

Frogs of seven granitic caves on Santa Catarina Island, Florianópolis Municipality, Santa Catarina State, southern Brazil

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Abstract. We here report on the frogs occurring in seven insular granitic caves in the Municipality of Florianópolis, Santa Catarina State, southern Brazil, located in the Atlantic Forest biome. We encountered adults of *Bokermannohyla hylax*, *Ischnocnema manezinho*, *Leptodactylus* cf. *paranaru*, *Rhinella* cf. *ornata*, and *Scinax catharinae*, of which. The most common species was *I. manezinho*, endemic to Florianópolis and classified as Near Threatened and Vulnerable on the endangered species lists of Santa Catarina State and Brazil. Our findings indicate that caves may be important refuges for frogs.

Keywords: Atlantic Forest, frogs, igneous rock, insular caves, subterranean environment

Introduction

Caves are defined as one of the habitats of the subterranean realm (or hypogean). Some of their characteristics include stable environmental conditions (such as temperature, humidity close to saturation, and permanent absence of light) and a tendency to harbour otherwise scarce food resources, mainly composed of allochthonous origin, carried to the caves by floods (Barr and Kuehne, 1971; Culver and Pipan, 2019). Brazilian caves supply abundant and diverse invertebrate food for frogs (Bernarde, 2012) while also providing a refuge from predation (Dos Santos, 2017). Moreover,

physiological water requirements generally restrict frogs to habitats with high humidity (Eterovick et al., 2010), and caves can provide a favourably humid environment with relative humidity of around 90%, even in seasons with low rainfall (Matavelli et al., 2015). In a global panorama, several studies have evaluated the status of frogs in caves, including their niche, population aspects, and life history, mainly in North America (Resetarits, 1986; Fenolio et al., 2005; del Castillo et al., 2009; Lúria-Manzano and Ramírez-Bautista, 2017), Southeast Asia (Biswas, 2014; Suwannapoom et al., 2018), Italy (Lunghi et al., 2017; Lungui et al., 2018), and Colombia (Lüddecke, 2003).

Subterranean habitats are considered one of the least studied environments for Brazilian anurans. Most reports are species descriptions (Vaz-Silva et al., 2018; Barcelos et al., 2020), notes of occurrence (Ferreira et al., 2009; Lima et al., 2012; Motta et al., 2020), general faunal lists for hypogean environments (Trajano, 1987; Trajano and Gnaspini-Neto, 1991; Pinto-da-Rocha, 1995; Trajano and Bichuette, 2006), and population study (Martins-Andrade et al., 2021). There are only two studies that have addressed community ecology and anuran richness in Brazilian caves, one by Matavelli et al. (2015), who indicated the occurrence of 54 species, and the other by Dos Santos (2017), who indicated 34 species of anurans, representing 3–5% of the 1144 Brazilian anurans (Segalla et al., 2021). However, these studies did not cover caves in southern Brazil or in insular regions of the country. Here we partially fill this gap by listing frogs in seven granitic caves in southern Brazil.

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Material and Methods

Study Area. The study was carried out in seven granitic caves (igneous rock caves; Santos, 2019) on Santa Catarina Island, Municipality of Florianópolis, Santa Catarina State, southern Brazil (Fig. 1), namely (1) Água Corrente Cave System, (2) Laje Cave, (3) Monte Verde Cave, (4) Pedras Grandes Cave, (5) Praia Brava Cave, (6) Saco Grande Cave, (7) Saco dos Limões Cave. The predominant biome of the island is Atlantic Forest with a subtropical humid climate (Alvares et al., 2013). Anthropogenic impacts were observed in some of these caves and their surroundings, such as construction of dams for water consumption and the use of the cave for the deposit of construction materials (Fig. 2).

Collections. We conducted active daytime searches for frogs during five field visits by a team of four researchers, in January, February, May, and September 2016, and in January 2017. We searched throughout the accessible areas of the caves, inspecting the ground, walls and, wherever possible, the cave ceiling (Dos Santos, 2017). We searched until all accessible microhabitats were

inspected. After manual collection, frogs were euthanised with a 10% lidocaine solution. Specimens were fixed in 10% formalin, then stored in 70% ethanol before processing in the Laboratório de Estudos Subterrâneos at the Universidade Federal de São Carlos (LES/UFSCar). Specimens were deposited in the Coleção de Anfíbios Célio F.B. Haddad (CFBH). Some animals were sheltered in places inaccessible to researchers, such as in deep rock crevices or in narrow conduits inside the cave, and those individuals were photographed to the extent possible, and their locations were included in this survey (Fig. 1). We identified specimens as close as possible to species level using collection specimens, species description, and the help of taxon group specialists, following the nomenclature of Frost (2021).

