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Snake diversity of the Barra do Rio Mamanguape environmental protection area in Northeast Brazil

The Barra do Rio Mamanguape Environmental Protection Area in northeast Brazil is one of the most important protected areas of the Brazilian Atlantic Forest. However, the diversity of several taxa in this park remains unknown. From 2019 to 2021, we studied the snake assemblage of the Barra de Mamanguape EPA to determine species composition, abundance, richness estimates, activity patterns, and natural history data. We documented 24 snake species from six families, which corresponded to approximately 42% and 28% of snakes from the Atlantic Forest of Paraíba State and from the Pernambuco Endemism Center, respectively. Estimates of species richness suggest that more snake species are found in this area. The most common species were Chironius flavolineatus and Boa constrictor, with the species rank-abundance distribution curve showing a sigmoidal pattern. Most species are diurnal and terrestrial, and occur in both forests and Restinga. All sampling methods (pitfall traps, active searches, and occasional encounters) were done for snake sampling. The ecological knowledge of snakes in the Barra de Mamanguape EPA is essential for the assessment of conservation strategies for this protected area in northeast Brazil.

Keywords: Snakes; Assemblage; Inventory; Natural History; Atlantic Forest.

Diversidade de serpentes da área de proteção ambiental Barra do Rio Mamanguape, Nordeste do Brasil

A Área de Proteção Ambiental Barra do Rio Mamanguape, no Nordeste do Brasil, é uma das áreas protegidas mais importantes da Mata Atlântica brasileira. No entanto, a diversidade de vários táxons nesta Unidade de Conservação permanece desconhecida. De 2019 a 2021, estudamos a comunidade de serpentes da APA Barra de Mamanguape para determinar a composição de espécies, abundância, estimativas de riqueza, padrões de atividade e dados de história natural. Documentamos 24 espécies de serpentes de seis famílias, que corresponderam a aproximadamente 42% e 28% das serpentes da Mata Atlântica do Estado da Paraíba e do Centro de Endemismo de Pernambuco, respectivamente. As estimativas de riqueza de espécies sugerem que mais espécies de serpentes poderão ser encontradas nesta área. As espécies mais comuns foram Chironius flavolineatus e Boa constrictor, com a curva de distribuição de rank-abundância de espécies apresentando um padrão sigmoidal. A maioria das espécies são diurnas e terrestres, e ocorrem tanto na floresta quanto na Restinga. Todos os métodos de amostragem (armadilhas de queda, buscas ativas e encontros ocasionais) foram feitos para amostragem de serpentes. O conhecimento ecológico de serpentes na APA Barra de Mamanguape é essencial para a avaliação de estratégias de conservação para esta área protegida no nordeste do Brasil.

Palavras-chave: Cobras; Montagem; Inventário; História Natural; Mata Atlântica.

Topic: **Conservação da Biodiversidade**

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INTRODUCTION

At the end of the 1990s there was an exponential increase in the number of ecological studies on snakes. This interest in snake ecology is due to an increase in the number of herpetologists working with snakes and advances in methods for surveying, capturing, marking, and tracking individuals (FITCH, 1987; MULLIN et al., 2011). Snakes are interesting ecological models (SHINE et al., 2000), because they occupy a central position in food webs, are good bioindicators, and are of medical interest (GREENE, 1997; MARQUES, 2018). There are approximately 4,000 snake species worldwide (UETZ et al., 2022), with 430 occurring in Brazil (COSTA et al., 2021) and 190 in the Atlantic Forest (MOURA et al., 2016; TOZETTI et al., 2018).

The Atlantic Forest is the second largest tropical forest in Brazil, after the Amazon, but it is the most threatened biome, suffering from intense deforestation and fragmentation since the period of European colonization (DEAN, 2004). This degradation is even more evident in the northern portion of the Atlantic Forest, located north of the São Francisco River (PRANCE, 1982; TABARELLI et al., 2005). This region, also known as the Pernambuco Endemism Center (PEC), is represented by small fragments (mostly less than 10 ha) inserted into urban and agricultural matrices (SILVA et al., 2000). Even though less than two percent of the original vegetation remains, PEC harbors high levels of biodiversity richness and endemism, with new species still being described (SILVEIRA et al., 2010; MEBERT et al., 2020; MONTIGELLI et al., 2020), This underscores the urgency to increase our knowledge of this region's biodiversity to develop effective conservation plans for the biome (TABARELLI et al., 2005; FRANÇA et al., 2020; PEREIRA FILHO et al., 2020).

