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There and Back Again—The Igatu Hotspot Siliciclastic Caves: Expanding the Data for Subterranean Fauna in Brazil, Chapada Diamantina Region

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Abstract: The caves of Igatu, municipality of Andaraí, belonging to the region known as Chapada Diamantina represent a new hotspot of subterranean fauna. These caves are siliciclastic, which are sedimentary rocks where silica predominates, such as sandstones and (following metamorphism) quartzites, which makes them even more relevant from the point of view of subterranean diversity. For five caves, which we named Igatu Cave System (ICS), thirty-seven obligate cave species were found, of which thirty-five were troglobitic and two were stygobitic. The troglobitic taxa for ICS belong to three phyla, nine classes, 18 orders, and 32 families, representing a high phylogenetic diversity. Some taxa were, for the first time, reported as troglobitic in Brazil and even worldwide, such as Acari and scutigeromorphans (Chilopoda). We started the studies in 2009 and continue trough long-term monitoring projects. Some threats, severe in the past, such as "garimpo" (illegal small-scale artisanal mining) continue nowadays in an incipient way; however, the urban expansion due to the touristic appeal is also considered a threat. Our data ranked ICS as the Brazilian hotspot with the highest number of troglobitic/stygobitic species.

Keywords: subterranean biodiversity; conservation; Bahia state; Northeastern Brazil

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1. Introduction

The occurrence of karst areas in South America with high versus low troglobite diversity was predicted by Trajano [1,2], who considered paleoclimatic fluctuations during the Quaternary to explain this particular biodiversity, citing the Upper Ribeira region and the Campo Formoso region. Following this discussion, caves from the Upper Ribeira karst area, Southeastern Brazil, and the Campo Formoso region, Northeastern Brazil, were validated as hotspots [3,4]. However, other areas in Northeastern Brazil (Serra do Ramalho region, Chapada Diamantina region) were also considered hotspots and/or of high biodiversity for subterranean fauna [5,6].

Gallão and Bichuette [5] reported, for the first time, the high diversity of troglobites for caves in siliciclastic rocks of the Igatu region (Chapada Diamantina, Northeastern Brazil) and discussed why these caves could be considered remarkable, not only in terms of troglobite numbers but also in terms of phylogenetic diversity. To date, the subterranean fauna of the siliciclastic caves of Chapada Diamantina is remarkable as all, with the occurrence of the troglobitic scorpion *Troglorhopalurus translucidus* Lourenço, Baptista and Giupponi, 2004, from Gruta do Lapão Cave [7], the co-occurrence of troglobitic fishes, a rare event in siliciclastic caves: *Glaphyropoma spinosum* Bichuette, Pinna and Trajano 2008, and a new species of *Copionodon* [8,9].

In this work, we updated and reinforced the siliciclastic caves of Igatu, located in the Chapada Diamantina region, State of Bahia, Northeastern Brazil, as a troglobites/stygobites hotspot. In addition to the taxonomic richness, this region also contains indicators of phylogenetic diversity (presence of relict taxa), aspects that must be considered in the conceptualization of biodiversity hotspots [5,6]. Igatu is also a biogeographical region with a significant reservoir of biodiversity threatened by human activities [5,6]. We considered here five caves of Igatu, all connected by subterranean drainage, and forming a system: Gruna Rio de Pombos, Gruna Canal da Fumaça, Gruna Lava Pé, Gruna da Parede Vermelha, and Gruna Cantinho caves. We named this system as Igatu Cave System (ICS).

2. Material and Methods

2.1. Igatu Region and Their Caves

Igatu is located in the Chapada Diamantina National Park (CDNP) and is a district of the municipality of Andaraí, in the central part of the State of Bahia, Northeastern Brazil (Figures 1 and 2). It is part of the Serra do Sincorá and geologically belongs to the Tombador Formation [10]. The region has several streams (including subterranean drainages), tributaries of the Rio Coisa Boa and Rio Piabas rivers, part of the Upper Paraguaçu River basin, within the Northeast Atlantic Forest ecoregion, which presents high rates of endemism. The five caves considered in this work are crossed by the same subterranean drainage (tributary of the Rio Coisa Boa), and they present small galleries and low-ceiling conduits. The caves showed a small extent considering the passages, not surpassing 0.5 to 0.9 km each. In general, the conduits were formed by mechanical erosion caused by water allied to tectonism, with little evidence of chemical dissolution (Figures 2 and 3).

