffhorus	Trinidad and Tobago	(Hoff, 1945b)
Leptolpium	Netherlands Antilles	(Van Den Tooren, 2002)
Linnaeolpium	Australia	(Harvey and Leng, 2008)
Neopachyolpium	Trinidad and Tobago	(Hoff, 1945b)
Nipponogarypus	Japan	(Morikawa, 1955, 1960
Tricholpium	Venezuela (Las Aves Island)	(Van Den Tooren, 2011)
Xenolpium	Australia, Madagascar, New Zealand, Seychelles	(Harvey, 2013; Beier, 1976a, 1940; With, 1907)
Fam. Garypinidae		
Galapagodinus	Galapagos Islands	(Beier, 1978)
Hemisolinus	St. Helena	(Beier, 1977)
Nelsoninus	New Zealand	(Beier, 1967)

(*continued on next page*)

Table 3 (*continued*)

Genus	Islands	Refs
Protogarypinus	Australia	(Beier, 1954, 1974
Fam. Cheiridiidae		
Nesocheiridium	Northern Mariana Islands	(Beier, 1957; Krajčovičová et al., 2020)
Fam. Pseudochiridiidae		
Paracheiridium	Madagascar	(Vachon, 1938)
Fam. Chernetidae		
Acanthicochernes	Solomon Islands, Papua New Guinea	(Beier, 1964a)
Adelphochernes	Philippines (Mindanao, Mindoro)	(Beier, 1966a, 1937
Apatochernes	New Zealand	(Beier, 1966a, 1996, 1976a, 1962, 1948
Austinochernes	Australia (South, Tasmania)	(Harvey, 2021b)
Austrochernes	Australia, Papua New Guinea	(Beier, 1967, 1996, 1965; Harvey and Volschenk, 2007)
Balgachernes	Australia (Western)	(Harvey, 2018)
Barbaraella	Australia (Western)	(Harvey, 1995)
Cacoxylus	Solomon Islands (Guadalcanal), Papua New Guinea	(Beier, 1964a)
Calymmachernes	Australia	(Beier, 1954)
Caribochernes	Dominican Republic	(Beier, 1976b)
Conicochernes	Australia	(Beier, 1954, 1933; Kennedy, 1989; E. Koch and Keyserling, 1885)
Corticochernes	Netherlands Antilles	(Van Den Tooren, 2008)
Chiridiochernes	Indonesia (Sulawesi)	(Muchmore, 1972)
Cyclochernes	Solomon Islands (Guadalcanal)	(Beier, 1970)
Eumecochernes	Hawaii	(Muchmore, 2000; Beier, 1932a)
Gelachernes	Solomon Islands, Papua New Guinea	(Beier, 1966a, 1940, 1970, 1971b
Haplochernes	Australia, Indonesia, Japan, Madagascar, Micronesia, Papua New Guinea, Samoa, Tuvalu, Vanuatu, Réunion	(Beier, 1976, 1957, 1932aa, 1940; Tullgren, 1905; Mahnert, 1975; With, 1907; E. Koch and Keyserling, 1885; Gao and Mark, 2017; Käster, 1927; Morikawa, 1953; Chamberlin, 1938)
Hebridochernes	New Caledonia, Papua New Guinea, Solomon Islands, Vanuatu	(Beier, 1966a, 1940, 1965, 1964a
Heterochernes	New Zealand	(Beier, 1932b)
Macrochernes	Cuba, Puerto Rico	(Muchmore, 1984b)
Maorichernes	New Zealand	(With, 1907)
Marachernes	Australia	(Harvey, 1992b)
Meiochernes	Micronesia	(Beier, 1957)
Nesiotochernes	New Zealand	(Beier, 1976a)
Nesidiochernes	Australia, Indonesia, Micronesia, New Caledonia, New Zealand, Northern Mariana Islands, Palau, Papua New Guinea	(Beier, 1966a, 1976a, 1974, 1957, 1965, 1964a
Nesochernes	Australia, New Zealand	(Beier, 1976a, 1932b
Opsochernes	New Zealand	(Beier, 1966a)
Paracanthicochernes	Solomon Islands (Guadalcanal)	(Beier, 1966a)
Parapilanus	Sri Lanka	(Beier, 1973)
Paraustrochernes	Australia, Papua New Guinea	(Beier, 1966a, 1974
Phaulochernes	New Zealand	(Beier, 1976a)
Reischekia	Indonesia, New Zealand	(Beier, 1976a, 1948, 1965
Satrapanus	Australia (Lord Howe Island)	(Beier, 1976a)
Selachochernes	Juan Fernandez Islands	(Mahnert, 2011)
Smeringochernes	Australia, Indonesia, Micronesia, Northern Mariana Islands, New Caledonia, Palau	(Beier, 1966a, 1976a, 1957, 1964a, 1965
Systellochernes	New Zealand	(Beier, 1976a, 1964a
Teratochernes	Micronesia	(Beier, 1957)
Thalassochernes	New Zealand	(Beier, 1976a; With, 1907)
Thapsinochernes	Guam, Palau	(Beier, 1957)
Fam. Cheliferidae		

