CONTRIBUTIONS OF MONITORING AND RESCUE DATA TO THE DESCRIPTION OF NEW SPECIES OF BRAZILIAN HERPETOFAUNA

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ABSTRACT: Our planet's biodiversity remains largely unexplored, highlighting the need for effective biodiversity management and conservation strategies. This study investigates the role of fauna monitoring and rescue data on the discovery of new herpetofauna species in Brazilian biomes. By analyzing a comprehensive database of published literature on reptiles and amphibians in Brazil, the study evaluated the influence of data from fauna studies within the scope of environmental licensing in the description of species, examining temporal variations and espionage in the discovery of species, inspired by activities associated with the description of new species. Descriptive statistics, mechanical analysis and spatial mapping techniques were employed to analyze the collected data. Our findings clearly demonstrate the importance of this information in expanding knowledge of herpetofauna biodiversity, informing conservation strategies, and supporting ecosystem management and policy decisions. The study revealed a significant increase in the number of published studies on amphibians and reptiles over the years. Positive correlations between the number of species described and the years of publication were observed for both groups. Fauna monitoring and rescue activities also contribute to the description of species, although they represent a small percentage of the total known species in Brazil. The year 2018 stood out as the year with the highest number of species of species, and environmental impact studies played a significant role in the discovery of new species. Amphibians had a greater number of described species than reptiles, with emphasis on the Amphisbaenidae family among reptiles. The Amazon Forest and Cerrado were identified as regions with high species diversity. The Hylidae family was the most representative among amphibians, while Amphisbaenidae dominated among reptiles. Hydroelectric dams and road construction were the main types of projects associated with the description of new species. Wildlife rescue activities have also played a significant role in species discovery. This article emphasizes the importance of knowing the biodiversity of amphibians and reptiles in Brazil and highlights the increase in research and publications on these groups. The inclusion of fauna monitoring and rescue data has led to the discovery and description of new species, hopeful for scientific research and conservation planning. Preserving natural areas and implementing habitat-specific conservation measures are crucial to protecting these species. Ongoing monitoring, research and collaboration among stakeholders are essential for species identification, conservation assessment and preservation of Brazil's wildlife diversity.

Keywords: species description, amphibians, reptiles, Brazil, fauna monitoring, fauna rescue, environmental impact studies.

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CONTRIBUIÇÕES DE DADOS DE MONITORAMENTO E RESGATE PARA A DESCRIÇÃO DE NOVAS ESPÉCIES DA HERPETOFAUNA BRASILEIRA

RESUMO: A biodiversidade do nosso planeta permanece amplamente inexplorada, o que aponta a necessidade de uma gestão eficaz da biodiversidade e estratégias de conservação. Este estudo investiga o papel dos dados de monitoramento e resgate da fauna na descoberta de novas espécies de herpetofauna em biomas brasileiros. Além disso, o presente trabalho examinou variações temporais e espaciais na descoberta de espécies e identificou atividades associadas à descrição de novas espécies. Estatística descritiva, análise de correlação e técnicas de mapeamento espacial foram empregadas para analisar os dados coletados. Nossas descobertas demonstram claramente a importância dessas informações na expansão do conhecimento da biodiversidade da herpetofauna brasileira, informando estratégias de conservação e apoiando o gerenciamento de ecossistemas e decisões políticas. O estudo revelou um aumento significativo no número de estudos publicados sobre anfíbios e répteis ao longo dos anos. Correlações positivas entre o número de espécies descritas e os anos de publicação foram observadas para ambos os grupos. As atividades de monitoramento e resgate da fauna também contribuíram para a descrição das espécies, embora representem uma pequena porcentagem do total de espécies conhecidas no Brasil. O ano de 2018 destacou-se como o ano com maior número de descrições de espécies, e os estudos de impacto ambiental tiveram um papel significativo na descoberta de novas espécies. Os anfíbios tiveram maior número de espécies descritas do que os répteis, com destaque para a família Amphisbaenidae entre os répteis. A Floresta Amazônica e o Cerrado foram identificados como regiões com alta diversidade de espécies. A família Hylidae foi a mais representativa entre os anfíbios, enquanto Amphisbaenidae dominou entre os répteis. As hidrelétricas e a construção de estradas foram os principais tipos de empreendimentos associados à descrição de novas espécies. As atividades de resgate de animais selvagens também desempenharam um papel significativo na descoberta de espécies. A inclusão de dados de monitoramento e resgate da fauna tem levado à descoberta e descrição de novas espécies, contribuindo para a pesquisa científica e planejamento de conservação. A preservação de áreas naturais e a implementação de medidas de conservação específicas do habitat são cruciais para proteger essas espécies. O monitoramento contínuo, a pesquisa e a colaboração entre as partes interessadas são essenciais para a identificação das espécies, avaliação da conservação e preservação da diversidade da vida selvagem do Brasil.

Palavras-chave: descrição de espécies, anfíbios, répteis, Brasil, monitoramento de fauna, resgate de fauna, estudos de impacto ambiental.