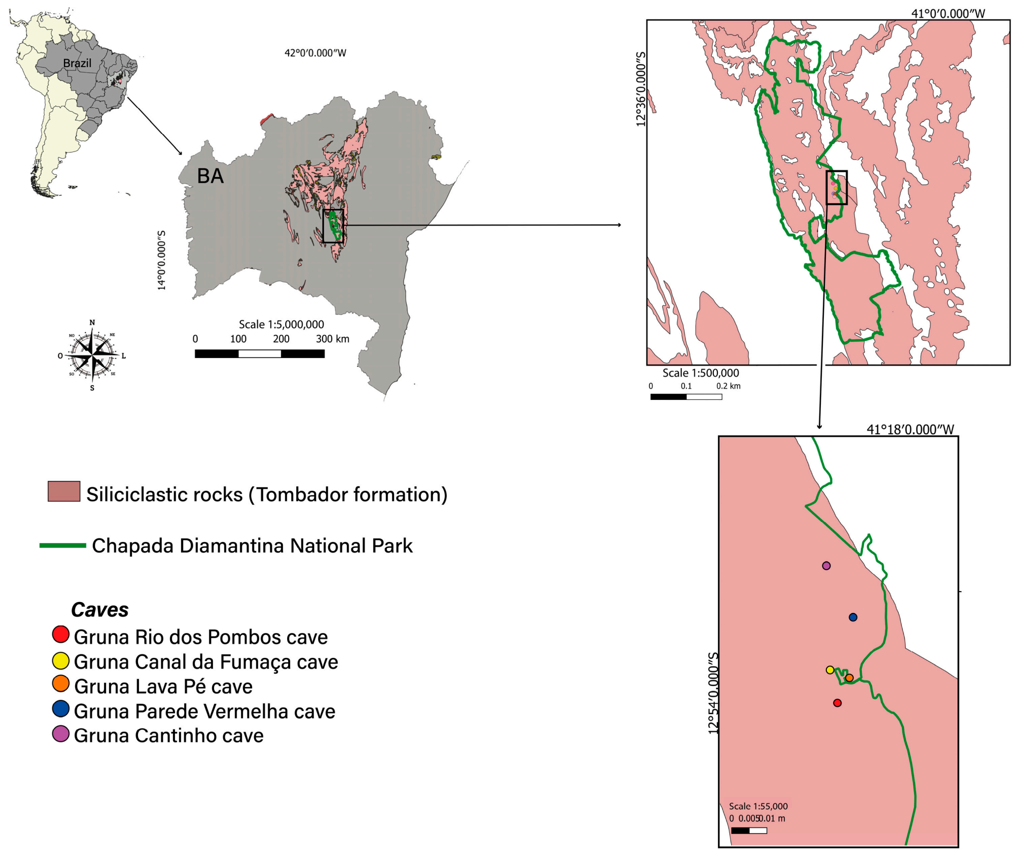

Figure 1. Map showing the region of Igatu Cave System (ICS), Chapada Diamantina region, Bahia state, Brazil. Developed in QGIS Development Team, QGIS Geographic Information System.

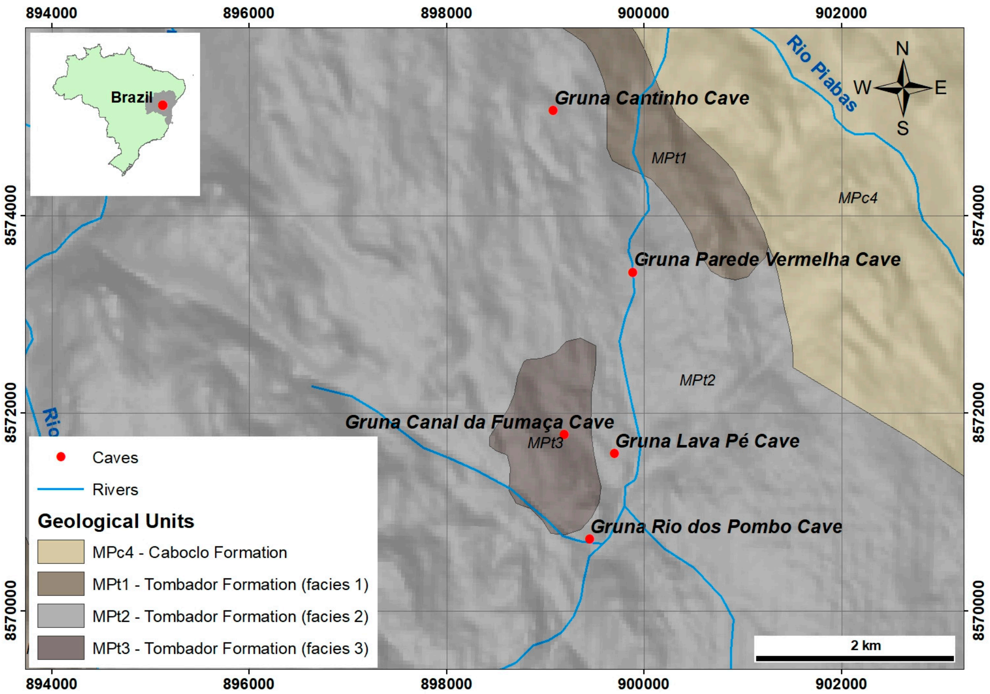

Figure 2. Geological map with details of Igatu Cave System (ICS) and surface drainages nearby. Blue lines: drainages. Developed in ArcGIS Desktop 10.6.1, version 10.6.1.9270; shapefiles for lithology: CPRM—Geological Map of Bahia, 1:1,000,000. 2003; shapefiles for drainages: ANA Metadata catalog (https://metadados.snirh.gov.br/geonetwork/srv/search?keyword=GEOFT_BHO_MASSA_DAGUA Accessed on 3 June 2023); shapefiles for relief: SRTM—Shuttle Radar Topography Mission.

The rocks exposed in Serra do Sincorá belong mainly to the Mesoproterozoic Tombador Formation [11] (Figure 2). In the Serra do Sincorá, the Tombador Formation is deposited on the Guiné Formation of the Paraguaçu Group. Its sandstones and conglomerates have the structure of a large anticlinorium with a wavy axis [11]. Severo Giudice [12] discussed that, geologically, the Chapada Diamantina is the product of a relief inversion, since it corresponds to the remnants of a sedimentary basin that settled over the São Francisco Craton about 1.8 billion years ago. The observed geological and geomorphologic elements of Igatu present themselves in different forms, such as mountains, tabular hills, waterfalls, caves (Figure 3), and rivers, and are responsible for a particular landscape, including its high number of caves (20+, ME Bichuette and JE Gallão, pers. obs.), with subterranean drainages and a rich fauna (Figure 3).