Biological surveys provide the groundwork for ecological studies and offer an outline for implementing conservation strategies (GREENE, 1994; SUTHERLAND, 1997; GIBBONS et al., 2004). The creation of snake inventories has been carried out throughout the Atlantic Forest, both in the Southeast Atlantic Forest (MARQUES et al., 2004; PONTES et al., 2009), and in the Northeast Atlantic Forest (FRANÇA et al., 2012; DIAS et al., 2014; MARQUES et al., 2016; ROBERTO et al., 2017). However, some environments have not been explored. Although snakes of COSTAl Restingas have been commonly studied in the Southeast and Central Atlantic Forest (ROCHA, 2000; SANTOS et al., 2012; MARQUES et al., 2016), little information is available on the northern portions of the biome. Sampaio et al. (2018) studied snakes of COSTAl Restingas from Barra de Gramame and found compositional similarities with southeastern Restingas and other open environments, such as Brazilian savannah and semi-arid forests.

Herein, we present the results of a two-year study of the snake assemblage of the Barra do Rio Mamanguape Environmental Protection Area, an important protected area of the Northeast Atlantic Forest. We focused on the composition, abundance, richness estimates, activity patterns, and natural history of snake species that occur in evergreen forests and coastal Restinga. We also compared our data with those of a snake assemblage studied in a similar area on the southern coast of the state.

MATERIALS AND METHODS

The study was conducted in the Barra do Rio Mamanguape Environmental Protection Area (or Barra

de Mamanguape EPA), a protected area that covers 14,640 ha in the estuary of the Mamanguape River located on the north coast of Paraíba State, Northeast Brazil (FIGURE 1) (06°47'19.0" "S, 34°59'22.0" W; SAD69). The Barra de Mamanguape EPA was created in 1993 and is characterized as a mosaic of natural Atlantic Forest physiognomies such as evergreen forests, mangroves and coastal restingas, and anthropic sugarcane plantations (ICMBio, 2014) (FIGURE 2). The climate is type As using the Köppen classification, receiving annually 1,200-1,800 mm of highly predictable and strongly seasonal precipitation, with a rainy season between March and September (NIMER, 1989), and an average temperature of 28 °C (LIMA et al., 1985). The long-term climatic data from the Barra de Mamanguape EPA are summarized in Figure 3.

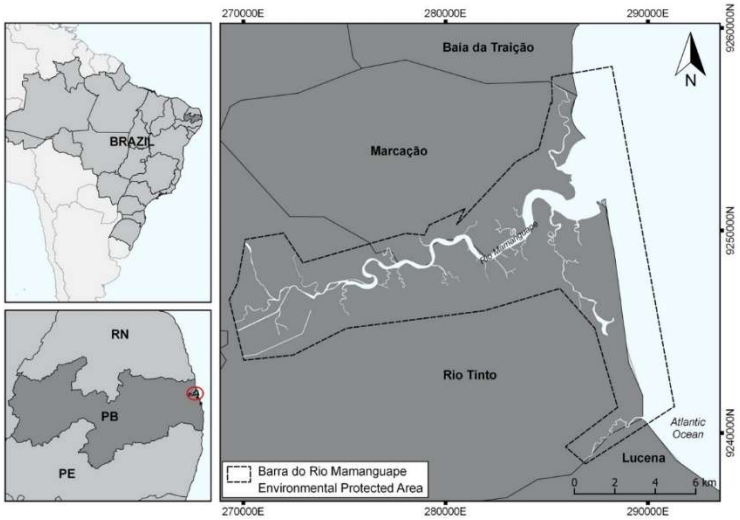

Figure 1: Schematic Map showing the shape of the Barra do Rio Mamanguape Environmental Protection Area located in Rio Tinto, Marcação, Baía da Traição and Lucena Municipalities in North Coast of Paraíba State, Northeast Brazil.