INTRODUCTION

The biodiversity of our planet is vast and complex, with numerous species still unknown to science. It is estimated that only a small portion of the planet's species are known to science (Mora et al., 2011), considering only our knowledge of the number of species (Linnean shortfall) (Brown & Lomolino 1998), which worsens when we consider knowledge about the geographic distribution of species (Wallacean shortfall) (Lomolino, 2004). These existing gaps in biological knowledge restrict the capacity for biodiversity management (Medeiros et al., 2011), which is essential for mitigating anthropogenic effects on natural environments (Medeiros et al., 2011; Hortal et al., 2015). However, the identification and delimitation of new species and its distribution require a rigorous scientific approach based on solid evidence and a detailed understanding of its ecology and biological requirements (Winston & Disney, 2000).

Thus, knowledge about biodiversity is crucial for improving conservation planning, especially due to rapid urban development (e.g. mining, road, hydroelectric and transmission line) that directly affects biological communities (Quintana & Hacon, 2011). In recent years, the use of fauna monitoring and rescue data has proven to be a valuable tool for discovering new species and understanding spatial species distribution. These data are collected by researchers, biologists, and conservation teams in various contexts, such as protected area monitoring programs, environmental impact studies, and animal rescues in areas affected by human activities (Silveira et al., 2010; Sarmento, 2022). The objective of these initiatives is to monitor and record the presence and behavior of different species to assess the conservation status of ecosystems and mitigate the negative impacts caused by human activities (Honaiser, 2009).

Data obtained through fauna studies aimed at environmental licensing provide valuable information on local biodiversity. These data may include records of sightings of rare or little-known species, information about their geographic distribution, genetic and morphological data, as well as aspects related to their ecology, such as food preferences, reproductive behavior, and interactions with the environment (da Silva et al., 2007; Maciel & Pagani, 2016; Giacoppini et al., 2021; Sarmento, 2022). This information provides essential support for the description of new species, allowing scientists to gain a more complete and accurate understanding of the biological diversity present in a particular location. Furthermore, it provides a unique opportunity to assess the conservation status of species and the ecosystems they inhabit (Sarmento, 2022).

Herpetofauna, comprising reptiles and amphibians, is considered poorly understood and greatly underestimated in terms of its richness (Nogueira et al., 2010). Currently, approximately 11,341 reptile species (Uetz, 2022) and 8,645 amphibian species (Frost, 2023) are recognized worldwide, and they are considered one of the most threatened groups among vertebrates, especially due to their high sensitivity associated with physiological, ecological, and life history characteristics that make them highly susceptible to global temperature increase and habitat quality conditions (Collins & Storfer, 2003; Cushman, 2006; Dawson et al., 2011; Huey et al., 2012). Therefore, studies on herpetofauna, including species listing, can serve as a fundamental basis for the development of strategies to mitigate the impacts of anthropogenic activities, as this group is sensitive to changes in environmental structure (Ferreira et al., 2012; Khatiwada et al., 2016; Turci & Bernarde, 2016). The use of fauna monitoring and rescue data plays an essential role in the description of new species, providing fundamental evidence for taxonomy, conservation, and understanding of biodiversity (da Silva et al., 2007; Maciel & Pagani, 2016; Giacoppini et al., 2021; Sarmento, 2022).

The main objective of this study is to analyze the contribution of data from studies with fauna in environmental licensing processes for the discovery of new species of herpetofauna in

Brazilian biomes. In addition, this study sought to: 1) Evaluate the influence of fauna monitoring and rescue data on the number of described species; 2) Observe variations in the number of species described over time based on data obtained through monitoring and rescue efforts; 3) Check the differences in the number of species described based on data from monitoring and rescue of fauna in each of the Brazilian biomes; 4) Identify which types of ventures or activities are most likely to discover new species.

Finally, the study aims to contribute to the understanding of the role of data collected by environmental consulting companies in providing valuable information for decision-makers. Our research provides a comprehensive overview of this data, highlighting its relevance and specific characteristics within different biomes and types of activities. This information can guide decision-makers in effectively utilizing advisory data for informed decision-making and resource allocation.

METHODS

Data compilation:

The data was obtained from the analysis of peer-reviewed published papers describing species. This information was gathered from the scientific literature, including papers published from 1986 to December 2022. The initial date was established because it was the year of publication of National Council for the Environment -CONAMA Resolution Nº. 001/1986, which provides for criteria and guidelines for environmental impact assessment. CONAMA is an advisory and deliberative body of the Brazilian Ministry of the Environment. Its primary objective is to establish norms and guidelines for the preservation, conservation and sustainable use of natural resources and the environment throughout the national territory. This resolution established that all undertakings with the potential to cause some type of impact on the environment must carry out studies that must be presented and evaluated by the competent Brazilian environmental agency. We searched for potential studies (articles describing each of the species and taxonomic reviews) in the following sources: (i) online academic databases (e.g., ISI Web of Knowledge, Google Scholar, Scielo, Scopus, JStore) (ii) digital libraries of state and federal Brazilian universitie. We used the nomenclature of the species listed in the Brazilian List of Reptiles and Amphibians of the Brazilian Society of Herpetology (Segalla et al., 2021; Guedes et al, 2023). Those species that were synonymized were also consulted in their respective description articles and taxonomic revision works. For this, the Amphibian Species of the Word (Frost, 2023) and The Reptile Database (Uetz, 2021) databases were consulted regarding the taxonomic history of the species. More recent articles (between 2021 and 2022), of species described after the publication of the official lists (2021) were included based on the most recent works. To find out which species were described during this period, we consulted the Species New to Science Science Dissemination Blog (https://novataxa.blogspot.com), which is constantly updated with the discovery of new species from different taxa.