From 1846 to 1871, there was intensive diamond mining ("garimpo"—small-scale artisanal mining) in the region, and the waste from the old mines can still be seen along the Paraguaçu River and also inside the caves (Figure 3). After a golden age of about 25 years, diamond mining began to decline in 1871, and attempts were made to mechanize mining in the first half of the 20th century [12]. In the 1980s, mechanized mining was reintroduced in the Serra do Sincorá, installed in the riverbeds inside and outside the Chapada Diamantina National Park (CDNP). These "garimpos" were finally closed in March 1996. However, this activity continues today and is the main threat to the subterranean biodiversity of Igatu. Another threat in Igatu is the urban expansion, with many constructions over the outcrops (Figure 4).

2.2. Samplings, Determinations, Classification

We carried out inventories in several caves of the Igatu region between 2009 and 2016. These inventories were the first ones in Igatu siliciclastic caves. On those occasions, we discovered 11 caves with representative cave fauna, most of them with subterranean drainage. In this work, we considered five caves that represent the ICS (Gruna da Parede

Vermelha, Gruna Canal da Fumaça, Gruna Lava Pé, Gruna Cantinho, Gruna Rio dos Pombos), reaching ca. 5 km in a linear extension altogether (Figures 1 and 2).

Figure 3. The landscape of the Igatu region, and physical aspects of its caves: (**a**) view of the Igatu landscape with siliciclastic outcrops; (**b**) Rio Coisa Boa River, tributary of Upper Paraguaçu River basin; (**c**,**d**) Gruna da Parede Vermelha cave; (**e**) Gruna Cantinho cave; (**f**) Gruna Canal da Fumaça cave; (**g**) Gruna Rio dos Pombos cave; (**h**) Gruna Lava Pé cave.

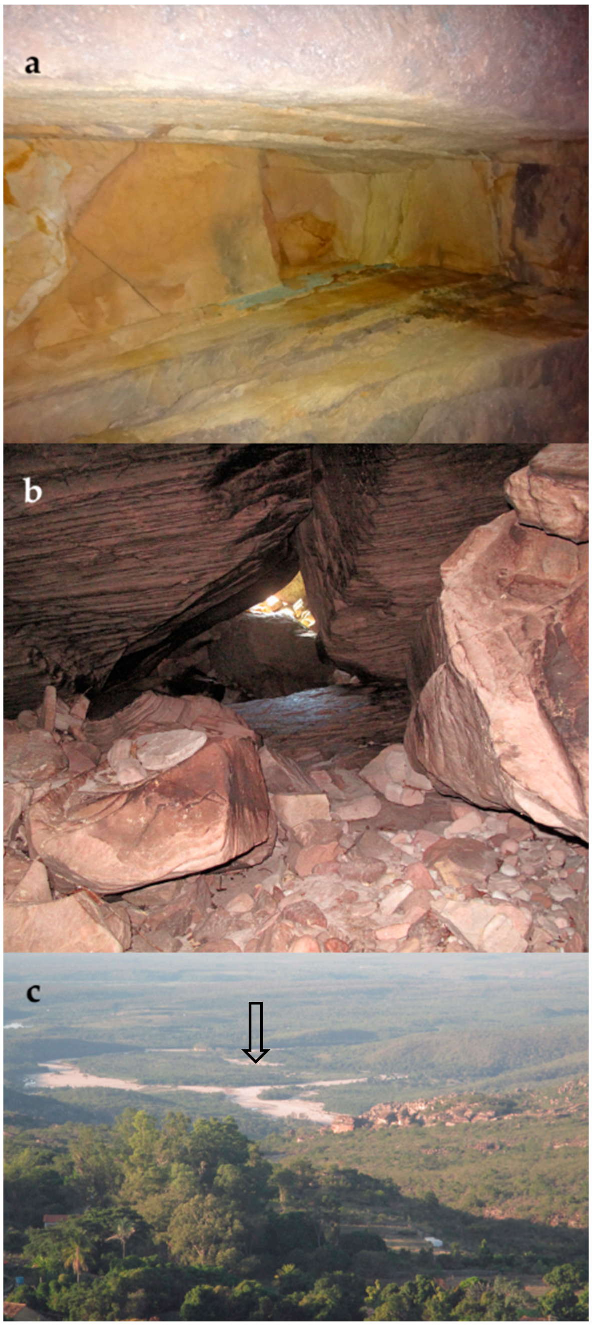

Figure 4. Alterations and impacts observed in caves and landscape of Igatu: (**a**) dug walls in Gruna do Cantinho cave; (**b**) pebbles and gravels washed due "garimpo"; (**c**) general view of Rio Paraguaçu River with silting sand due to past activities of "garimpo" in Igatu (arrow), note the urbanization next to it. This activity was allowed until 1996 and is incipient nowadays.

We investigated several terrestrial and aquatic microhabitats by active search, without the installation of traps. The main observed substrates for the cave fauna were animal detritus (guano, etc.), vegetal debris, roots, rocky blocks, walls, and ceilings. The subterranean drainages consisted mainly of a soft bottom composed of sand and pebbles, in general, with lentic waters and few organic matter. Surveys were conducted by two to four researchers per cave, to avoid severe impacts by overcollecting. Specimens were identified in the laboratory using taxonomic keys, specific literature, and expert consultation/confirmation for some groups (Araneomorphae: A. Brescovit; Collembola: J. G. Palacios-Vargas and D. Zeppelini; Diplopoda: S. Golovatch; Chilopoda: A. Chagas-Jr.; Acari: M. Santos de Araújo;

Isopoda: I. S. Campos-Filho; Coleoptera: R. Bessi; Gastropoda: R. Salvador). Most of the taxa were confirmed as new and were also considered in the list.

