Species composition and richness of the herpetofauna of the semiarid environment of Nordestina, in northeastern Bahia, Brazil

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Resumo

Composição e riqueza da herpetofauna no semiárido do município de Nordestina, no Nordeste do estado de Bahia, Brasil. A herpetofauna da Caatinga continua subestimada. A falta de conhecimento levou essa região a ser considerada de baixa riqueza e endemismo. Este estudo tem como objetivo determinar a composição e riqueza de espécies da herpetofauna no município de Nordestina. Os dados foram coletados utilizando diferentes técnicas amostrais, como armadilha de interceptação e queda e procura ativa. A riqueza da herpetofauna foi estimada utilizando o estimador Bootstrap. Além disso, foram calculados também a dominância e equitabilidade por grupo taxonômico. No total, foram registrados 3.969 espécimes distribuídos em 49 espécies. As serpentes apresentaram maior riqueza, enquanto os lagartos foram mais abundantes. Para os anuros, estimou-se, aproximadamente, $14 \pm 0,8$ espécies, com alta uniformidade (índice de Pielou J' = 65,8%) e baixa dominância (D = 23,3%), enquanto que, para os répteis, o valor de riqueza estimado foi o mesmo observado, também com alta uniformidade (J' = 55,7%) e baixa dominância (D = 23,9%). No geral, a área apresenta um padrão de equitabilidade e baixa dominância, o que é uma característica dos ambientes mais conservados e nos leva a destacar a importância desta região para a manutenção da biodiversidade do bioma Caatinga.

Palavras-chave: Anfíbios; Áreas prioritárias; Caatinga; Conservação; Répteis

Abstract

The herpetofauna of the Caatinga is still underestimated. A lack of knowledge of this group led the region to be perceived as having low species richness and endemism. This study aims to determine the species composition of the herpetofauna of the municipality of Nordestina. Data were collected using different techniques, such

as pitfall traps and active searching. We used a bootstrap method to estimate the species richness of the local herpetofauna. We also calculated dominance and evenness indices. We recorded 3,969 specimens of 49 species. Snakes had the highest species richness, while lizards were more abundant. Anurans comprised 14 ± 0.8 species, with high evenness (J' = 65.8%) and low dominance (D = 23.3%). The number of squamate species was the same as the amount observed (n = 36), and also had high evenness (J' = 55.7%) and low dominance (D = 23.9%). In general, the studied area showed a pattern of evenness with low dominance, in addition to environmental stability, which is a characteristic of most conserved environments and leads us to stress the importance of this region to the maintenance of the biodiversity of the Caatinga biome.

Key words: Amphibians; Caatinga; Conservation; Priority areas; Reptiles

Introduction

The Caatinga is a biome that contains forests and shrublands consisting mainly of small trees and shrubs, with stony soils and an arid climate with low and irregular rainfall (PRADO, 2003; QUEIROZ et al., 2017). It is an exclusively Brazilian biome, encompassing an approximate area of 800,000 km², which represents 11% of the national territory. Most of its territory is located in northeastern Brazil, with the exception of some areas situated in the northern end of the state of Minas Gerais (BUCHER, 1982; LEAL et al., 2005; SILVA et al., 2017). Little is known about the biodiversity of the Caatinga, and it is likely that the species richnesses of many groups are still underestimated (SILVA et al., 2004). This lack of knowledge led this region to be perceived as having low richness and endemism, and as suffering few anthropogenic impacts. However, recent advances in research disprove this notion (SILVA et al., 2004).

Currently the Caatinga is considered the richest semiarid biome, with high endemism, and anthropogenic pressures on it grow exponentially (SILVA; BARBOSA, 2017). Even so, there are few studies about its biological diversity. Most of the region was poorly sampled, which limits any existing knowledge of its biodiversity and directly affects the implementation of effective management strategies for biodiversity conservation (FREITAS; VERÍSSIMO, 2012). Because of these deficient conservation strategies, only a small number of protected areas have been created in the Caatinga (TABARELLI; VICENTE, 2002). Considering all of the protected areas in Brazil, public and private, only 8.53% of the protected territory is located in this biome (MMA, 2018). Besides being small in number and size, most of these conservation units do not have an adequate infrastructure for researchers, which makes it even more difficult to develop scientific reports on the region, such as biological inventories, and to create management and conservation plans (TABARELLI; VICENTE, 2002).