Those studies that contained any mention of projects and/or activity resulting from an environmental impact study (e.g., UHE, PCH, fauna rescue, fauna monitoring) or even mention of the contracting company were considered, and the following information was transcribed to a database: taxonomic group (amphibians, reptiles), year of description), project development (e.g., mining, road, hydroelectric and transmission line), and scientific journal.

Site description:

We selected scientific studies published in Brazil, covering different regions and biomes of the country. The choice to focus on species described in Brazilian territory is based on solid knowledge of local environmental legislation and the need to meet the requirements of environmental studies within the scope of environmental licensing.

It is important to note that all researchers involved in the studies are Brazilian specialists, with extensive knowledge and experience in national environmental legislation. This aspect provides greater technical rigor and reliability to the results obtained, reinforcing the relevance of the studies carried out. This Brazil is internationally recognized for having one of the most advanced and comprehensive environmental laws in the world. The solid regulatory base established has been an important driving factor for the wide adoption of fauna monitoring and rescue work in projects subject to environmental licensing.

Research Methods:

We included in this database, studies that reported describing new reptiles and amphibian's species (taxon), year, project development and the enterprise name. Lack of information were filled with NA. We also included information from the geographical location (when provided, we tabulated latitude, longitude, locality, municipality and state).

Taxonomic data:

We used animal taxonomic information for amphibians according to Frost (2023) and for the reptile's species Uetz et al. (2023). We added one column with the current scientific name based on previous authors where this association was possible (e.g., changes on generic attribution, species group name synonymy, species identified as sp. or spp. were sometimes identifiable by distribution). In addition, we recorded the basic publishing information of each study (author, title, year, journal).

Data analyses

The descriptive analyses represented in graphs and tables, we sought to evaluate whether the number of descriptions increased over the years, through a Spearman correlation analysis (Zar, 1999). The analysis procedures were performed in Rstudio software version 4.2.3 (Rstudio, 2023).

To observe the spatial distribution of information and determine which Brazilian biome had the highest number of described species in recent years, we plotted the data on a map with divisions of Brazil according to the Brazilian Institute of Geography and Statistics - IBGE (IBGE, 2019). In order to observe the regions where more species were described and, consequently, more representative, heat maps were made using a shapefile (.shp) file using the Qgis software version 3.20 (Qgis, 2021). The heat map uses a so-called kernel density technique to estimate the density of occurrences in different regions of space. When viewing a heat map, regions with a higher concentration of occurrence are represented by more intense nuclei, while areas with lower density are represented by lighter nuclei. This allows you to quickly identify locations of high activity or concentration, as well as locations with less occurrence.

Data limitations

Due to the enormous number of species of reptiles and amphibians described in recent years, it is quite possible that our data have limitations regarding the information from the analyzed articles. Many species, even if they come from fauna monitoring and rescue data, most of the time, there is no such specification in the article. These specifications may be precisely those sought in this article, either in the citation of a company where the data were collected or in the form of acknowledgments to a company. This is often due to fear on the part of researchers to cite enterprises in the articles, as they need authorization from the companies. In addition, many species that are sent to scientific collections carry incomplete information or the researchers themselves fail to present this information.