For confirmation of troglobitic/stygobitic status, we also conducted several samplings in the epigean environment. We classified troglobites/stygobites as those species that did not occur in the epigean environment coupled with morphological clues (troglomorphisms). We used the presence of traits often observed in troglobitic fauna, such as reduced eyes, pigmentation, elongation of appendages, and hypertrophy of nonvisual sensory structures, but which are not found in presumed epigean relatives, as evidence for their long-term solation and evolution in subterranean habitats. To recognize these troglomorphisms, we performed comparisons with close epigean relatives, including those ones collected in the same region. We followed the classification proposed by Culver and Pipan [13] to classify troglobites: cave-obligate species that cannot complete their life cycle outside of subterranean habitats.

All material was deposited in scientific collections in Brazil, including Laboratório de Estudos Subterrâneos (LES), Museu de Zoologia da Universidade de São Paulo (MZUSP), Universidade Federal de Mato Grosso (UFMT), Universidade Estadual da Paraíba (UEPB), Museu Nacional do Rio de Janeiro (MNRJ), and Instituto Butantan (IB).

3. Results

The updated troglobitic/stygobitic species now counts with 37 troglobitic/stygobitic species in five caves (Table 1, Figures 5 and 6). Taxa are distributed in three phyla (Arthropoda, Mollusca, Chordata), nine classes, 18 orders, and 32 families, representing a high phylogenetic diversity. The five caves share part of the recorded species, with Gruna da Parede Vermelha being the richest one, with 19 troglobitic/stygobitic species.

Table 1. Troglobitic/stygobitic species recorded from ICS (Igatu Cave System), Brazil. Gen., genus; sp., species.

Taxonomic Group	Taxon	Cave
Diplopoda: Polydesmida: cf. Chelodesmidae	Gen. sp.	Gruna Cantinho
Diplopoda: Polydesmida: Oniscodesmidae	*Crypturodesmus* sp.	Gruna Cantinho, Gruna da Parede Vermelha
Chilopoda: Scutigeromorpha: Pselliodidae	*Sphendononema* sp.	Gruna da Parede Vermelha, Gruna Canal da Fumaça
Chilopoda: Scolopendromorpha: Scolopocryptopidae	*Scolopocryptops troglocaudatus* Chagas-Jr and Bichuette, 2015	Gruna Cantinho, Gruna Lava Pé
Chilopoda: Scolopendromorpha: Cryptopidae	*Cryptops* sp.	Gruna Lava Pé
Arachnida: Acari: Mesostigmata: Pachylaepidae	Gen. sp.	Gruna Cantinho
Arachnida: Acari: Mesostigmata: Dithinozerconidae	Gen. sp.	Gruna Rio dos Pombos
Arachnida: Acari: Sarcoptiformes: Oehserchestidae	Gen. sp.	Gruna da Parede Vermelha
Arachnida: Scorpiones: Buthidae	*Troglorhopalurus translucidus* Lourenço, Baptista and Giupponi, 2004	Gruna da Parede Vermelha, Gruna Canal da Fumaça, Gruna Cantinho, Gruna Lava Pé, Gruna Rio dos Pombos
Arachnida: Araneae: Theraphosidae	*Tmesiphantes hypogeus* Bertani, Bichuette and Pedroso, 2013	Gruna da Parede Vermelha
Arachnida: Araneae: Ctenidae	*Ctenus igatu* Polotow, Cizauskas and Brescovit, 2022	Gruna Canal da Fumaça

Table 1. *Cont.*

Taxonomic Group	Taxon	Cave
Arachnida: Araneae: Gnaphosidae: Prodidominae	Gen. sp.	Gruna Rio dos Pombos
Arachnida: Araneae: Ochyroceratidae	*Ochyrocera* sp.	Gruna Cantinho
Arachnida: Araneae: Pholcidae	*Metagonia* sp.	Gruna Rio dos Pombos, Gruna Cantinho
Arachnida: Araneae: Telemidae	Gen. sp.	Gruna da Parede Vermelha
Arachnida: Opiliones: Gonyleptidae	*Discocyrtus pedrosoi* Kury, 2008	Gruna da Parede Vermelha, Gruna Canal da Fumaça, Gruna Cantinho, Gruna Lava Pé, Gruna Rio dos Pombos
Arachnida: Opiliones: Tricommatidae	Gen. sp.	Gruna Cantinho
Arachnida: Pseudoscorpiones: Chernetidae	*Spelaeochernes* sp.	Gruna da Parede Vermelha
Arachnida: Pseudoscorpiones: Chthoniidae	*Pseudochthonius* sp.	Gruna da Parede Vermelha
Arachnida: Pseudoscorpiones: Syarinidae	Gen. sp.	Gruna da Parede Vermelha
Arachnida: Palpigradi: Eukoeneniidae	*Eukoenenia* sp.	Gruna Lava Pé, Gruna Cantinho
Malacostraca: Isopoda: Philosciidae	*Metaprosekia igatuensis* Campos-Filho, Fernandes and Bichuette, 2020	Gruna Rio dos Pombos
Malacostraca: Isopoda: Philosciidae	*Benthana xiquinhoi* Campo-Filho, Bichuette and Taiti, 2019	Gruna Lava Pé, Gruna da Parede Vermelha
Malacostraca: Isopoda: Philosciidae	Gen. sp.	Gruna da Parede Vermelha
Malacostraca: Isopoda: Plathyartridae	*Trichorhina* sp.	Gruna Rio dos Pombos, Gruna Lava Pé
Malacostraca: Isopoda: Platyarthridae	Gen. sp.	Gruna da Parede Vermelha, Gruna Rio dos Pombos
Collembola: Entomobryomorpha: Entomobryidae	*Verhoeffiella* sp.	Gruna da Parede Vermelha
Collembola: Entomobryomorpha: Entomobryidae: Heteromurinae: Heteromurini	Gen. sp.	Gruna Cantinho, Gruna Rio dos Pombos
Collembola: Entomobryomorpha: Paronellidae	*Troglopedetes* sp.	Gruna da Parede Vermelha, Gruna Cantinho
Diplura: Projapygidae	Gen. sp.	Gruna Rio dos Pombos
Insecta: Zygentoma: Nicoletiidae	Gen. sp.	Gruna Canal da Fumaça
Insecta: Blattaria: Blattellidae	Gen. sp.	Gruna da Parede Vermelha
Insecta: Coleoptera: Scydmaenidae	Gen. sp.	Gruna Cantinho
Insecta: Coleoptera: Staphylinidae: Pselaphinae	Gen. sp.	Gruna da Parede Vermelha
Gastropoda: Stylommatophora: Systrophiidae	*Happia* sp.	Gruna da Parede Vermelha, Gruna Canal da Fumaça, Gruna Lava Pé, Gruna Rio dos Pombos
Actinopterygii: Siluriformes: Trichomycteridae	*Copionodon* sp.	Gruna da Parede Vermelha, Gruna Canal da Fumaça, Gruna Cantinho, Gruna Lava Pé, Gruna Rio dos Pombos
Actinopterygii: Siluriformes: Trichomycteridae	*Glaphyropoma spinosum* Bichuette, de Pinna and Trajano, 2008	Gruna da Parede Vermelha, Gruna Canal da Fumaça, Gruna Cantinho, Gruna Lava Pé, Gruna Rio dos Pombos