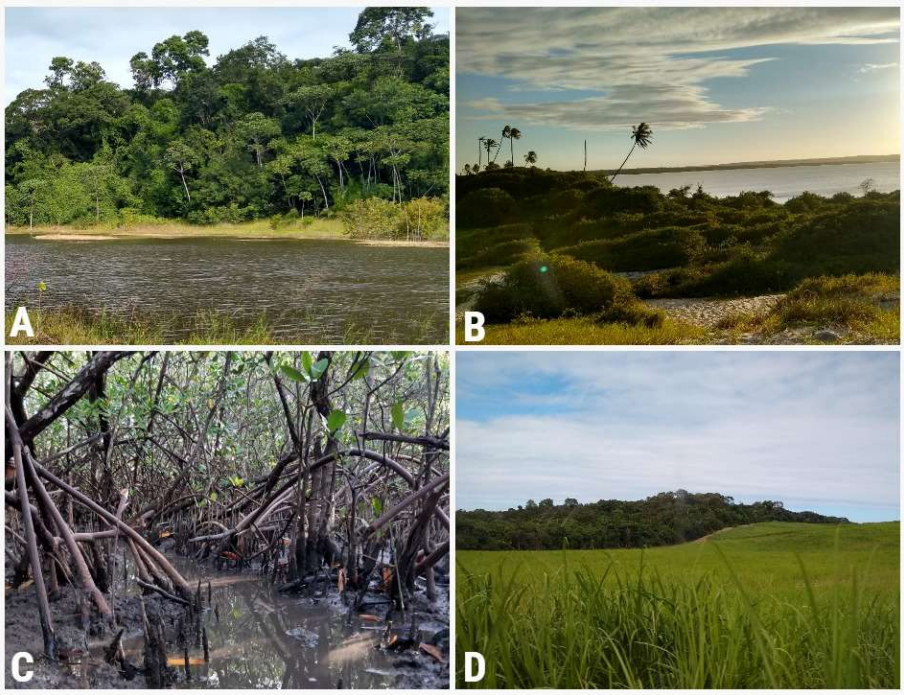

Figure 2: Phytophisiognomies of Atlantic Forest in Barra de Mamanguape EPA. A. Forest, B Restinga, C Mangrove, D Sugarcane crops surrounding forest patches. Photograph credits: A, B, D - Vanessa BARBOSA; C- Isis Chagas.

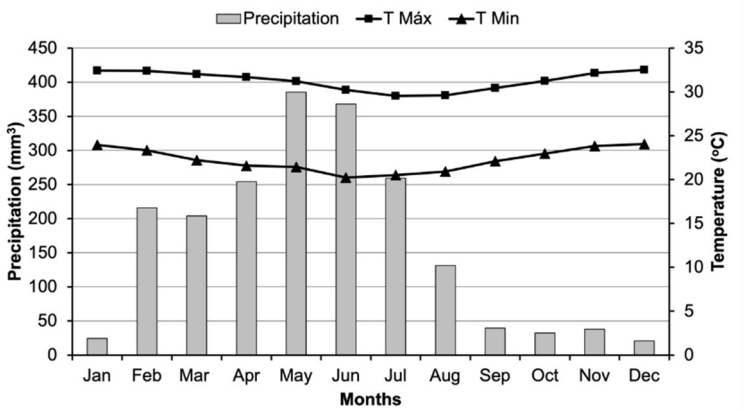

Figure 3: Long-term climatic data (2019-2021) from the Barra do Rio Mamanguape Environmental Protection Area.

Snake specimens were obtained from May 2019 to August 2021, with an obligatory pause due to the COVID19 pandemic period from March 2020 to October 2020. During this period, the Barra de Mamanguape EPA was under complete lockdown. During the fieldwork, we employed the following snake survey methods: pitfall traps with drift fences, active searches, and donation of specimens by locals (or occasional encounters by third in Mesquita et al. (2013)). For pitfall traps, we established two sets of 20 arrays, one in a forest environment and the other in a Restinga environment, each consisting of four 60 L plastic buckets sunk into the ground with three 6-m plastic drift fences, totaling 80 traps. The buckets were opened for five days each month from May 2019 to March 2020. The active searches consisted of untimed searches of trails chosen randomly in forests and restaurants. Regarding the donated specimens, we did not encourage residents to kill snakes; however, it is usual for them to kill all encountered snakes, therefore, we asked them to preserve the dead snakes for further identification. Additionally, some locals took photographs of the snakes for identification.

For each specimen found in Barra de Gramame, we recorded information on location (using GPS), time, habitat use, microhabitat, and morphology. Most individuals were captured and identified, ecological information was recorded, and the snakes were released in the same area they were captured after they were marked with fluorescent elastomers (FREITAS et al., 2013). However, some specimens were found dead; thus, they were preserved in 10% formalin and deposited in the Coleção Herpetológica da Universidade Federal da Paraíba. Snakes were captured or collected under an ICMBio collection permit (SISBIO license 74327-1).

For all active snakes encountered during the searches, we recorded the hours of capture and the habitat in which the snake was found. Capture hours were grouped into seven time periods (05:00-07:59; 08:00-11:59; 12:00-14:59; 15:00-17:59; 18:00-20:59; 21:00-23:59; 00:00-02:59) to better characterize snake activity patterns. We classified habitats into one of two categories: evergreen forest and coastal restinga. We also categorized the snake species based on their general habits (terrestrial, fossorial, cryptozoic, arboreal, or aquatic). Finally, for all individuals, we recorded two morphological variables: total length (TL) using a ruler or measuring tape, and mass using spring scales.

We constructed species accumulation curves for the snakes of the Barra de Mamanguape EPA using a combined method of extrapolation and rarefaction (CHAO et al., 2014) implemented in the R package iNEXT

(iNEXT: Interpolation and Extrapolation for Species Diversity) version 2.0.20 (HSIEH et al., 2016). In addition, we used species richness estimators (with nonparametric incidence-based estimators: bootstrap, Chao 2, ICE, Jacknife 1 and 2, and abundance-based data: ACE and Chao 1) to determine the expected snake richness in the area (Colwell and Coddington 1994). The tests were performed using the Software R v.4.0.4 program (R DEVELOPMENT CORE TEAM, 2021).