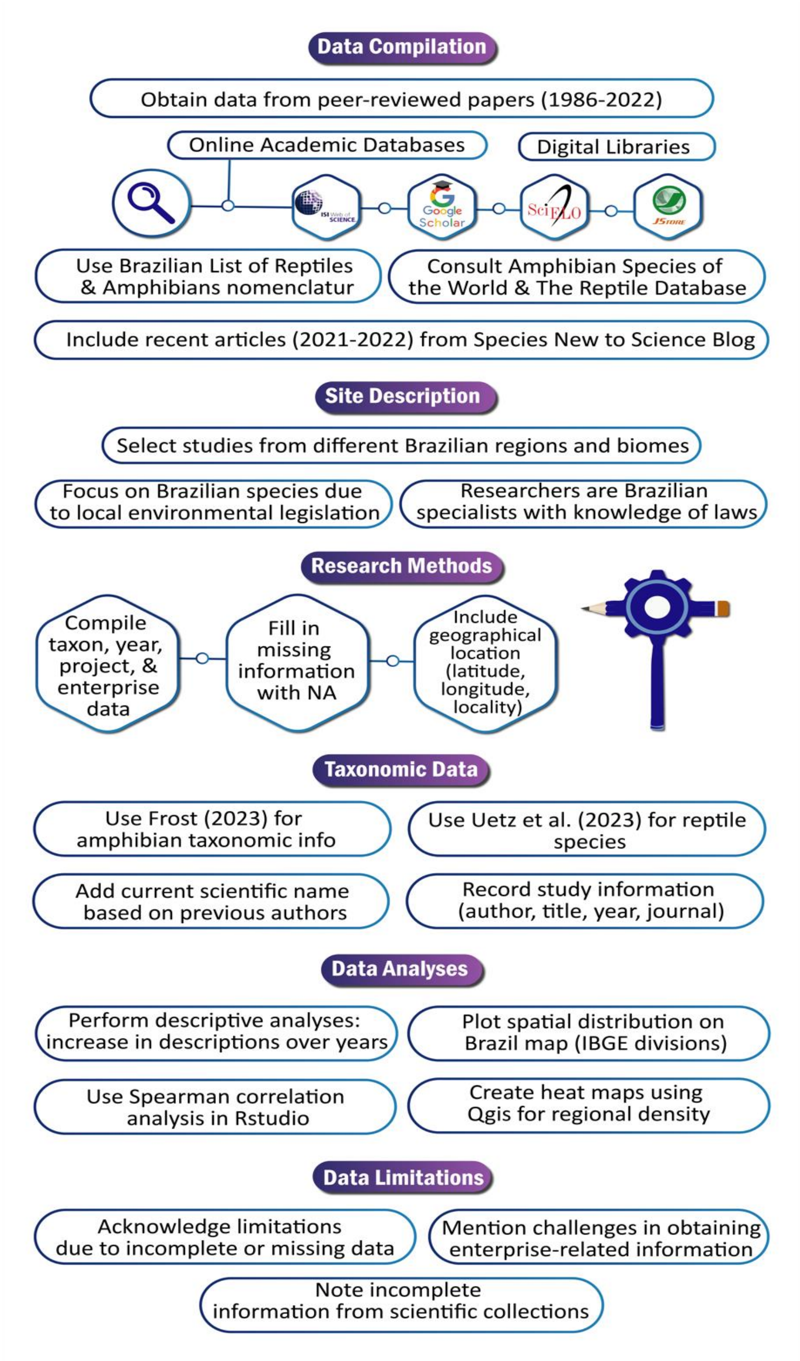

Figure 1. Organizational chart representing the methodological step-by-step.

RESULTS

Of the known species in Brazil, 625 amphibian species (belonging to the orders Anura, Caudata, and Gymnophiona) and 294 reptile species (belonging to the orders Squamata and Testudines) have been described since 1986, representing 61.75% and 34% respectively of the currently recognized species in Brazil (Guedes et al. 2023; Segalla et al., 2021).

A total of 83 species of amphibians and reptiles were described based on specimens from environmental licensing processes. Representatively, of the total number of species of amphibians (S = 1.188) and reptiles (S = 856) currently known in Brazil, 3.9% of amphibians were described based on the use of information from environmental licensing processes. With regard to reptiles, this number also remained very close, with 3,08% of the species currently known in Brazil having been described using these data.

We have observed a significant increase in the number of studies published since 1986 related to amphibians and reptiles. When considering only amphibians, there was positive correlation between the number of described species and the years in which they were described (Spearman's Rs = 0.8, p<0.01; Figure 2A). The same correlation was observed when considering only reptiles (Spearman's Rs =0.4, p < 0.05; Figure 2B) and when considering all species (Spearman's Rs = 0.8, p<0.01; Figure 2C). Considering only the species described through data from studies with fauna in environmental licensing processes, we also observed a significant increase in the number of studies published since 1986 related to amphibians and reptiles. When considering only amphibians, there was a positive and significant voice between the number of described species and the years in which they were described (Spearman's Rs = 0.7, p<0.01; Figure 2a). Considering reptiles, we observed a weak and non-significant voice between the years of publication and the number of described species (Spearman's Rs = 0.3, p = 0.09; Figure 2b). Considering the groups, we observed a positive and significant relationship between the years of publication and the number of described species (Spearman's Rs = 0.7, p<0.01; both Figure 2c).