Results

We collected specimens of the hylids *Bokermannohyla hylax* (Heyer, 1985) and *Scinax catharinae* (Boulenger, 1888) and the brachycephalid *Ischnocnema manezinho* (Garcia, 1996) (Table 1, Fig. 3A–E). We also found

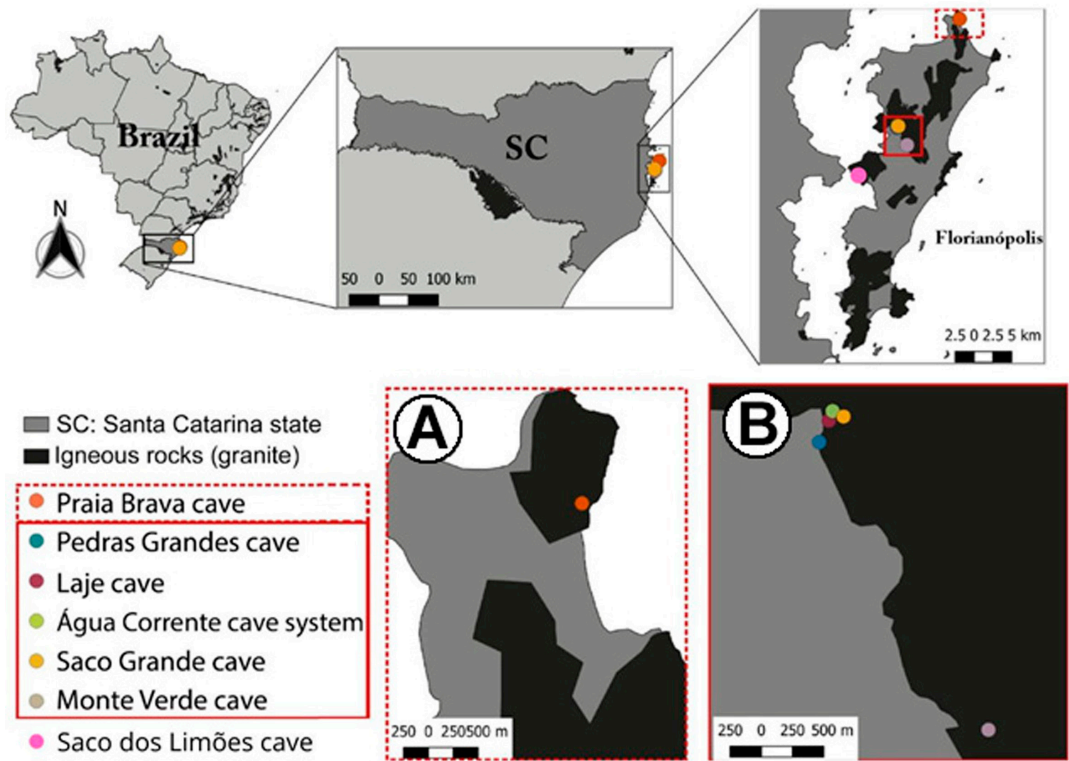


Figure 1. The location of the seven caves in Florianópolis Municipality, Santa Catarina State, Brazil, where we studied the presence of anurans. (A) Location of Praia Brava Cave, on the north coast of the Santa Catarina Island. (B) Location of Pedras Grandes Cave, Laje Cave, Água Corrente Cave System, Saco Grande Cave, and Monte Verde Cave in the central part of Santa Catarina Island.