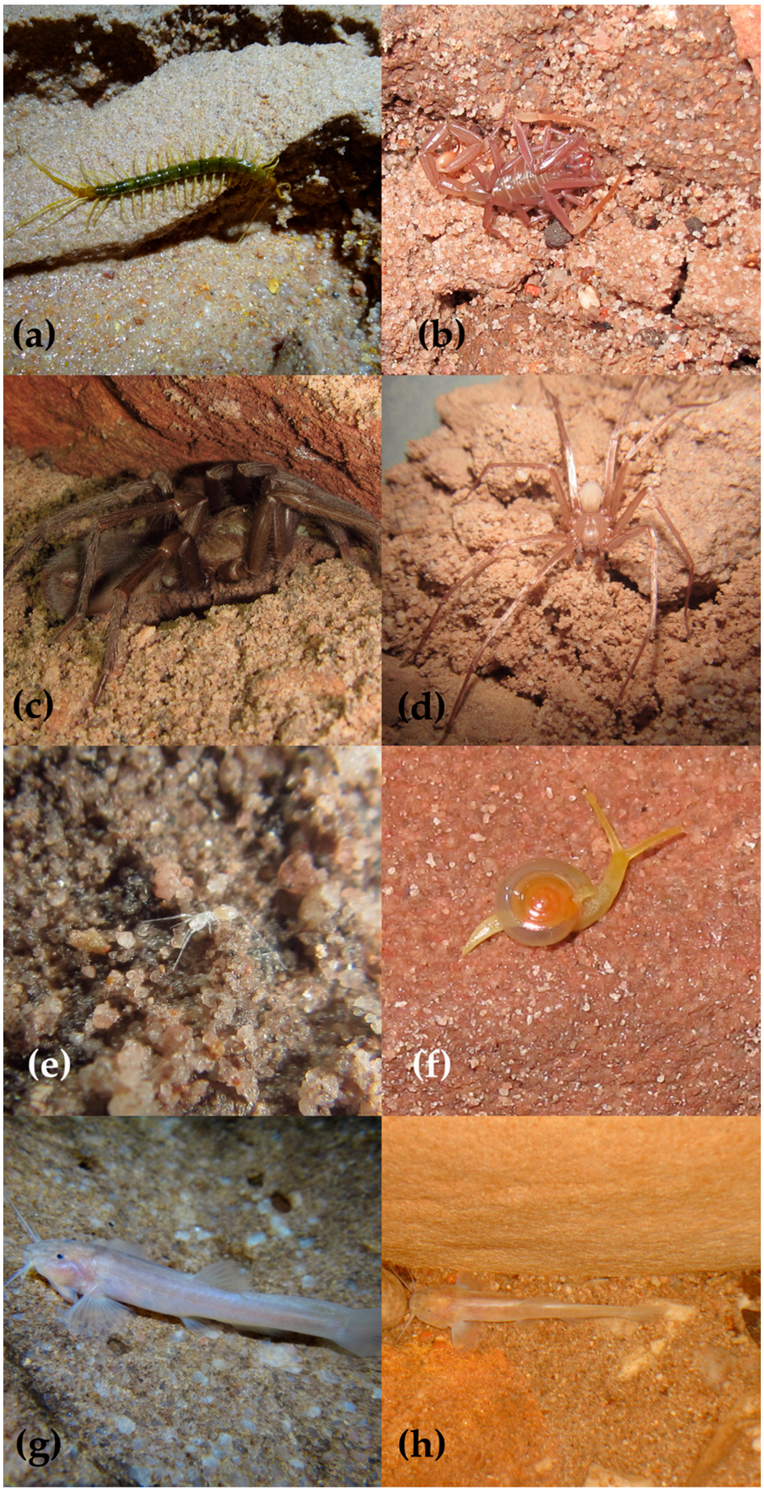

Figure 5. Troglobitic/stygobitic fauna of ICS, Bahia State, Brazil: (**a**) *Scolopocryptops troglocaudatus* (Scolopendromorpha); (**b**) *Troglorhopalurus translucidus* (Scorpiones); (**c**) *Tmesiphantes hypogeus* (Mygalomorphae); (**d**) *Ctenus igatu* (Araneomorphae); (**e**) *Eukoenenia* sp. (Palpigradi); (**f**) *Happia* sp. (Stylommatophora); (**g**) *Copionodon* sp. (Siluriformes); (**h**) *Glaphyropoma spinosum* (Siluriformes).