In light of this issue, inventories of areas of the Caatinga – especially areas that have never been studied before – are essential to understand the constitution of these environments and the biodiversity in them. This could not be different with regard to their herpetofauna. A study by Rodrigues (2003) estimated that a total of 167 species live in the whole Caatinga area. Since its publication, many surveys have been conducted in the Caatinga, adding 85 species of amphibians and reptiles to this total (ALBUQUERQUE et al., 2012; GARDA et al., 2017; MESQUITA et al., 2017).

Despite increased recognition of the species richness of the Caatinga herpetofauna over the years, the facts above clearly demonstrate that this group is still insufficiently known, since many areas of the Caatinga remain unexplored and its conservation is directly hampered by this deficiency. Here we publish, for the first time, the species composition, richness and threat status (IUCN) of amphibians and reptiles from the municipality of Nordestina, as well as an evaluation of the conditions necessary to preserve this area, which until now was considered an unknown area for conservation.

Materials and Methods

This study was carried out in a semiarid area, at a site owned by Lipari Mineração LTDA (10º54'7.96"S, 39º25'20.64"W), which occupies approximately 664.71 acres within the municipality of Nordestina, in the northern region of the state of Bahia, in Brazil

(Figure 1). The species records used in this study refer to the fauna rescue and monitoring programs done by Lipari Mineração LTDA during its business license acquisition process (INEMA license nº 8.589/2014) and start of operations (INEMA license nº 12.591/2016), which occurred in two distinct periods: January to April, 2015, and March to October, 2016, resulting in a total of 12 months of sampling, including the dry and rainy seasons.

The data were collected using a passive technique called pitfall trap and direct methods such as active searching followed by hand capture. Pitfall traps are recommended for this type of study, since they facilitate the registration of specimens that are difficult to find by visual search. During the carrying out of the fauna rescue and monitoring programs 440 pitfall traps were installed, distributed among 110 stations throughout the study area. Each station contained four 30-liter buckets arranged in a Y shape. Each station operated only once, for seven days, thus generating a sampling effort of 3,080 days in total.

The second technique, active searching, was used during the fauna rescue program. While the process of mechanized deforestation was being performed, two samplers captured the specimens that appeared. This activity lasted 52 weeks (from Monday to Friday) during the two previously mentioned periods (January-April, 2015, and March-October, 2016). Thus, the sampling effort consisted of 260 days of active searching (nine hours per day). All of the captured specimens were released in the protected area belonging to Lipari Mineração LTDA, beside the study area and with similar environmental characteristics.

To estimate the species richness of the herpetofauna, we produced rarefaction curves from 1,000 randomizations of sampling order. Thus, it was possible to assess the representativeness of the sample. We used species richness data in these analyses, and each week of field work corresponded to a sample, resulting in 52 samples for the studied area. We used presence/absence data in a bootstrap estimator to determine