Figure 2. Urban expansion and anthropogenic impacts in the studied caves in Florianópolis Municipality, Santa Catarina State, Brazil. (A) Satellite view obtained from Google Earth to show the proximity of urban construction to Pedras Grandes Cave as of late 2021, with the red pointer positioned over the cave's entrance. (B) Basin construction for water accumulation in Saco Grande Cave. (C) Deposit of construction material at Saco dos Limões Cave. Photos (B, C) by Deborah Lee Bertolini.

one individual of the leptodactylid *Leptodactylus* cf. *paranaru* and one individual of the hylid *S.* cf. *catharinae* in Pedras Grandes Cave; one individual of *S.* cf. *catharinae* in Praia Brava Cave; and one individual of the toad *Rhinella* cf. *ornata* in Laje Cave. Some tadpoles were also found in water bodies near the cave entrance (Fig. 3F). Considering that we focused our searches on adults, we did not have the material to collect tadpoles or analyse their morphological characteristics in the field. Therefore, the tadpoles were photographed but not collected or identified.

Discussion

In temperate regions, caves can serve as important refuges and foraging places in hostile climatic conditions for amphibians, in the short or long term (Niemiller and Miller, 2009; Biswas, 2014). We assume that the frogs we observed also used the caves as shelter and refuge, although there is little information about anurans in Brazilian caves. The two studies that addressed anurans in Brazilian granitic caves (caves formed by igneous rocks) specifically were conducted in southeastern Brazil and involved a total of 17 caves where seven species from five families were found (Matavelli et al., 2015; Dos Santos, 2017). These also included an unidentified species of *Ischnocnema*, the toads *Rhinella crucifer* (Wied-Neuwied, 1821) and *R. ornata* (Spix, 1824), the cycloramphids *Thoropa miliaris* (Spix, 1824) and *T. taophora* (Miranda-Ribeiro, 1923), the hylid *Scinax fuscovarius* (Lutz, 1925), and the odontophrynid *Proceratophrys boiei* (Wied-Neuwied, 1821). In the seven caves of Florianópolis, in southern Brazil, we recorded three species with confirmed species level identification and three species (four specimens) only to the level of genus. Of the families we recorded, three coincide with previous studies and Leptodactylidae is a new record for caves in Brazil.

We use “cf.” to indicate a small possibility of uncertainty with the identification of *Leptodactylus* cf. *paranaru*, *Scinax* cf. *catharinae*, and *Rhinella* cf. *ornata*, which we did not collect. *L. paranaru* Magalhães et al., 2020 is a member of the *L. latrans* clade that was only recently elevated to species status as an endemic of the coastal Atlantic Forest in southeastern Brazil, from the states of São Paulo to Rio Grande do Sul (Magalhães et al., 2020). *Leptodactylus latrans* (Steffen, 1815) is a ground-dwelling species that calls in ponds or swamps (Haddad et al., 2013; de Sá et al. 2014). *Rhinella ornata* is also a ground-dwelling species, with less specialized calling sites, generally present in lotic waters, such

Table 1. Anuran species observed in granitic caves in Florianópolis Municipality, Santa Catarina State, Brazil, with the number of specimens observed (*n*). Asterisks (*) indicate uncollected specimens, which were observed but inaccessible due to their location within the cave. The accession numbers of specimens deposited in scientific collection are provided in parentheses. Watercourse were classified as intermittent (presence of water only in the rainy season), perennial (presence of water throughout the year), and none (no watercourse present).

Cave	Species (Specimen Numbers)	<i>n</i>	GPS Coordinates	Watercourse	Date
Água Corrente	<i>Bokermannohyla hylax</i> (CFBH 40912, 42118)	2	27.5361°S, 48.4977°W	Perennial drainage	1 May 2016
	<i>Ischnocnema manezinho</i> (CFBH 40913)	1	27.5361°S, 48.4977°W		1 May 2016
	<i>Scinax catharinae</i> (CFBH 42119)	1	27.5361°S, 48.4977°W		24 January 2017
Laje	<i>Ischnocnema manezinho</i> (CFBH 40914)	1	27.5369°S, 48.4980°W	Perennial drainage	1 May 2016
	<i>Rhinella</i> cf. <i>ornata</i> *	1	27.5369°S, 48.4980°W		27 September 2016
Monte Verde	<i>Ischnocnema manezinho</i> (CFBH 42116, 42117)	2	27.5620°S, 48.4850°W	Intermittent drainage	29 September 2016
Pedras Grandes	<i>Ischnocnema manezinho</i> (CFBH 42115)	1	27.5386°S, 48.4988°W	Perennial drainage	25 January 2017
	<i>Leptodactylus</i> cf. <i>paranuru</i> *	1	27.5386°S, 48.4988°W		28 September 2016
	<i>Scinax</i> cf. <i>catharinae</i> *	1	27.5386°S, 48.4988°W		2 February 2016
Praia Brava	<i>Ischnocnema manezinho</i> (CFBH 40916)	1	27.3922°S, 48.4144°W	Perennial drainage	1 May 2016
	<i>Scinax</i> cf. <i>catharinae</i> *	1	27.3922°S, 48.4144°W		16 January 2016
Saco dos Limões	<i>Ischnocnema manezinho</i> (CFBH 40915)	1	27.6078°S, 48.5402°W	None	1 May 2016
Saco Grande	<i>Bokermannohyla hylax</i> (CFBH 40911, 42114)	2	27.5365°S, 48.4968°W	Perennial drainage	1 May 2016