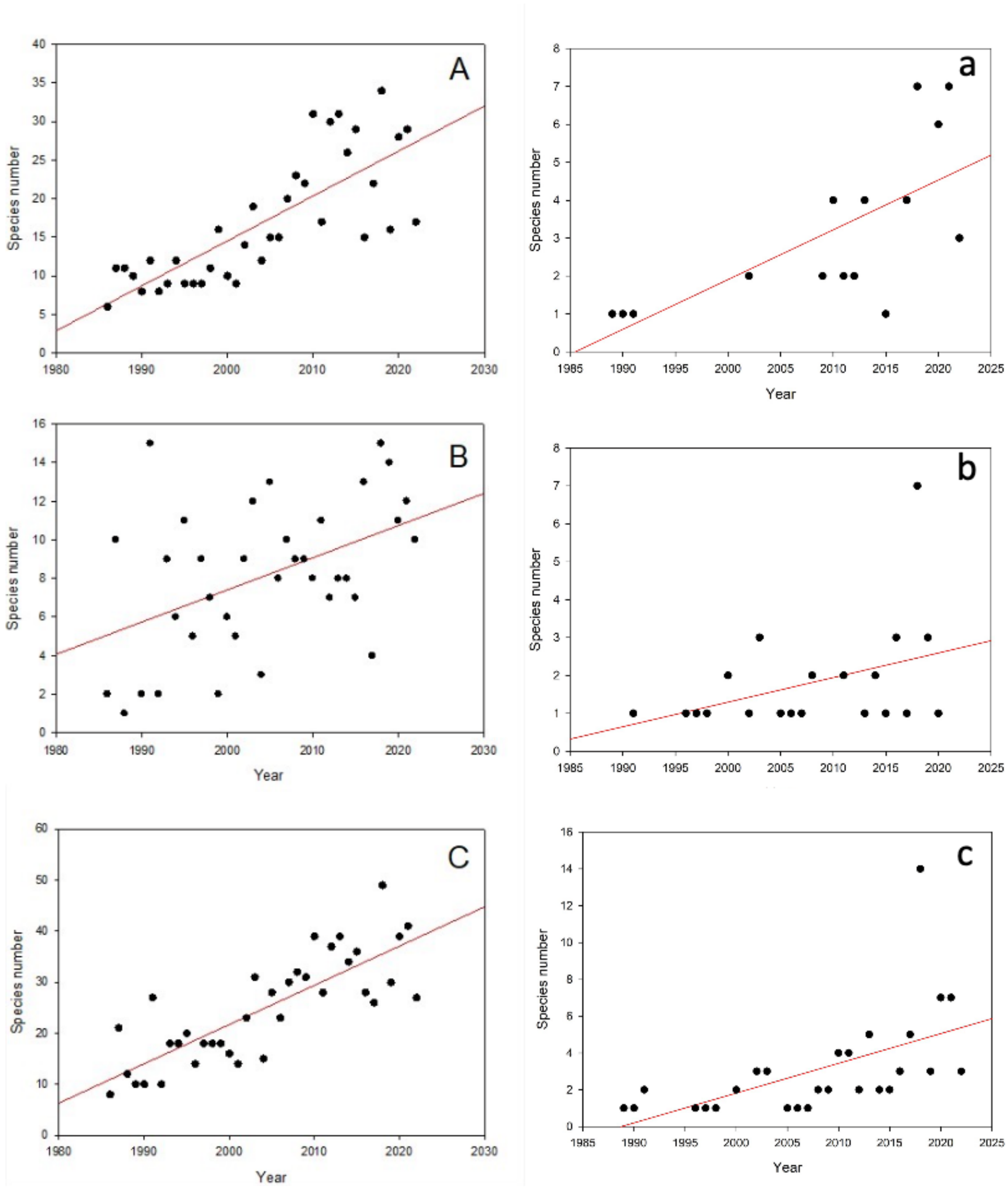

Figure 2. Temporal variation of published studies between 1986 and 2022. (A) Amphibians; (B) Reptiles; (C) General (Amphibian + Reptiles) and Temporal variation of published studies based on data from studies with fauna in environmental licensing processes. (a) Amphibians; (b) Reptiles; (c) General (Amphibian + Reptiles).

The year with the highest number of descriptions was 2018, with 14 species described, representing 16.8% of the total (Table 1). Over the last 10 years (2013-2022), 51 species were described using data from environmental impact study, which accounts for approximately 6% of the species described since 1986. The year in which more species were described was 2018 (n=14), followed by 2021 with six species discovered in Brazil through information from environmental monitoring. We found the 47 amphibians (56.62%) and 36 reptiles (43.37%) were described. Within reptiles, the Amphisbaenidae alone was responsible for 44.4% (n=16) of the descriptions based on environmental consulting data between the years analyzed.

Table 1. Species described through data from information gathered in studies with fauna in environmental Brazilian licensing processes.