FIGURE 1: Location of Nordestina in the state of Bahia, Brazil. The photos to the side represent the different environments in the study area. From top to bottom: shrubland, rupestrian grasslands and wetlands.
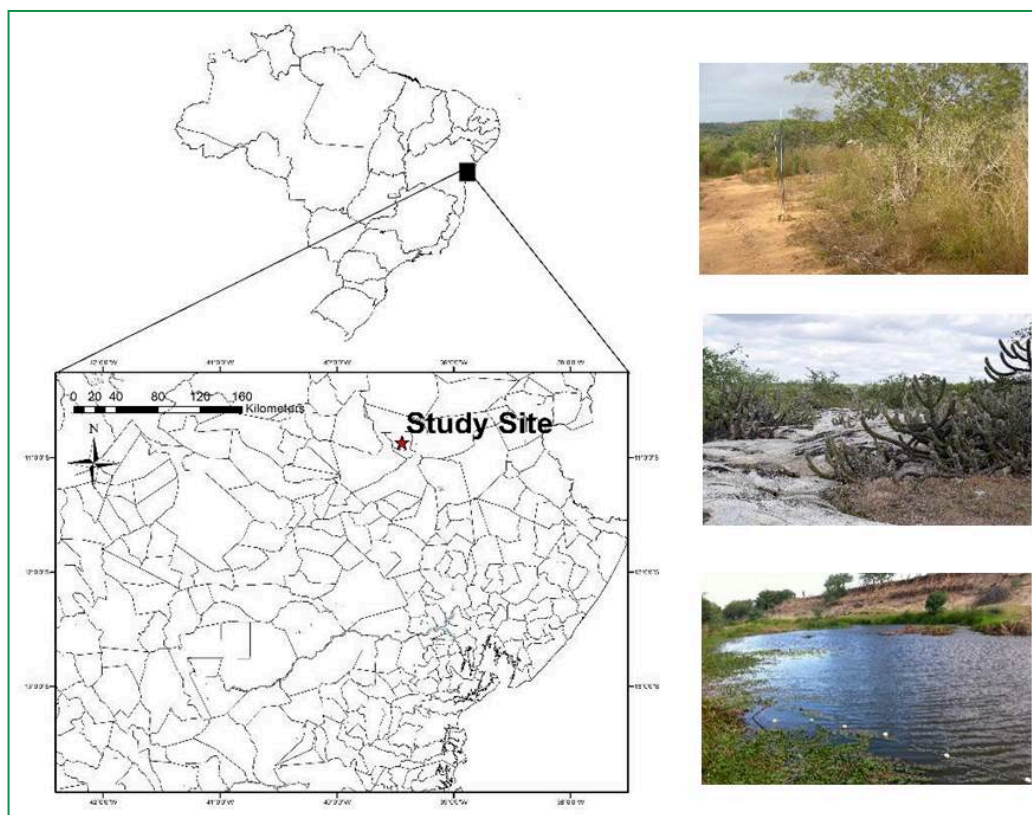
the expected richness of amphibians and reptiles. This estimator uses data from all collected species to estimate their total richness and is not restricted to rare species. The rarefaction curves were generated in *EstimateS*, v. 9.1.0 (COLWELL, 2013). Also, we evaluated the total dominance in the area (using a 1-Simpson index), and we employed Pielou's index (J') as an evenness measure (MAGURRAN, 2004) to evaluate the preservation conditions of the area, since more conserved environments tend to have greater evenness and lower dominance (MAGURRAN, 2004). The analyses described above were performed using *Past*, v. 2.17 (HAMMER et al., 2001).

Results

During the fauna rescue process, 3,969 individuals were recorded and distributed among 49 species (Table 1). Between those, snakes had the greater richness (n = 16); followed by lizards (n = 15); anurans

(n = 13); testudines (n = 3); and amphisbaenians (n = 2). With regard to abundance, lizards had the largest number of individuals (n = 3,022); followed by anurans, with 614 individuals; snakes, with 192 individuals; amphisbaenians, with 132 individuals; and, finally, testudines, with nine individuals sampled (Table 1). Three species were represented by a single individual (singletons): *Chelonoidis carbonaria* (Spix, 1824), *Leptodactylus vastus* Lutz, 1930 and *Oxybelis aeneus* (Wagler, 1824); and two species were represented by two individuals (doubletons): *Leptophis ahaetulla ahaetulla* (Linnaeus, 1758) and *Xenodon merremii* (Wagler, 1824).

The rarefaction curves of both groups, amphibians and squamates, tended to asymptotes, which suggests that most herpetofauna species were recorded. A total of 13 species of anurans were observed, which is very close to the value suggested by the bootstrap estimator: n = 14 ± 0.8 (Figure 2A). The estimated richness of squamates, on the other hand, was of 36 ± 1.3 species, the same amount as the one observed (Figure 2B).

TABLE 1: List of anurans, testudines and squamates (lizards, amphisbaenians and snakes) recorded in this study, in Nordestina, northeastern Bahia, Brazil. Threat status by IUCN – International Union for Conservation of Nature: Not Evaluated (NE), Data Deficient (DD) and Least Concern (LC). Sampling techniques: Pitfall Trap (PT) and Active Search (AS).