Among the troglobites/stygobites recorded for ICS, eight were formally described: *Discocyrtus pedrosoi* Kury, 2008, *Glaphyropoma spinosum* Bichuette, de Pinna and Trajano 2008, *Troglorhopalurus translucidus* Lourenço, Baptista and Giupponi 2004, *Tmesiphantes hypogeus* Bertani, Bichuette and Pedroso 2013, *Metaprosekia igatuensis* Campos-Filho, Fernandes and Bichuette, 2020, *Benthana xiquinhoi* Campo-Filho, Bichuette and Taiti, 2019, *Ctenus igatu*

Polotow, Cizauskas and Brescovit, 2022, and *Scolopocryptops troglocaudatus* Chagas-Jr and Bichuette, 2015. ICS is the type-locality of seven species.

Figure 6. Troglobitic fauna of ICS, Bahia State, Brazil: (**a**) cf. *Chelodesmidae* sp. (Diplopoda: Polydesmida); (**b**) *Crypturodesmus* sp. (Diplopoda: Polydesmida); (**c**) *Cryptops* sp. (Chilopoda: Scolopendromorpha); (**d**) *Verhoeffiella* sp. (Collembola: Entomobryomorpha), 1.5 mm body size; (**e**) *Troglopedetes* sp. (Collembola: Entomobryomorpha), 1.1. mm body size; (**f**) *Sphendononema* sp. (Scutigeromorpha).

Considering the taxonomical records and some aspects of natural history, we can make some highlights.

For Myriapoda, most millipede species found in Brazilian subterranean habitats belong to the orders Polydesmida and Spirostreptida [14]. Polydesmida includes eight of 13 troglobitic species described for Brazil, all of which occur in limestone caves. For the Igatu region, two undescribed troglobitic Polydesmida are recorded: *Crypturodesmus* and one cf. Chelodesmidae. The genus *Crypturodesmus* (Oniscodesmidae) has been registered in Brazil and Mexico [15]. In the subterranean environment, the genus has been recorded in limestone caves in the states of Mato Grosso do Sul, São Paulo, and Paraná [14], and now for the ICS. In the family Chelodesmidae, five troglobitic species are known: two in

Brazilian limestone caves and three in Jamaica, Puerto Rico, and Spain, suggesting relict lineages [16]. This suggests that few, if any, radiations of chelodesmids have occurred within caves in the past [16].

Similarly, chilopods are representative of ICS; there are seven described troglobitic species for Brazil (two of the Order Geophilomorpha and five of the Order Scolopendromorpha). One of them occurs in the Igatu Cave System: *Scolopocryptops troglocaudatus*. Even more, a new species of the genus *Cryptops* (Scolopendromorpha) and a new species of the genus *Sphendononema* (Order Scutigeromorpha) also occur in ICS (A. Chagas-Jr., pers. comm.). *Cryptops* have a worldwide distribution, occurring in caves in Brazil, Europe, Australia, and Cuba [17]. The genus is common in Brazil, with three troglophilic and two troglobitic species described for limestone and iron ore caves [17]. Igatu caves have mainly exposed sandstone rock as a substrate, and their surroundings are mostly composed of outcrops; the discovery of a highly troglomorphic species of *Cryptops*, with appendages elongated in relation to the body, including antennae and anal legs (A. Chagas-Jr., pers. comm.), and the non-occurrence in the epigean environment reinforce its troglobitic status. *Scolopocryptops troglocaudatus* is the second troglobitic Scolopocryptopinae described and the first discovered in Brazil [18]. Additionally, this species is one of the most troglomorphic Scolopendromorpha known, with the anal leg reaching 2/3 of the body length [18]. Another relevant record for ICS caves is the new species of *Sphendononema* genus, representing the first troglobitic Scutigeromorpha worldwide; its legs, annal legs, and antennae are greatly elongated and the specimens showed low body sclerotization (comparatively with the widely distributed *S. guildingii*). These results corroborate the importance of ICS for Myriapoda taxonomic knowledge. In addition, these data reinforce the phylogenetic diversity of the ICS cave fauna.

There are about forty-three troglobitic species of Isopoda in Brazil and among them, two are known for Igatu caves, *Metaprosekia igatuensis* and *Benthana xiquinhoi*. In addition to these described species, three other new ones were also recorded (Table 1). The troglomorphisms were mainly a reduction in number of ocelli (or absence), body depigmentation, associated with low tolerance to dry conditions, also observed for other troglobitic isopods.

The fauna of Pseudoscorpiones are represented by 12 families and 22 genera in Brazilian caves [19], and the troglobitic fauna counts with 24 species, belonging to Chernetidae, Chthoniidae, Bochicidae, and Ideoroncidae families. Three undescribed species were recorded for ICS (Chernetidae, Chthoniidae, and Syarinidae families), the most modified (specialized) were Chthoniidae and Syarinidae, and the later one represents the first record for troglobitic species considering the family in Brazil (Table 1).

The scorpion *Troglorhopalurus translucidus* was discovered and described for Gruta do Lapão, in another region of Chapada Diamantina (municipality of Lençóis). This cave also belongs to the Espinhaço Supergroup, Tombador formation, however, at its northernmost point. Few specimens were recorded in the type-locality. On the contrary, in the Igatu caves, the abundance and distribution were greater, possibly representing the source population for the species. *Troglorhopalurus translucidus* is the most troglomorphic scorpion of the Buthidae family known and, together with *T. lacrau* (Lourenço and Pinto-da-Rocha, 1997), comprise the only two troglobitic scorpions known from Brazil. Some other subterranean scorpions in Brazilian caves are troglophiles, such as *Tityus blaseri* Mello-Leitão, 1931 and *T. spelaeus* Moreno-Gonzáles, Pinto-da-Rocha and Gallão, 2021, both species occur in caves and epigean habitats in the state of Goiás, *T. confluens* Borelli, 1899, in caves and epigean habitats in the states of Mato Grosso and Mato Grosso do Sul, *T. stigmurus* (Thorell, 1876), widely distributed in northeastern Brazil, with facultative cave populations in the state of Sergipe [20], and *T. obscurus* Gervais, 1843, with a well-established population in the caves of North Brazil (state of Pará) (J.E. Gallão, pers. obs.).