as ponds, swamps, or stream backwaters (Haddad et al., 2013; Pereyra et al., 2016). These two species explore both open and forested areas (Haddad et al., 2013), contributing to their abundance and distribution throughout Brazil. *R. crucifer*, a phylogenetically closely related species to *R. ornata*, was reported to occur in granitic caves in the Atlantic Forest by MataVELLI et al. (2015).

The other three species are endemic to the Brazilian Atlantic Rainforest, with nocturnal habits in forested areas (Haddad et al., 2013). *Bokermannohyla* and *Scinax* are treefrog genera in the family Hylidae, the most diverse anuran family in Brazil (Segalla et al., 2019). *B. hylax* is abundant year-round in dense Atlantic Rainforest (Bertoluci, 2002; Armstrong and Conte, 2010; Ceron et al., 2017). *Scinax catharinae* is restricted to southern Brazil, and it is the only species of the *S. catharinae* group to occur in Florianópolis (Lourenço et al., 2019). It is a rare species that is usually found in native and non-native forests (Lucas and Fortes, 2008; Ceron et al., 2017). *Scinax fuscovarius* waMartis also recorded from granitic caves by Dos Santos (2017). This species occurs widely in many environments in South America, in forests, open areas, as well as peri-urban and urban areas (Frost, 2021), so the occupation of a subterranean environment is not surprising for this habitat generalist, as caves can provide a humid shelter for this species.

However, whether or not this species is using the cave as shelter is a question that still need more studies.

There are currently 39 valid species in the genus *Ischnocnema* (Frost, 2021), mostly associated with the Atlantic Forest (Canedo and Haddad, 2012). These species are taxonomically complex, being mainly identified through advertisement call and DNA sequences due to their cryptic morphology (Taucce et al., 2018). Usually dwelling in leaf litter, they lack a tadpole stage and have direct terrestrial development (mode 23 *sensu* Haddad and Prado, 2005; Hedges et al., 2008). *Ischnocnema manezinho* is endemic to Florianópolis, where it is mainly found in Maciço da Costeira Municipal Park, but populations also occur in Lagoa do Peri Municipal Park (Garcia, 1996). Due to its restricted geographical distribution, *I. manezinho* is listed as Vulnerable in Brazil (ICMBIO, 2018) and in Santa Catarina State (FATMA, 2011), and as Near Threatened globally (Garcia and Silvano, 2004). The caves where *I. manezinho* was recorded are under severe environmental impact, mainly because of the unrestricted urban expansion, warehouse deposits, and waste left by visitors.

Our study is the first to document the presence of *B. hylax*, *I. manezinho*, *S. cf. catharinae*, and *L. cf. paranuru* in subterranean habitats in Brazil, and ours is the first report of these species and *R. cf. ornata* for granitic caves. Considering their habits and natural history, these