Taxa	Total number of individuals	IUCN	Sampling Techniques	
Anura			PT	AS
Bufonidae				
Rhinella granulosa (Spix, 1824)	199	LC	x	x
Rhinella jimi (Stevaux, 2002)	7	LC	x	x
Hylidae				
Corythomantis greeningi Boulenger, 1896	3	LC		x
Scinax gr. *ruber*	4	NE		
Scinax x-signatus (Spix, 1824)	41	LC	x	x
Leptodactylidae				
Leptodactylus macrosternum Miranda-Ribeiro, 1926	3	LC	x	x
Leptodactylus troglodytes Lutz, 1926	3	LC	x	x
Leptodactylus vastus Lutz, 1930	1	LC		x
Physalaemus sp.	53	NE	x	x
Pleurodema diplolister (Peters, 1870)	176	LC	x	x
Microhylidae				
Dermatonotus muelleri (Boettger, 1885)	112	LC	x	x

Odontophrynidae

Proceratophrys cristiceps (Müller, 1884) | 8 | LC | x | x

Phyllomedusidae

Pithecopus nordestinus Caramaschi, 2006 | 4 | DD | | x

Testudines				
Chelidae				
Phrynops geoffroanus (Schweigger, 1812)	5	NE		x
Mesoclemmys tuberculata (Lüderwaldt, 1926)	3	NE		x
Testudinidae				
Chelonoidis carbonaria (Spix, 1824)	1	NE		x
Squamata				
Gekkonidae				
Hemidactylus cf. *agrius* Vanzolini, 1978	15	NE		x
Hemidactylus brasilianus (Amaral, 1935)	45	NE		x
Lygodactylus klugei (Smith, Martin & Swain, 1977)	24	NE		x
Gymnophthalmidae				
Acratosaura mentalis (Amaral, 1933)	22	NE		x
Vanzosaura multiscutata (Amaral, 1933)	24	NE	x	x
Iguanidae				
Iguana iguana iguana (Linnaeus, 1758)	25	NE		x
Mabuyidae				
Brasiliscincus heathi (Schmidt & Inger, 1951)	21	NE	x	x
Phyllodactylidae				
Gymnodactylus geckoides Spix, 1825	247	NE	x	x
Phyllopezus pollicaris pollicaris (Spix, 1825)	180	NE		x
Polychrotidae				
Polychrus acutirostris Spix, 1825	40	NE		x
Teiidae				
Ameivula nigrigula (Arias, de Carvalho, Rodrigues & Zaher, 2011)	1243	NE	x	x
Salvator merianae Duméril & Bibron, 1839	15	LC	x	x
Tropiduridae				
Tropidurus sp.	91	NE	x	x
Tropidurus hispidus (Spix, 1825)	1013	NE	x	x
Tropidurus semitaeniatus (Spix, 1825)	17	LC	x	x
Amphisbaenidae				
Amphisbaena cf. *vermicularis* (Wagler, 1824)	60	NE		x
Leposternon polystegum (Duméril, 1851)	72	LC		x
Boidae				
Boa constrictor constrictor Linnaeus, 1758	4	NE		x
Epicrates assisi Machado, 1945	4	NE		x
Colubridae				
Apostolepis cearensis Gomes, 1915	16	NE	x	x
Boiruna sertaneja Zaher, 1996	6	NE		x

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Leptophis ahaetulla ahaetulla (Linnaeus, 1758)	2	NE	x
Oxybelis aeneus (Wagler, 1824)	1	NE	x
Oxyrhopus trigeminus Duméril, Bibron & Duméril, 1854	65	NE	x
Philodryas nattereri Steindachner, 1870	30	NE	x
Philodryas olfersii Lichtenstein, 1823	5	NE	x
Pseudoboa nigra (Duméril, Bibron & Duméril, 1854)	15	NE	x
Thamnodynastes cf. *pallidus* (Linnaeus, 1758)	6	LC	x
Thamnodynastes sp.	17	NE	x
Xenodon merremii (Wagler, 1824)	2	NE	x
Elapidae			
Micrurus lemniscatus lemniscatus (Linnaeus, 1758)	4	LC	x
Viperidae			
Bothrops erythromelas Amaral, 1923	11	LC	x
Crotalus durissus (Lineu, 1758)	4	LC	x