We compared the richness and richness estimates of Barra de Mamanguape EPA and Barra de Gramame (SAMPAIO et al., 2018) which are very similar areas located on the southern coast of Paraíba State. The major difference between these areas is the presence of a "Tabuleiro" environment in Barra de Gramame. To compare these areas, we reconstructed the accumulation curve for the Gramame snakes using iNEXT.

RESULTS AND DISCUSSION

We recorded 278 individuals from 24 species, 18 genera, and six families (Boidae, Colubridae, Dipsadidae, Elapidae, Typhlopidae, and Viperidae) (TABLE 1, FIGURE 4, and 5). Dipsadidae was the richest family, with 10 species, whereas Viperidae was represented by a single species. The most common snake species was *Chironius flavolineatus*, followed by *Boa constrictor* and *Micrurus ibiboboca*. The rarest species were *Epicrates assisi, Drymarchon corais*, *Hydrodynastes gigas*, *Helicops angulatus, Boiruna sertaneja*, and *Phimophis guerini,* each with only one record. The species rank abundance distribution curve showed a sigmoidal pattern resembling a log-normal distribution with an initial steep gradient, as the few high-ranking species had much higher abundances than the low-ranking species, followed by a shallow gradient of higher evenness for rare species (WHITTAKER, 1970; MAGURRAN, 2004) (FIGURE 6).

Table 1: Summary of natural history information of the snakes in Barra do Rio Mamanguape Environmental Protection Area. No: number of individuals. Inside parenthesis in No = is number of individuals measured; TL = Total length ± standard deviation. M = Mass ± standard deviation. HT = Habitats (F = forests and R = Restinga); H = Habits (AB = arboreal, AQ = aquatic, C = cryptozoic, FO = fossorial, T = terrestrial); A = Activity (N = nocturnal and D = diurnal).

Family/Species	No	TL	M	HT	H	A
Typhlopidae						
Amerotyphlops brongersmianus (VANZOLINI, 1976)	6 (4)	138.2 ± 18.6	2.37 ± 0.7	F; R	FO	N
Amerotyphlops paucisquamus (DIXON et al., 1979)	2 (2)	155.1 ± 10.9	3.41 ± 0.9	F; R	FO	N
Boidae						
Boa constrictor (LINNAEUS, 1758)	27 (3)	1249 ± 619	1561 ± 1960	F; R	T, AB	D; N
Epicrates assisi (MACHADO, 1945)	1	-	-	R	T, AB	N
Colubridae						
Chironius flavolineatus (JAN, 1863)	154 (114)	873 ± 222.1	45.8 ± 28.7	F; R	AB	D
Drymarchon corais (BOIE, 1827)	1	-	-	R	T; AB	D
Leptophis dibernardoi (ALBUQUERQUE et al., 2022)	3	-	-	F; R	AB	D
Oxybelis aeneus (WAGLER, 1824)	2 (1)	1429	73	F; R	AB	D
Spilotes pullatus (LINNAEUS, 1758)	5 (1)	2145	1032	F; R	T; AB	D
Tantilla melanocephala (LINNAEUS, 1758)	11 (9)	244.1 ± 59.4	3.11 ± 1.09	F; R	T; C	D; N
Dipsadidae						
Boiruna sertaneja (ZAHER, 1996)	1	-	-	R	T	N
Helicops angulatus (LINNAEUS, 1758)	1	-	-	R	AQ, T	D
Hydrodynastes gigas (DUMÉRIL et al., 1854)	1	-	-	R	AQ, T	D
Oxyrhopus trigeminus (DUMÉRIL et al., 1854)	10 (4)	395.3 ± 170	15.7 ± 12.5	F; R	T	D; N
Philodryas nattereri (STEINDACHNER, 1870)	13 (1)	674	24	R	T	D
Philodryas olfersii (LIECHTENSTEIN, 1823)	3 (2)	862 ± 145.6	62 ± 50.9	F; R	T; AB	D
Philodryas patagoniensis (GIRARD, 1858)	12 (1)	1091	168	R	T	D
Phimophis guerini (DUMÉRIL et al., 1854)	1	-		R	T; C	N

Taeniophallus affinis (GUNTHER, 1858)	2 (1)	330.89	6.6	F; R	T	D
Taeniophallus occipitalis (JAN, 1863)	4 (2)	382.7 ± 41.4	9.4 ± 0.5	F; R	T	D
Xenodon merremii (WAGLER, 1824)	5 (1)	915	330	F; R	T	D
Elapidae						
Micrurus ibiboboca (MERREM, 1820)	14 (9)	668.5 ± 275	52.9 ± 26.6	F; R	T; C	D; N
Micrurus potyguara (PIRES et al., 2014)	1	379	6.7	F	T; C	D; N
Viperidae						
Bothrops leucurus (WAGLER, 1824)	2	-	-	F	T	N