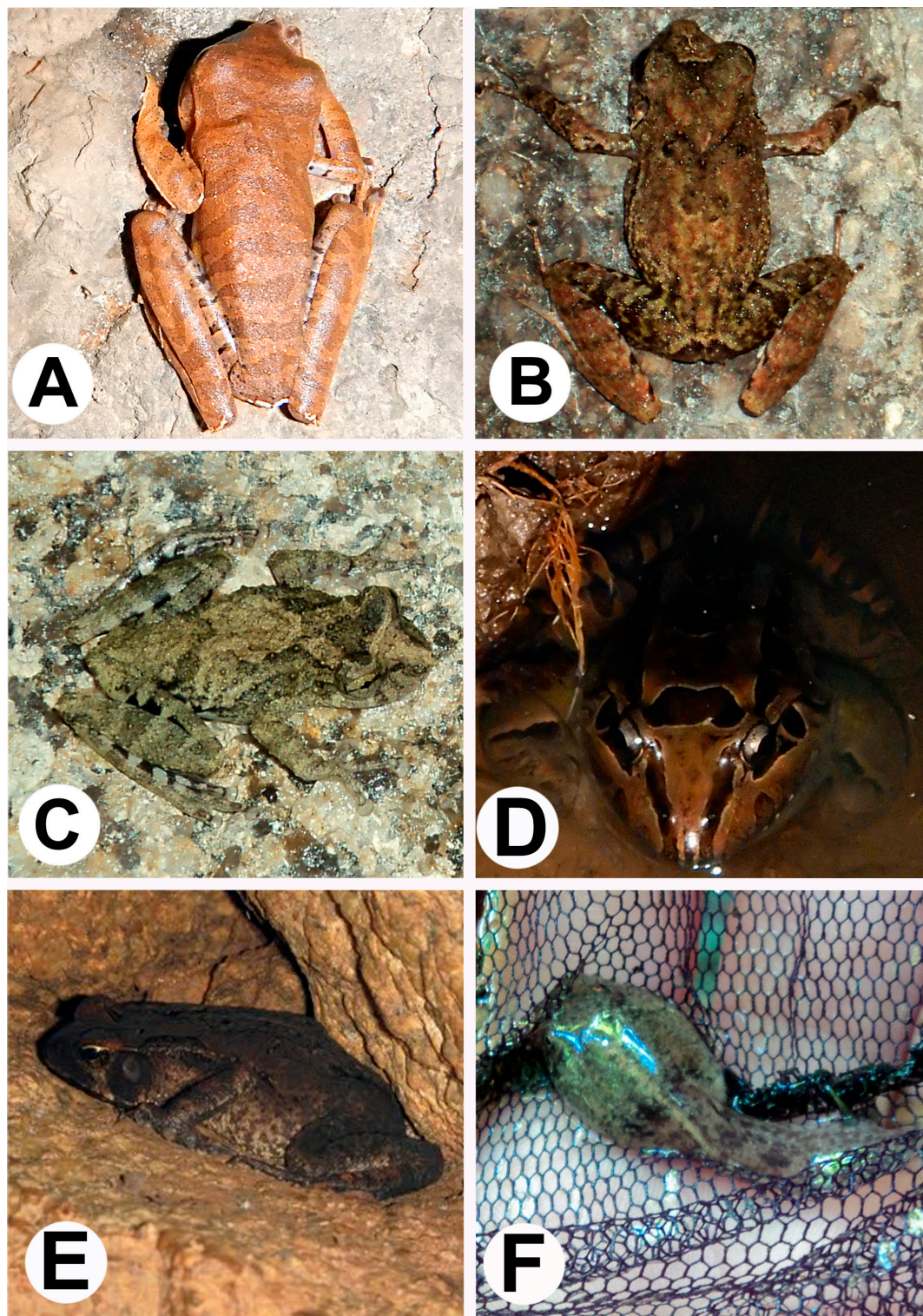


Figure 3. Anurans recorded in granitic caves in Florianópolis Municipality, Santa Catarina State, southern Brazil. (A) *Bokermannohyla hylax*. (B) *Ischnocnema manezinho*. (C) *Scinax catharinae*. (D) *Leptodactylus* cf. *paranaru* (not collected). (E) *Rhinella* cf. *ornata* (not collected). (F) Unidentified tadpole, not assigned to species. Photos by Maria E. Bichuette (A, D–F) and Deborah Lee Bertolini (B, C).

species possibly use caves as refuges. We observed these species in caves both in the dry (May) and rainy seasons (September, January, February), apparently without any association to the reproductive seasons of the species. Among these genera, *B. martinsi* (Bokermann, 1964) is the only species known to systematically occupy caves, show high levels of territoriality, and transit among caves (Martins-Andrade et al., 2021). However, further studies are needed on cave use by Brazilian amphibians to investigate how common this environment is for the native species. Furthermore, although we do not have an identification of the tadpoles found, their presence indicates the possibility of reproduction inside the cave. The tadpoles or eggs might have been carried into the cave by rain runoff, and we cannot be certain that frogs reproduce there. Therefore, the natural history of frogs that occupy caves in Brazil also needs investigation.

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