FIGURE 2:   Rarefaction curves of anurans (A) and squamates (B) sampled in Nordestina, northeastern Bahia, Brazil, created from 1000 randomizations. The red-dotted line represents the observed species richness, while the black line represents the species richness suggested by the bootstrap estimator.
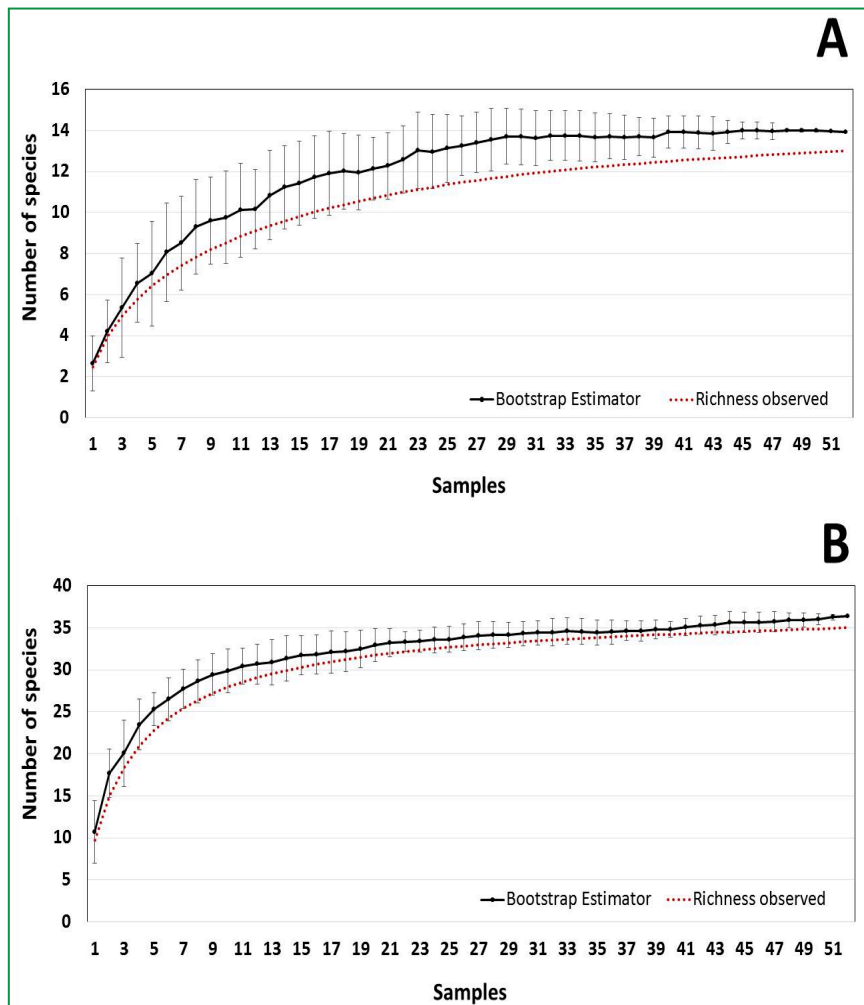
Additionally, the diversity parameters complemented the observation of the pattern of the local herpetofauna. Thus, it was possible to observe that anurans had high evenness (J' = 65.8%) and low dominance (D = 23.3%), with *R. granulosa* as the dominant species, representing 32.4% of anuran records. Squamates showed a similar pattern, with high evenness (J' = 55.7%) and low dominance (D = 23.9%), and *A. nigrigula* as the dominant taxon (representing 37% of squamate records).

Discussion

During this period, the two most common species were *A. nigrigula* and *T. hispidus*, with 1,243 and 1,013 individuals, respectively. According to Rodrigues (2003), both species are heliothermic and have good adaptability in open areas with hot and dry climates. The Caatinga has both of these characteristics, thus favoring the survival of those species, which may explain the high abundance of them observed in this study. Despite these two species being highly abundant when compared with others, in general, the area demonstrated high evenness with low dominance. As suggested by Magurran (2004), that is a characteristic of preserved areas, which leads us to stress the importance of the Nordestina region to the maintenance of the biodiversity of the Caatinga.