Figure 4: Snake species recorded in Barra do Rio Mamanguape Environmental Protection Area. A - *Amerotyphlops brongersmianus;* B- *Amerotyphlops paucisquamus;* C- *Boa constrictor;* D- *Epicrates assisi;* E- *Chironius flavolineatus;* F- *Drymarchon corais;* G- *Leptophis dibernardoi;* H- *Oxybelis aeneus;* I- *Spilotes pullatus*; J- *Tantilla melanocephala*; K - *Boiruna sertaneja*; L - *Helicops angulatus* (Photograph credits: A, B, K - Frederico FRANÇA; F - Willanilson Pessoa; C, D, E, G, H, I, J, L - Vanessa BARBOSA).

The rarefaction curve (iNEXT) did not reach the asymptote (FIGURE 7) and predicted greater richness in the area, indicating that new species will be found in future surveys. The species richness estimators corroborate the result of the rarefaction curve and produced estimates higher than the observed richness, ranging from 25.32 ± 1.50 (ICE) to 30.95 ± 1.46 (JACKNIFE 2) (TABLE 2).

We compared the estimated richness of the snake assemblage of Barra de Mamanguape EPA (north coast of Paraíba state) with another snake assemblage found in a very similar area along the southern coast of Paraíba: the snakes from Barra de Gramame (SAMPAIO et al., 2018). Both assemblages present similar richness, with 24 in Mamanguape and 27 in Gramame, with 19 species present in both areas, and higher richness estimates for Barra de Gramame (FIGURE 8).

Table 1 summarizes the natural history data of the snakes at the Barra de Mamanguape EPA. The assemblage contained species with different sizes, habits, and habitats. The largest species recorded were *Spilotes pullatus* and *Boa constrictor,* measuring more than 1,900 mm and weighing more than 1,000 g, while

the smallest species was the blind snake *Amerotyphlops brongersmianus*, with the largest individuals measuring less than 300 mm and weighing less than 5 g (TABLE 1). Most species are present in terrestrial (19) and arboreal (8) habitats. *Amerotyphlops* spp., *Tantilla melanocephala*, *Phimophis guerini*, and *Micrurus* spp. are fossorial or cryptozoic species found underground or under leaf litter, and *Hydrodynastes gigas* and *Helicops angulatus* are aquatic species. Most species (14) were found in both environments (forests and Restinga), whereas eight were found exclusively in Restinga, and only *Bothrops leucurus* and *Helicops angulatus* were recorded only inside the forest.

Figure 5: Snake species recorded in Barra do Rio Mamanguape Environmental Protection Area. A- *Hydrodynastes gigas*; B- *Oxyrhopus trigeminus*; C- *Philodryas nattereri*; D - *Philodryas olfersii*; E- *Philodryas patagoniensis*; F- *Phimophis guerini*; G- *Taeniophallus affinis*; H - *Taeniophallus occipitalis*; I- *Xenodon merremii*; J- *Micrurus ibiboboca*; K - *Micrurus potyguara*; L - *Bothrops leucurus* (Photograph credits: C, F, K, L - Frederico FRANÇA; E- Rafaela FRANÇA; A, B, D, G, H, I, J - Vanessa BARBOSA).

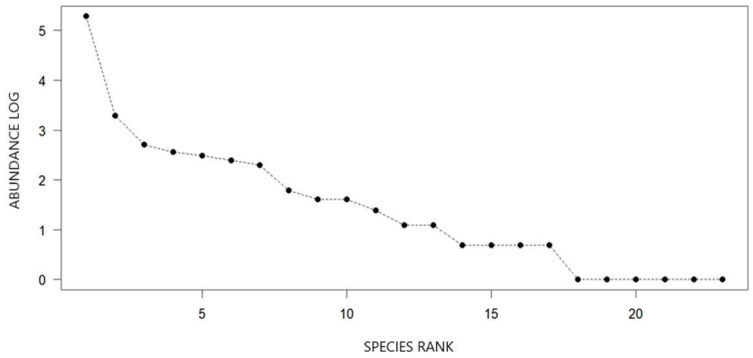

Figure 6: Snake rank abundance curve for the Barra do Rio Mamanguape Environmental Protection Area, northeast Brazil.

Table 2: Richness estimators of snakes from the Barra do Rio Mamanguape Environmental Protection Area.