Taxon	Year	Project development	Enterprise name	Coordinate		Municipality	State
				Latitude	Longitude		
AMPHIBIA							
Anura							
Aromobatidae							
Allobates caldwellae	2020	Road	Road BR-319	−3.371297	−59.864575	Careiro	Amazonas
Allobates hodli	2010	Hydroelectric	UHE Jirau	-9.334700	-64.737500	Porto Velho	Rondônia
Allobates kamilae	2022	Hydroelectric	UHE Jirau	–9.133275	–64.497260	Porto Velho	Rondônia
Allobates paleci	2022	Hydroelectric	UHE Teles Pires	−9.2583	−56.8057	Jacareacanga	Pará
Allobates tinae	2018	Hydroelectric	UHE Santo Antônio	–8.75980	–67.30890	Boca do Acre	Amazonas
Anomaloglossus stepheni	1989	Hydroelectric	UHE Balbina	-4.852222	-53.583254	Presidente Figueiredo	Amazonas
Bufonidae							
Amazophrynella xinguensis	2018	Hydroelectric	UHE Belo Monte	-5.116747	-51.298389	Anapú	Pará
Melanophryniscus spectabilis	2002	Hydroelectric	PCH Xavantina	-27.077842	-52.078440	Nova Teutônia	Santa Catarina
Rhinella inopina	2012	Hydroelectric	PCH São Domingos II	-13.383333	-46.335317	São Domingos	Goiás
Rhinella sebbeni	2015	Hydroelectric	UHE Serra da Mesa	-16.349859	-48.947072	Goiânia	Goiás
Rhinella teotoniensis	2022	Hydroelectric	UHE Santo Antônio	-8.763547	-63.897172	Porto Velho	Rondônia
Craugastoridae							
Oreobates antrum	2018	Hydroelectric	PCH Galheiros	-13.427906	-46.256700	Divinópolis de Goiás	Goiás
Dendrobatidae							
Ameerega berohoka	2011	Hydroelectric	PCH Piranhas, PCH Santo Antônio do Caiapó	-16.380052	-51.058393	Arenópolis	Goiás
Ameerega munduruku	2017	Hydroelectric	UHE Teles Pires	-9.570360	-56.577919	Jacareacanga	Pará
Hylidae							
Aplastodiscus lutzorum	2017	Hydroelectric	UHE Queimado	-13.875245	-47.661002	Alto Paraíso de Goiás	Goiás
Boana eucharis	2021	Hydroelectric	UHE Jirau	-9.642839	-56.271408	Alta Floresta	Mato Grosso
Boana icamiaba	2018	Hydroelectric	UHE Belo Monte	-2.60960	-56.19611	Juriti	Pará
Dendropsophus bilobatus	2020	Hydroelectric	UHE Santo Antonio	-9.412453	-64.442438	Porto Velho	Rondônia

Taxon	Year	Project development	Enterprise name	Coordinate		Municipality	State
				Latitude	Longitude		
Ololygon skaios	2010	Minering	Angloamerican do Brasil	-15.057875	-48.886486	Santa Rita do Novo Destino	Goiás
Scinax chiquitanus	1990	Hydroelectric	UHE Jirau	-9.271427	-64.640725	Porto Velho	Rondônia
Scinax goya	2018	Hydroelectric	PCH Mambaí II	-14.677805	-46.493959	Sitio d'Abadia	Goiás
Scinax onca	2017	Hydroelectric	UHE Jirau	-5290713	-61.892172	Beruri	Amazonas
Scinax pedromedinae	1991	Hydroelectric	UHE Jirau	-9.271427	-64.640725	Porto Velho	Rondônia
Scinax ruberoculatus	2018	Road	Road BR-319	-9.944444	-62.501111	Tapauá	Amazonas
Scinax strussmannae	2018	Road	Road BR-319	-9.944444	-62.501111	Tapauá	Amazonas
Trachycephalus mambaiensis	2009	Hydroelectric	PCH Santa Edwiges I e II	-14.290000	-46.193611	Mambaí	Goiás
Leptodactylidae							
Adenomera amicorum	2021	Hydroelectric	UHE Belo Monte	-3.149111	-54.840278	Belterra	Pará
Adenomera aurantiaca	2021	Hydroelectric	UHE Belo Monte	-4.756617	-56.394333	Trairão	Pará
Adenomera gridipappi	2021	Hydroelectric	UHE Jirau	-9.414418	-64.429558	Porto Velho	Rondônia
Adenomera inopinata	2021	Hydroelectric	UHE Belo Monte	-5.240183	-56.915383	Itaiatuba	Pará
Adenomera tapajonica	2021	Hydroelectric	UHE Belo Monte	-5.052133	-56.876833	Itaiatuba	Pará
Microhylidae							
Elachistocleis bumbameuboi	2010	Hydroelectric	UHE Ponta da Madeira	-11.525725	-61.011626	Espigão d'Oeste	Rondônia
Elachistocleis carvalhoi	2010	Minering	Minering Serra do Sossego	-7.166667	-48.533333	Aragominas	Tocantins
Odontophrynidae							
Proceratophrys bagnoi	2013	Hydroelectric	UHE Serra da Mesa	-13.829861	-48.321389	Minaçu	Goiás
Proceratophrys branti	2013	Hydroelectric	PCH São Domingos II	-10.505025	-46.433334	Mateiros	Tocantins
Proceratophrys dibernardoi	2013	Hydroelectric	PCH Pontal do Prata	-17.563533	-52.552764	Mineiros	Goiás
Proceratophrys huntingtoni	2012	Hydroelectric	UHE Manso	-14.871541	-55.785548	Rosário Oeste	Mato Grosso
Proceratophrys korekore	2021	Hydroelectric	UHE Foz do Apiacás	-9.316944	-56.776600	Jacareacanga	Pará
Proceratophrys strussmannae	2011	Hydroelectric	PCH Ombreiras	-15.090000	-58.740278	Araputanga	Mato Grosso
Phyllomedusidae							
Pithecopus oreades	2002	Hydroelectric	UHE Serra da Mesa	-13.750000	-48.300000	Serra da Mesa	Goiás
Strabomantidae							
Pristimantis giorgii	2020	Hydroelectric	UHE Belo Monte	-2.993917	-50.080158	Portel	Pará