Based on a compilation of studies about the herpetofauna of the Caatinga, a total of 239 species was listed (ALBUQUERQUE et al., 2012; GARDA et al., 2017; MESQUITA et al., 2017). The species richness of the Nordestina municipality observed in the present study corresponds to approximately 20.5% of this total (49 species). Also, the richness found at the studied site is similar to that of protected areas in the Caatinga: the Serra da Capivara National Park (37 species; CAVALCANTI et al., 2014), Seridó Ecological Station (41 species; CALDAS et al., 2016), Raso da Catarina Ecological Station (53 species; GARDA et al., 2013), Aiuaba Ecological Station (57 species, COSTA et al., 2018), the Catimbau National Park (58 species; PEDROSA et al., 2014) and the northern portion of the Chapada Diamantina National Park, located in the

municipality of Palmeiras (75 species; MAGALHÃES et al., 2015).

Despite the high richness found in this study, none of the species cited here is included on the Red List of Threated Species (IUCN, 2019) or the Red Book of Threatened Species of Fauna of Brazil (MMA, 2018), and most of them have not been assessed or appear as deficient data. Fauna inventories, such as the present study, can help to change the current situation, since they provide relevant contributions to the evaluation of the species richness of still unexplored areas.

Furthermore, the scarcity of studies on the Caatinga has influenced the policies geared toward the conservation of its biological diversity (TABARELLI; SILVA, 2003). Consequently, there are only a small number of protected areas in the region (TABARELLI; VICENTE, 2002), while anthropogenic pressures increase (SILVA; BARBOSA, 2017). Recently, the Ministry of Environment of Brazil (MMA, 2016) updated the priority areas for conservation in the Caatinga. The total number of priority areas is 282. Despite the reduction of 10 areas since the last update (MMA, 2007), there are two priority areas on the list that are located near the site of this study. The most distant area is 80 km away from the study site and was classified as a High Importance area (Ca027), while the other area was classified as Insufficiently Known Importance (Ca032) and is approximately 62 km away from the site (Figure 3). These facts reinforce the importance of these two regions to the conservation of biodiversity in the Caatinga and the relevance of our results, since the high biodiversity found here offers new scientific knowledge of the region, which may aid in the implementation of conservation plans in the two priority areas near the study site.

Finally, our results demonstrate that environmental licensing programs provide important data on local biodiversity, as also observed in other studies that used data from environmental licensing programs and thus resulted in new fauna inventories (COUTO-FERREIRA et al., 2011; MARQUES et al., 2011; MOTA et al., 2012), new knowledge of fauna distribution extension (MELO et al., 2014) and landscape ecology for management strategies (MENEZES et al., 2007). Therefore, we

recommend that the results obtained by environmental licensing are published, as they can contribute greatly to the knowledge of areas that are still little sampled, and may serve as a basis for guides on the species of this biome, similarly to what is done in this study (Figure 4-49).