Richness estimators	Mean ± Std Deviation
Observed Richness	24
ACE	27.12 ± 2.61
CHAO 1	26.14 ± 0.52
ICE	25.32 ± 1.50
JACKNIFE 1	28.95 ± 0.56
JACKNIFE 2	30.95 ± 1.46
BOOTSTRAP	25.83 ± 0.44

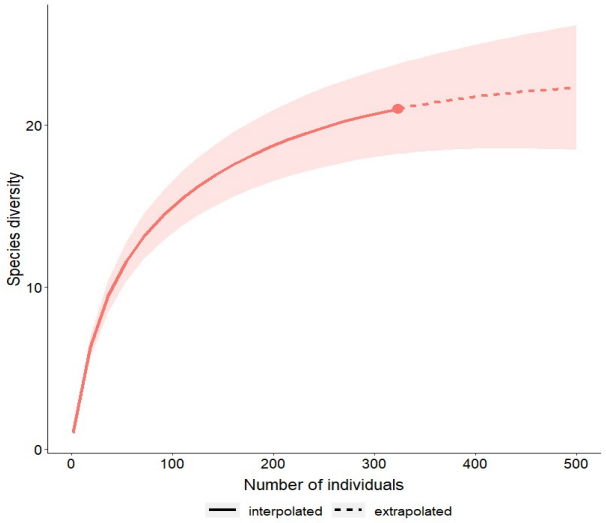

Figure 7: iNEXT individual-based rarefaction curve showing the richness (interpoled curve) and expected richness (extrapoled curve) of snakes of Barra do Rio Mamanguape Environmental Protection Area, northeast Brazil.

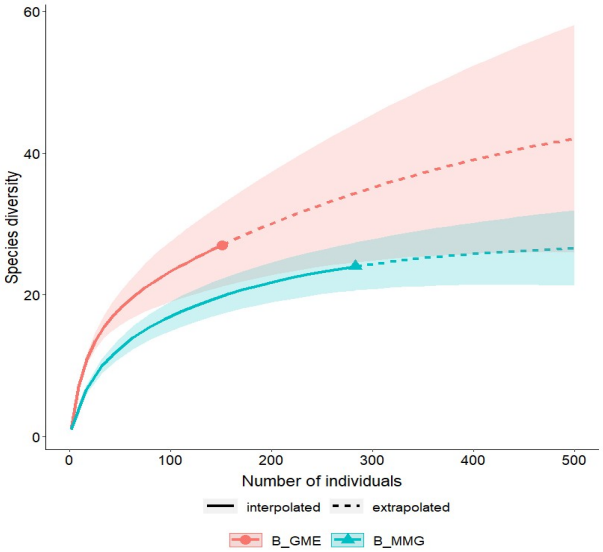

Figure 8: iNEXT rarefaction curves comparing the richness (interpoled curve) and expected richness (extrapoled curve) of snakes of Barra do Rio Mamanguape Environmental Protection Area (B_MMG) in North Coast, and snakes of Barra de Gramame (B_GME), in South Coast of Paraíba state.

Table 3: Number of individuals found active during different times of the day for snake species in the Barra do Rio Mamanguape Environmental Protection Area.

Espécie	**05:00-07:59**	**08:00-11:59**	**12:00-14:59**	**15:00-17:59**	**18:00-20:59**	**21:00-23:59**	**00:00-02:59**
Boa constrictor	0	7	3	6	6	1	0
Boiruna sertaneja	0	0	0	1	0	0	0
Chironius flavolineatus	0	0	3	3	0	0	0
Leptophis dibernardoi	0	0	1	2	0	0	0
Oxybelis aeneus	1	0	0	0	0	0	0
Spilotes pullatus	0	1	2	1	0	0	0
Tantilla melanocephala	0	0	0	0	1	0	0
Hydrodynastes gigas	0	1	0	0	0	0	0
Helicops angulatus	0	0	0	1	0	0	0
Oxyrhopus trigeminus	0	2	0	0	3	1	1
Philodryas nattereri	1	3	1	2	0	0	0
Philodryas olfersii	0	2	0	1	0	0	0
Philodryas patagoniensis	0	3	4	1	0	0	0
Taeniophallus affinis	0	1	0	0	0	0	0
Taeniophallus occipitalis	0	0	2	0	0	0	0
Xenodon merremii	0	3	1	0	0	0	0
Micrurus ibiboboca	0	0	1	2	7	1	0

Most snakes present in the Barra de Mamanguape EPA according to the literature (see PEREIRA FILHO et al., 2017) were strictly diurnal (13 species), but many were nocturnal (6 species), and others were active during both periods (5 species) (TABLE 1). We found that daily snake activities occurred from 05:00 to 02:59

h and varied among species (TABLE 3). No species were found to be active during all time periods, and most snakes were active in the late morning (08:00 h to 11:59 h) and late afternoon (15:00 h to 17:59 h). *Boa constrictor*, *Oxyrhopus trigeminus*, *Philodryas nattereri*, and *Micrurus ibiboboca* were active during four to five time periods. Only *Oxyrhopus trigeminus* was active between 00:00 h and 02:59 h, and only *Oxybelis aeneus* and *Philodryas nattereri* were active early in the morning (until 07:59 h).