For Opiliones, the Brazilian subterranean fauna is remarkable with several representatives in trogloxenes and troglophiles species distributed in several families [21]. The updated number of described troglobitic opilionids counts with 14 species for Brazilian caves, most are Gonyleptidae. In addition to the described *Discocyrtus pedrosoi*, one undescribed troglomorphic Tricommatidae was recorded from Igatu caves.

To date, no troglobitic mite is known of from Brazil; however, several have been described as occurring in caves, as cave-dwellers. Three species recorded in the Igatu caves (Pachylaepidae, Dithinozerconidae, and Oehserchestidae families) presented troglomorphic characters when compared to the described species of these families (M. S. de Araújo, pers. comm.) such as elongated legs, as well as reduced sclerotization. In addition, surface collections did not reveal any mite species from these families, which justifies their troglobite status. Studies on the taxonomy of these taxa are urgently needed, which could corroborate the proposed category and also would provide important data on the biogeography of these families.

About the mygalomorphae spiders, *Tmesiphantes hypogeus* is the only known theraphosid troglobitic spider for Brazil. The species was discovered and described with females specimens only for Igatu caves. No male was found.

There are about 30 troglobitic Araneomorphae spiders for Brazil, with a dominance of Ochyroceratidae, Gnaphosidae, and Tetrablemmidae families, among others [22]. Igatu is remarkable due the occurrence of *Ctenus igatu*, a highly troglomorphic Ctenidae spider, in addition to three undescribed species of the families Ochyroceratidae, Pholcidae, and Gnaphosidae (Table 1).

There are at least 17 species of troglobitic Palpigradi for Brazil, all of which belong to the family Eukoeneniidae and most are from the genus *Eukoenenia*. In Igatu, there is one species of *Eukoenenia* that has not yet been described.

Brazil harbors 49 formally described troglobitic Collembola, none of which are from Igatu. The new records at ICS are of three undescribed species (*Verhoeffiella*, specimens of Heteromutini tribe, and *Troglopedetes* genus). It is worth noting that for these caves, we recorded the genus *Verhoeffiella,* which was previously recorded only in the Dinaric region of Europe. If confirmed by future detailed taxonomical studies, the presence of this genus would be a major discovery for Entomobryiidae biogeography. Even more, considering the records of *Troglopedetes* genus, this is the first record in South America of an European and Southern Asia genus, although there are many records of the related genus *Trogolaphysa* from the region. Like for *Verhoeffiella*, its discovery in Igatu raises an interesting and puzzling biogeographical problem.

In Brazilian caves, there are records of at least 24 troglobitic coleopterans, most of which are from the Carabidae family. None of the described species occur in the Igatu caves; however, there are two undescribed species belonging to the families Scydmaenidae and Staphylinidae, showing low abundance, and each one is restricted to only one cave.

For gastropods, there are currently 21 troglobitic species for Brazilian caves, but none are described for the caves of Igatu. In this region, there is only one troglobite, which remains undescribed, of the genus called *Happia* (Systrophiidae).

With regard to the stygobiotic fauna, we found that it was poor in Igatu. We recorded only two species, both of which were fishes. There are about 36 troglobitic fishes in Brazil [9], and two were found in Igatu: *Glaphyropoma spinosum* and an undescribed species of the genus *Copionodon*, both of which were widely distributed in Igatu caves. Both species belong to the subfamily Copionodontinae, endemic to the Chapada Diamantina region, and co-occur in the caves, which is a rare event in general. The wide distribution of these two Copionodontinae populations corroborates the connectivity of ICS caves.

The number of troglobites/stygobites for Igatu (37) does not include other relevant caves of the same geological supergroup (Espinhaço), such as Gruta do Lapão (municipality of Lençóis) and Gruta do Castelo (municipality of Mucugê). The total number of troglobitic species in the region rises up to 46 when these two caves are taken into account.

4. Discussion

Gallão and Bichuette [5] registered 162 cave-dwelling species in 11 caves from the Igatu region, with doubts about the possible connections between them. At that time, they considered 23 troglobitic species distributed in an area of 25 km^2. Now we reach 37 species for five caves, all connected by a subterranean drainage (part of the Rio Coisa river), covering a linear extension of 4.3 km. This extension is significantly smaller than that observed for other caves considered hotspots in Brazil and worldwide: the Areias Cave System in southeastern Brazil, formed by three connected caves, currently harbors more than 31 species and has about 8.5 km of mapped passages (ME Bichuette and JE Gallão, updated data); the Água Clara Cave System in northeastern Brazil, formed by four caves, harbors 31 species and has about 25.8 km of mapped passages [23]; the Huautla Cave System in Oaxaca, Mexico, harbors 27 species and has about 89 km of mapped passages [24]; the Fern Cave System in northeastern Alabama, USA, harbors 27 species and has over 25 km of mapped passages [25].