FIGURE 3:   Priority areas for biodiversity conservation in the Caatinga. On the map, their geographical proximity to the study site can be clearly noted (MMA, 2007).
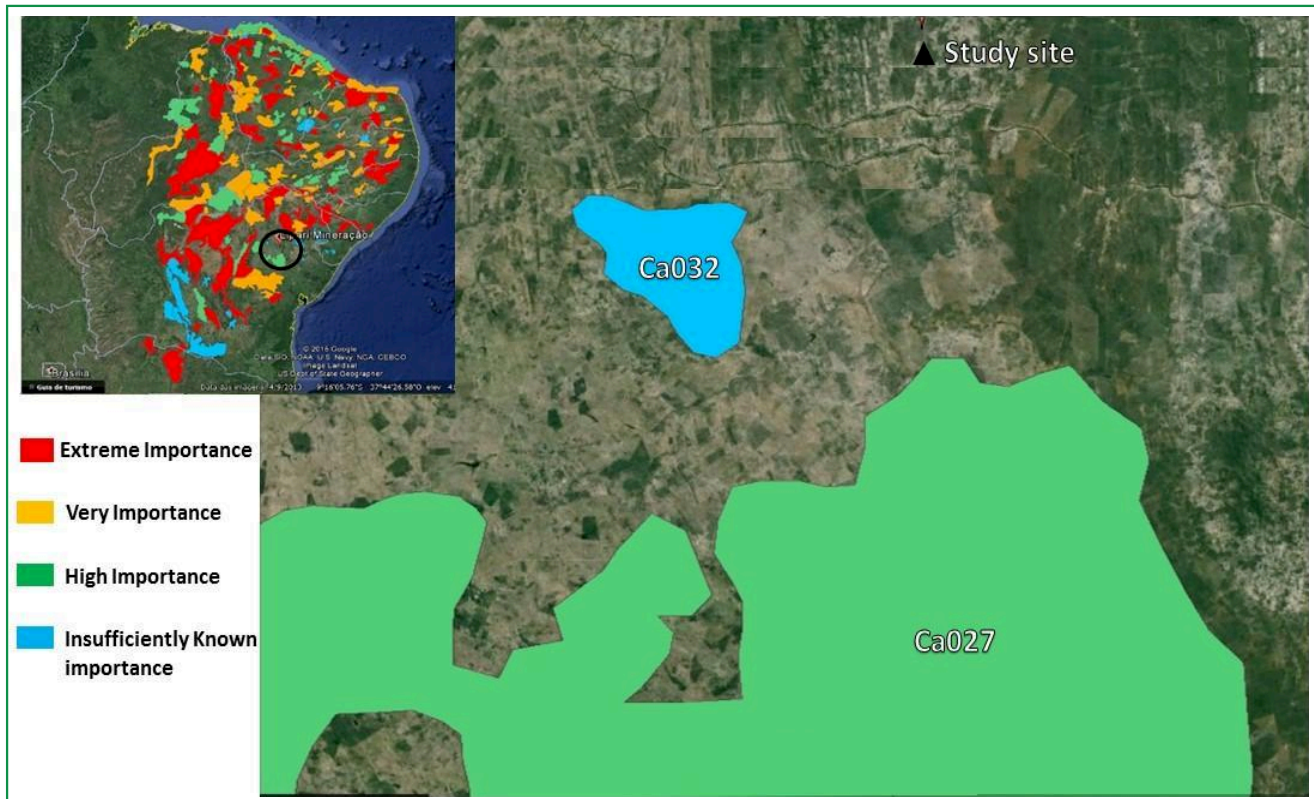
FIGURE 4-15: Anurans collected in the Nordestina municipally: 4. *Rhinella granulosa*; 5. *Rhinella jimi*; 6. *Corythomantis greening*; 7. *Pithecopus nordestinus*; 8. *Scinax x-signatus*; 9. *Leptodactylus macrosternum*; 10. *Leptodactylus troglodytes*; 11. *Leptodactylus vastus*; 12. *Physalaemus* sp.; 13. *Pleurodema diplolister*; 14. *Dermatonotus muelleri*; 15. *Proceratophrys cristiceps*.