(*continued on next page*)

Table 3 (*continued*)

Genus	Islands	Refs
Aporochelifer	Indonesia (Flores)	(Beier, 1953)
Australochelifer	Australia	(Beier, 1974)
Canarichelifer	Canary Islands, Ilhas Selvagens	(Beier, 1964b)
Cubachelifer	Cuba, Dominican Republic	(Hoff and Clayton, 1946)
Kashimachelifer	Japan	(Morikawa, 1957)
Papuchelifer	Indonesia, Papua New Guinea	(Beier, 1965)
Pilochelifer	Mauritius, Reunion	(Harvey, 2013; Mahnert, 1975)
Philomaoria	Australia, New Zealand	(Beier, 1976a)
Protochelifer	Australia, New Zealand	(Beier, 1967, 1968, 1966a, 1976a, 1948; Chamberlin, 1949)
Pseudorhacochelifer	Canary Islands, Madeira	(Beier, 1976b; Mahnert, 1997; Vachon, 1961)
Stygiochelifer	Indonesia (Java)	(Tullgren, 1912)
Telechelifer	Sri Lanka	(Chamberlin, 1949)
Fam. Atemnidae		
Mesatemnus	Cyprus	(and and Beier, 1952)
Trinidadatemnus	Trinidad and Tobago	(Van Den Tooren, 2008)
Fam. Withiidae		
Protowithius	Juan Fernandez Islands	(Beier, 1955)
Rugowithius	Australia	(Harvey, 2015)
Scotowithius	St. Helena	(Beier, 1977)
Sphallowithius	St. Helena	(Beier, 1977)
Sundowithius	Indonesia (Sumatra)	(Thorell, 1889)
Thaumatowithius	Reunion, Mauritius	(Beier, 1940; Mahnert, 1975)