Taxon	Year	Project development	Enterprise name	Coordinate		Municipality	State
				Latitude	Longitude		
Pristimantis latro	2017	Hydroelectric	UHE Belo Monte	-3.470398	-51.201216	Anapu	Pará
Pristimantis moa	2020	Hydroelectric	UHE Estreito	-7.859953	-47.953439	Palmeirante	Tocantins
Pristimantis pictus	2020	Hydroelectric	UHE Teles Pires	-9.467133	-55.825869	Novo Mundo	Mato Grosso
Pristimantis pluvian	2020	Hydroelectric	UHE Teles Pires	-9.920367	-58.241514	Cotriguaçu	Mato Grosso
Caudata							
Plethodontidae							
Bolitoglossa madeira	2013	Hydroelectric	UHE Jirau	-9.181169	-64.401006	Porto Velho	Rondônia
Gymnophiona							
Siphonopidae							
Brasilotyphlus guarantanus	2009	Hydroelectric	PCH Braço Norte III e IV	-9.683178	-54.962939	Guarantã do Norte	Mato Grosso
REPTILIA							
Squamata							
Amphisbaenidae							
Amphisbaena acangaoba	2020	Eolic Park	Complexo Eólico Campo Largo	-10.472580	-41.459380	Umburanas	Bahia
Amphisbaena anaemariae	1997	Hydroelectric	UHE Serra da Mesa	-14.033333	-48.216667	Serra da Mesa	Goiás
Amphisbaena caetitensis	2018	Minering	Fazenda do Engenho	-13.846667	-42.274722	Caetité	Bahia
Amphisbaena caiari	2014	Hydroelectric	Usina Hidroelétrica Santo Antônio	-8.783333	-63.950000	Porto Velho	Rondônia
Amphisbaena cunhai	1991	Hydroelectric	UHE Samuel	-8.974177	-63.284093	Rio Jamari	Rondônia
Amphisbaena filiformis	2016	Hydroelectric	UHE Estreito	-7.245833	-47.777222	Babaçulândia	Tocantins
Amphisbaena hoogmoedi	2018	Hydroelectric	UHE Teles-Pires	-9.352000	-56.692000	Jacareacanga	Pará
Amphisbaena littoralis	2014	Transmition line	Linha de Transmissão Alegria-Assu	-5.125417	-36.383556	Guamaré	Rio Grande do Norte
Amphisbaena lumbricalis	1996	Hydroelectric	UHE Xingó	-9.620556	-37.792778	Piranhas	Alagoas
Amphisbaena mebengokre	2019	Hydroelectric	Usina Hidrelétrica Santo Antonio do Caiapó	-16.456944	-51.378056	Arenópolis	Goiás
Amphisbaena mensae	2000	Hydroelectric	UHE Serra da Mesa	-15.816667	-52.166667	Minaçu	Goiás
Amphisbaena mongoyo	2019	Minering	Fazenda Esperança	-14.790817	-40.720817	Vitória da Conquista	Bahia
Amphisbaena saxosa	2003	Hydroelectric	UHE Luís Eduardo Magalhães	-9.750000	-48.350000	Lajeado	Tocantins
Amphisbaena uroxena	2008	Vegetation supression	Fazenda Caraíba	-13.163611	-41.405278	Cascavel	Bahia

Taxon	Year	Project development	Enterprise name	Coordinate		Municipality	State
				Latitude	Longitude		
Leposternon cerradensis	2008	Hydroelectric	UHE Espora	-18.663444	-51.871639	Aporé	Goiás
Leposternon maximus	2011	Hydroelectric	PCH Santa Edwiges II	-14.354167	-46.194444	Buritinópolis	Goiás
Anomalepididae							
Liotyphlops sousai	2018	Hydroelectric	PCH Passos Maia	-26.703889	-51.918056	Passos Maia	Santa Catarina
Dipsadidae							
Apostolepis adhara	2018	Hydroelectric	UHE São Salvador	-12.805267	-48.219942	São Salvador do Tocantins	Tocantins
Apostolepis cerradoensis	2003	Hydroelectric	UHE Serra da Mesa	-13.532787	-48.219554	Minaçu	Goiás
Apostolepis kikoi	2018	Hydroelectric	APM Manso	-15.460833	-55.750000	Chapada dos Guimarães	Mato Grosso
Atractus boimirim	2016	Hydroelectric	UHE Samuel	-8.750000	-63.450000	Porto Velho	Rondônia
Atractus dapsilis	2019	Minering	Plato Teófilo - MRN	-1.760728	-55.862926	Oriximiná	Pará
Atractus edioi	2005	Hydroelectric	UHE Cana Brava	-12.421359	-48.161944	Minaçu	Goiás
Atractus tartarus	2016	Hydroelectric	UHE Belo Monte	-4.666667	-47.933333	Rondon do Pará	Pará
Thamnodynastes almae	2003	Hydroelectric	Usina Hidroelétrica Luiz Gonzaga	-8.850000	-38.750000	Rodelas	Bahia
Thamnodynastes phoenix	2017	Hydroelectric		-9.324722	-40.547222	Petrolina	Pernambuco
Elapidae							
Micrurus boicora	2018	Hydroelectric	UHE Rondon II	-11.950000	-60.683333	Pimenta Bueno	Rondônia
Gymnophthalmidae							
Bachia cacerensis	1998	Tannery	Curtume Tannery	-16.166667	-57.683333	Cáceres	Mato Grosso
Bachia didactyla	2011	Hydroelectric	AHE Cachoeirão	-13.533333	-58.800000	Sapezal	Mato Grosso
Bachia psamophila	2007	Hydroelectric	UHE Luís Eduardo Magalhães	-10.033333	-48.383333	Porto Nacional	Tocantins
Bachia scaea	2013	Hydroelectric	UHE Jirau	-9.448694	-64.833475	Porto Velho	Rondônia
Leptotyphlopidae							
Trilepida fuliginosa	2006	Hydroelectric	UHE Queimados	-16.250000	-46.950000	Luziânia	Goiás
Mabuyidae							
Psychosaura agmosticha	2000	Hydroelectric	UHE Xingó	-9.400000	-37.966667	Xingo	Alagoas
Teiidae							
Tupinambis matipu	2018	Hydroelectric	UHE Guporé	-13.059680	-52.381380	Querência	Mato Grosso