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FIGURE 16-18: Testudines collected in Nordestina municipally: 16. *Phrynops geoffroanus*; 17. *Mesoclemmys tuberculata*; 18. *Chelonoidis carbonaria*.
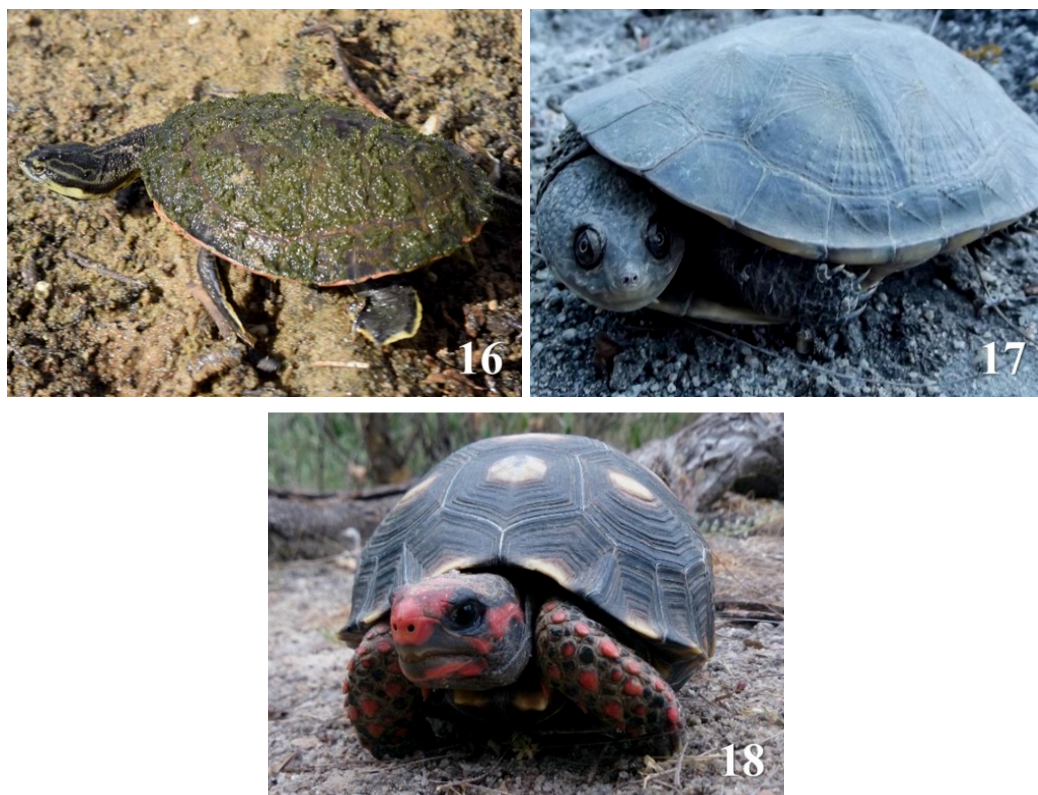
FIGURE 19-49: Squamates collected at Nordestina municipally: 19. *Hemidactylus brasilianus*; 20. *Lygodactylus klugei*; 21. *Acratosaura mentalis*; 22. *Vanzosaura multiscutata*; 23. *Iguana i. iguana*; 24. *Brasiliscincus heathi*; 25. *Gymnodactylus geckoides*; 26. *Phyllopezus p. pollicaris*; 27. *Polychrus acutirostris*; 28. *Ameivula nigrigula*; 29. *Salvator merianae*; 30. *Tropidurus hispidus*; 31. *Tropidurus semitaeniatus*; 32. *Amphisbaena* cf. *vermicularis*; 33. *Leposternon polystegum*; 34. *Boa c. constrictor*; 35. *Epicrates assisi*; 36. *Apostolepis cearensis*; 37. *Boiruna sertaneja*; 38. *Leptophis a. ahaetulla*; 39. *Oxybelis aeneus* 40. *Oxyrhopus trigeminus*; 41. *Philodryas nattereri*; 42. *Philodryas olfersii*; 43. *Pseudoboa nigra*; 44. *Thamnodynastes* cf. *pallidus*; 45. *Thamnodynastes* sp.; 46. *Xenodon merremii*; 47. *Micrurus l. lemniscatus*; 48. *Bothrops erythromelas*; 49. *Crotalus durissus*.
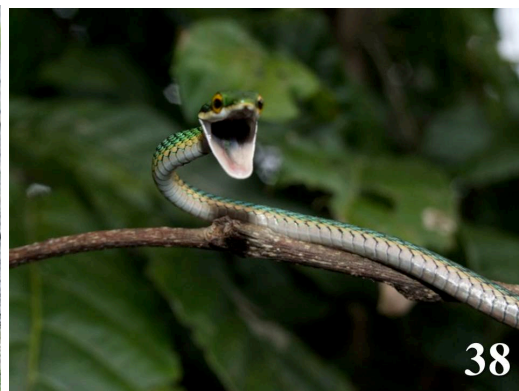
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