All sample methods contributed to snake sampling. A total of 18 individuals of five species (*Amerotyphlops brongermianus*, *A. paucisquamus*, *Tantilla melanocephala*, *Taeniophallus affinis*, and *Taeniophallus occipitalis)* were captured in pitfall traps, both *Amerotyphlops* species recorded exclusively by this method. Another 78 individuals of seven species were recorded as specimens donated by local people. *B*. *sertaneja, Epicrates assisi, Drymarchon corais, Helicops angulatus, Hydrodynastes gigas, Philodryas patagoniensis,* and *Xenodon merremi* were recorded exclusively using this method. The remaining 182 individuals were captured during active searches and incidental encounters.

CONCLUSIONS

The richness of the snake assemblage of the Barra do Rio Mamanguape Environmental Protection Area corresponds to approximately 42% and 28% of snakes from the Atlantic Forest of Paraíba and Pernambuco Endemism Center, respectively (FRANÇA et al., 2020; PEREIRA FILHO et al., 2017, 2021). Compared to other protected areas from the North of Atlantic Forest, the assemblage of Barra de Mamanguape EPA presents more species than APP Mata do Buraquinho in Paraíba (n= 17, SANTANA et al., 2008), State Park Cachoeira do Urubu in Pernambuco (n= 11, BARBOSA et al., 2019), RPPN Pedra D'antas/ RPPN Frei Caneca in Pernambuco (n= 19, ROBERTO et al., 2017), RVS Matas de Água Azul in Pernambuco (n= 22, OLIVEIRA et al., 2021), and State Park Dois Irmãos in Pernambuco (n= 23, BARBOSA et al., 2020a), and less species than REBIO Guaribas in Paraíba (n= 29, RODRIGUES et al., 2015; n=42, MESQUITA et al., 2018), and RVS Matas do Siriji in Pernambuco (n=25, LIMA et al., 2021).

Most species (70%) in the snake assemblage of the Barra de Mamanguape EPA are widely distributed in Brazil and South America (NOGUEIRA, 2019). However, some species are restricted to northeastern Brazil, with a limited distribution in the Caatinga and north of the Atlantic Forest, particularly *Amerotyphlops paucisquamus*, *Boiruna sertaneja*, *Epicrates assisi*, *Leptophis dibernardoi*, *Micrurus ibiboboca*, *M. potyguara*, and *Bothrops leucurus* (NOGUEIRA, 2019; COSTA et al., 2021). The assemblage had six out of the seven snake families present in Paraíba (PEREIRA FILHO et al., 2017), with only the family Leptotyphlopidae absent. However, it is very likely that the leptotyphlopid *Epictia borapeliotes* may be available in future inventories, since it is a species commonly found in other localities of the northeast coast (PEREIRA FILHO et al., 2017; SAMPAIO et al., 2018). The Dipsadidae family was the most abundant in the assemblage. This is one of the largest families of snakes (> 700 species), with all living representatives restricted to the New World and most in South America (CADLE et al., 1992; VIDAL et al., 2010; UETZ et al., 2022). The richness estimators indicated the likely presence of up to six more species in the area, and most of them were dipsadid snakes that were previously found in Paraíba's coast (SAMPAIO et al., 2018; FRANÇA et al., 2019), such as *Dipsas mikanii*,

Erythrolamprus poecilogyrus, *E. taeniogaster*, *Lygophis dilepis, Oxyrhopus petolarius, Psomophis joberti, Pseudoboa nigra,* and *Sibon nebulatus.*

Comparing the snake assemblage composition with an assemblage present in a very similar area along the southern coast of the state, called Barra do Rio Gramame (SAMPAIO et al., 2018), we found related fauna, with 79% of the species present in Barra de Mamanguape EPA also appearing in Gramame. The species *Hydrodynastes gigas* and *Phimophis guerini* are rare in other localities in northeastern Brazil but are present in both areas. Additionally, *Boa constrictor* and *Tantilla melanocephala* were found in Restingas, and *Chironius flavolineatus* and *Spilotes pullatus* were found in the forests in both areas. The main difference between the areas is the presence of a "Tabuleiro" environment in Gramame. Lowland Tabuleiro forests are evergreen forests with natural savanna enclaves (called tabuleiros) that occur over faster-draining sand soils and are a characteristic environment of the Northern Atlantic Forest (OLIVEIRA FILHO et al., 1993; FRANÇA et al., 2020). These "Tabuleiros" maintain some fauna with affinities to open environments (RODRIGUES et al., 2015) which favors a greater number of snakes in Gramame than in Mamanguape.