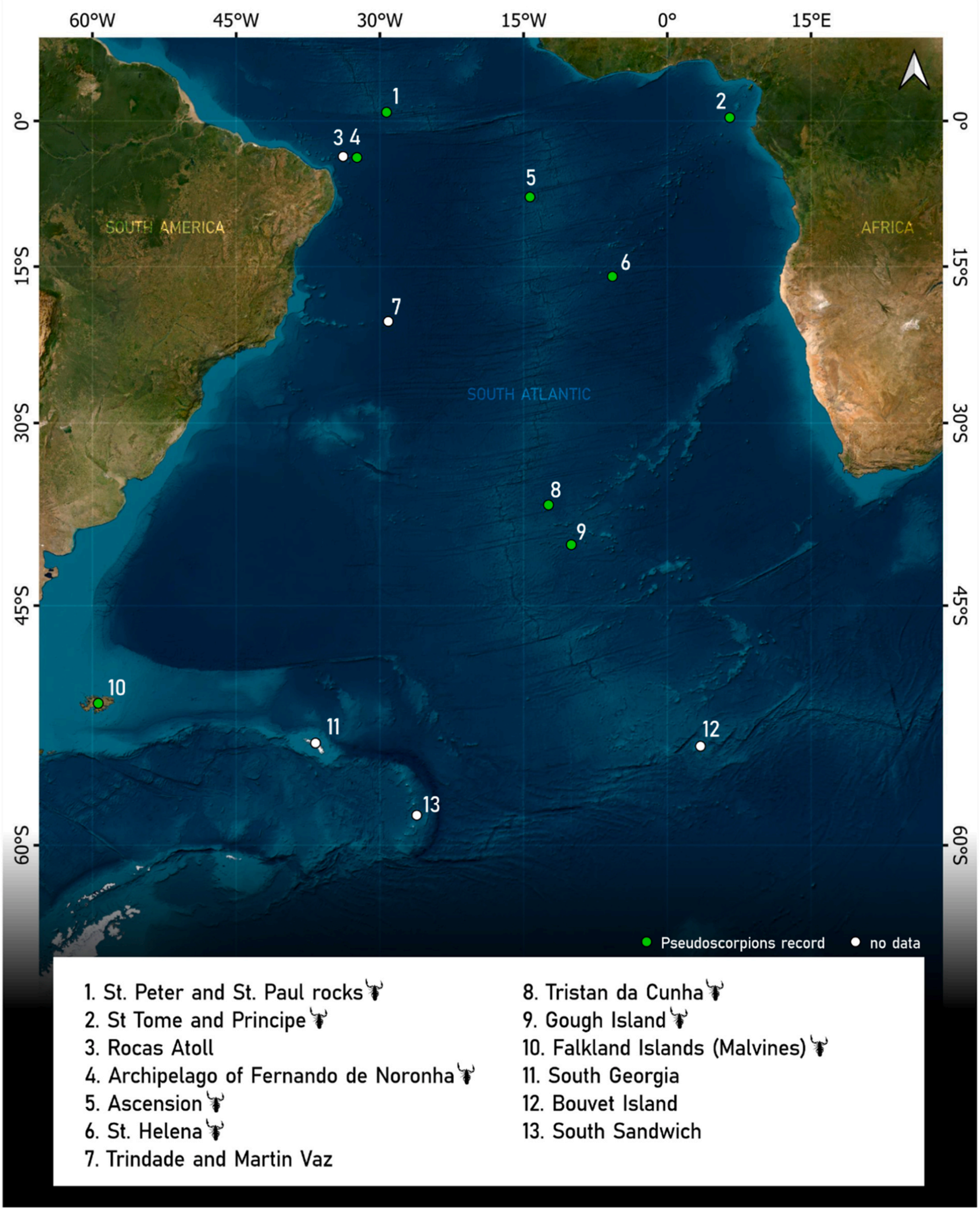

Fig. 7. South Atlantic oceanic islands with Pseudoscorpions recoded.

Ethics approval

Not applicable.

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CRediT authorship contribution statement

Jonas Gallão: Formal analysis, Conceptualization. **Luis Stievano:** Methodology, Data curation, Conceptualization. **Celia Machado:** Formal analysis, Conceptualization. **Maria Bichuette:** Resources, Conceptualization. **Douglas Zeppelini:** Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Misael Oliveira-Neto:** Software, Investigation, Formal analysis, Data curation, Conceptualization. **Estevam de Lima:** Project administration, Methodology, Investigation, Data curation, Conceptualization. **Bruna Lopes:** Methodology, Investigation, Formal analysis, Data curation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

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Code availability

Not applicable.

Consent to publish

We confirm that this manuscript has not been published elsewhere and is not under consideration by another journal.

Consent to participate

Not applicable.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.gecco.2024.e02971.

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