If we consider the troglobitic/stygobitic fauna of ICS in a phylogenetic context, we can realize the great diversity of these troglobites distributed in a variety of higher taxa. Currently, for ICS, nine classes, 18 orders, and 32 families are represented for 37 troglobitic/stygobitic species. Phylogenetic diversity also assists in choosing priorities for conservation. The extinction of species without close relatives is more damaging than extinction of species with close relatives [26,27], and so, the best conservation strategies are those that address the greatest possible phylogenetic diversity [27,28]. Although we did not perform any phylogenetic diversity test in this work, Gallão and Bichuette [5] performed tests for 11 caves of Igatu and in addition to calling attention to the troglobitic/stygobitic fauna, these authors demonstrated the relevance of one cave, the Gruna da Parede Vermelha, which, at the time, presented the greatest phylogenetic diversity considering subterranean fauna [5]. These comparisons emphasize the importance of Igatu with a greater potential for a higher number of troglobites/stygobites. In support of this idea, the Gruna da Parede Vermelha cave has about 0.7 km of mapped passages and harbors 18 troglobitic/stygobitic species at present.

We must also consider the lithology of the caves of Igatu (sandstone), which is generally neglected in inventories of subterranean fauna in general, not only cave-restricted species. In this sense, with the inclusion of troglophilic and trogloxene populations, we reached 184 species for the five caves considered here, which was clearly high for siliciclastic caves. When we compared with other studies conducted in siliciclastic areas in Brazil, we note how Igatu stood out in all relevant aspects considering biodiversity value, whether in number of subterranean species in general, of troglobitic/stygobitic species, and also phylogenetic diversity (Table 2).

Table 2. Comparison among siliciclastic regions with records of troglobitic/stygobitic fauna in Brazil. TR/STY: number of troglobitic/stygobitic species.

Region	Geomorphological Information	Number of Caves	TR/STY	Total of Species	References
Altamira and Medicilândia—North Brazil	Altamira—Itaituba	7	2	62	[29]
Altinópolis—Southeastern Brazil	Serra Geral, Botucatu Formation	9	0	83	[30]
Rurópolis—North Brazil	Altamira—Itaituba	1	0	16	[31]
Manoel Viana and São Pedro do Sul—South Brazil	Serra Geral, Botucatu Formation	3	0	30	[32]
Chapada Diamantina—Northeastern Brazil	Serra do Espinhaço, Tombador Formation	11	25	162	[5]
Altinópolis—Southeastern Brazil	Serra Geral, Botucatu Formation	8	0	131	[33]
Lima Duarte—Southeastern Brazil	Andrelândia geological group	20	6	469	[34]
Itirapina—Southeastern Brazil	Serra Geral, Botucatu Formation	1	3	67	E.L.B. Carvalho, undergraduated monograph (unpubl. data)
Altamira—North Brazil	Altamira—Itaituba	26	17	596	M.E. Bichuette, unpubl. data
Chapada Diamandina—Northeastern Brazil	Serra do Espinhaço, Tombador Formation	5	37	184	This study

There is currently a minimum threshold that counts only the number of troglobitic species to identify a cave or cave system as a hotspot. Culver and Sket [35] set this threshold at 20 species, and in a recent work, Culver et al. [36] increased this threshold to 25 species. However, Trajano et al. [6] discussed that caves and/or cave systems of Brazil can be considered as spots (or hotspots) not only based on the number of troglobitic/stygobitic species but also on phylogenetic diversity (such as the presence of relict taxa) as well as genetic diversity (such as the accumulation of autapomorphies). In this way, Trajano et al. [6] listed six sites: the Upper Ribeira karstic area in the state of São Paulo, the Serra da Bodoquena karst area in the state of Mato Grosso do Sul, the São Domingos karst area in the state of Goiás, in addition to the Chapada Diamantina karst area, the Serra do Ramalho karst area and the Chapada Diamantina siliciclastic area, the last three in the state of Bahia, and the last one considered in this work. It was noted that paleoclimatic fluctuations, in addition to geomorphological changes, have determined a high diversity of troglobites/stygobites in the state of Bahia as a whole [6], and the Igatu region clearly follows this pattern.

If we spread the number of siliciclastic caves of Chapada Diamantina from five to seven (five caves of Igatu region + Gruta do Lapão cave + Gruta do Castelo cave), we reach 46 species of troglobites/stygobites, some shared between them, representing an expressive subterranean biodiversity for a unique geological formation (Tombador Formation), with different facies, significantly increasing the relevance of the siliciclastic caves from Chapada Diamantina region.

The fauna of ICS is clearly remarkable, as previously stated by Gallão and Bichuette [5]. In contrast to the findings of Sousa Silva et al. [34], who considered the existence of caves with more than 30 troglobites/stygobites in Brazil, or even more, impossible, considering caves in siliciclastic rocks. This kind of affirmation, disregarding the existence of something not tested is clearly speculative and could threaten the decision on proposed areas particularly rich and unique in subterranean fauna, the case of Chapada Diamantina, which is one of the Brazilian regions with highest endemism rates [5,6,22], and a high rate of endemism to the subterranean fauna is expected too. Herein, we reinforced the hypothesis by Gallão and Bichuette [5], updating the number of troglobitic/stygobitic species to 37, in a small area covered by five sandstone caves, including beetles, centipedes, collembolans, acari, scorpions, spiders, gastropods, fish, and more. Most sandstone caves of Chapada Diamantina were heavily impacted by diamond mining ("garimpo") in the past, since 1846 and reaching until 1996. In recent years, the "garimpo" activity occurred in clandestine and residual ways. The five caves of Igatu Cave System were inserted in the Chapada Diamantina National Park (CDNP) and are legally protected. Even so, there are threats, such as the residual and clandestine "garimpo" in a small scale, and the urban expansion due the tourism in the region. Ecological long-term studies, allied to citizen science, are crucial to provide support in the effective protection of Igatu caves and its remarkable and particular fauna.

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