Furthermore, while it was found that only 20% of snakes inhabited forests on the south coast of Gramame, we found approximately 60% of snakes occupying the forest patches in Mamanguape. There is a lack of large forest patches on the south coast because most of the forests have been removed or reduced by agriculture and urbanization (FURRIER et al., 2016; SAMPAIO et al., 2018). On the north coast, remnants of forests preserved in protected areas are still found, such as Mata do Oiteiro in Barra do Rio Mamanguape Environmental Protection Area, SEMA III of the Guaribas Biological Reserve, and Gargaú Private Natural Heritage Reserve (PEREIRA et al., 2007; PEREIRA FILHO, et al., 2017; MESQUITA et al., 2018). Although these patches are surrounded by sugarcane plantations, they still maintain species typically related to forests, such as *Imantodes cenchoa*, *Thamnodynastes hypoconia*, *Pseustes sulphureus*, and *Lachesis muta*.

The snake assemblage of the Barra de Mamanguape EPA is dominated by the two most abundant species: *Chironius flavolineatus* and *Boa constrictor*. Although *B. constrictor* is found in many different environments in the Neotropics, it is commonly abundant in other Restingas along the Brazilian coast (DIAS et al., 2014, MARTINS et al., 2012; SAMPAIO et al., 2018). The distribution of *C. flavolineatus* is restricted to the Cerrado and the Northeast Atlantic Forest (COSTA et al., 2022). The species feeds on anurans (PINTO et al., 2008) and probably the abundance of this resource, and the less congeneric competing species in the area can allow this high abundance of *C. flavolineatus*. The species' rank-abundance curve showed a sigmoidal pattern resembling a log-normal distribution (MAGURRAN, 2004). This pattern is typical of species-rich assemblages, wherein there are few species with high dominance and many species with high equitability, and are commonly observed in South American snake assemblages (LEYNAUD et al., 2001; FRANÇA et al., 2013).

Daily activity patterns have revealed that most species are diurnal, mainly regarding phylogenetical clades that are present in the assemblage (FRANÇA et al., 2013). All Typhlopidae and most Pseudoboini (*Boiruna sertaneja* and *Phimophis guerini*, except for *Oxyrhopus trigeminus*) are exclusively nocturnal. Although we have found some active individuals of *Oxyrhopus trigeminus* during the day, they were mainly

found to be active at night and even at dawn, after 00:30 h. Additionally, all Philodryadini and most Colubridae (except for *Tantilla melanocephala*) are exclusively diurnal. *Tantilla melanocephala* is completely different in morphology, diet, habits, and activity from the other colubrids (OLIVEIRA et al., 2020). Most diurnal species, which were found active both in the morning and afternoon, became less active at mid-day (daily warm peaks), reflecting a smaller encounter rate between 12:00 h and 14:59 h. In addition, many nocturnal snakes were more active during twilight (i.e., crepuscular activity) between 18:00 h and 20:59 h, compared to the rest of the night after 21:00 h. This same pattern was found in a snake assemblage in central Brazil (FRANÇA et al., 2013) and should be related to daily temperature variation. Interestingly, some snakes can be found to be active during the daytime, as at night. The coral snake species *Micrurus ibiboboca* and *M. potyguara* that inhabit the coast of the northeast Atlantic Forest can be found active throughout the day, although these species are considered nocturnal in other parts of Brazil (SILVA JUNIOR, 2016).

Our study reinforces the importance of applying several complementary sampling methods for snake inventory work (MESQUITA et al., 2013; BARBOSA et al., 2019; OLIVEIRA et al., 2021). Records of fossorial and cryptozoic species are greatly facilitated using pitfall traps (ENGE, 2001). At the same time, this methodology does not capture very large snakes that manage to escape from buckets buried in the ground. Thus, large snakes (more than one meter long) are more likely to be found in active searches than smaller snakes. Another important sampling method used in snake surveys is the donation of specimens or occasional encounters by a third party. Even though snake encounters by this method are merely incidental (MESQUITA et al., 2013), it is an efficient method to increase the richness of the assemblage, as residents from the study area tend to see more animals during all periods than recently arrived researchers. In addition, the participation of local helpers in field research can favor the development of environmental education practices that are very important for the preservation of protected areas (BARBOSA et al., 2020a, b).

Biodiversity inventories must be carried out continuously in protected areas to evaluate the real conservation efficiency of these areas (PRINGLE, 2017), and then, new studies of snake ecology and other herpetofauna species have been conducted in the Barra do Rio Mamanguape Environmental Protection Area (BARBOSA, 2022). Despite its importance for the preservation of Atlantic Forest biodiversity, the Mamanguape Protection Area, like other coastal areas of Paraíba, has been suffering a real loss of their environmental quality due to agriculture, urbanization and tourism pressures, which reflects on the decrease of natural productivity of coastal ecosystems, the reduction of water and forest resources and loss of biodiversity (ROSA et al., 2002; MUEHE, 2010), so any effort to preserve the northeast coastal areas must be conducted.

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