Taxon	Year	Project development	Enterprise name	Coordinate		Municipality	State
				Latitude	Longitude		
Tupinambis palustris	2002	Hydroelectric	Usina Hidreletrica Tres Irmaos	-20.665636	-51.301442	Pereira Barreto	São Paulo
Tropiduridae							
Stenocercus albolineatus	2015	Hydroelectric	UHE Guaporé	-15.137088	-58.979277	Vale de São Domingos	Mato Grosso

The group of amphibians was the most representative in number of species described in the Amazon Biome, with 31 species (65.9%), followed by the Cerrado (n=15; 31.9%). Only a single Brazilian amphibian (*Melanophryniscus spectabilis*) was known to science through data from environmental studies in the Atlantic Forest (**Erro! Fonte de referência não encontrada.**). Most of reptiles were described from the Cerrado (n=17; 47.22%), followed by the Amazon Forest (n=9; 25%) and Caatinga (n=8; 22.2%). One species has only been described from the Pantanal (*Bachia cacerensis*) and one was described for the Atlantic Forest (*Liotyhplops sousai*) (Figure 3).

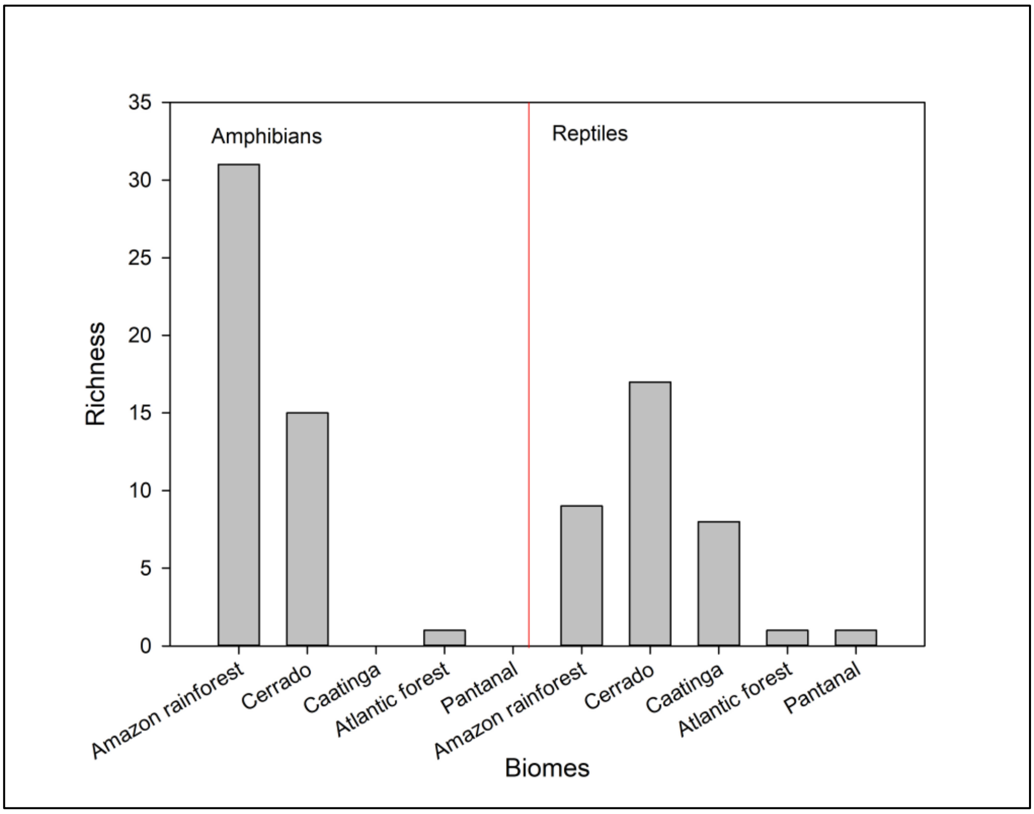

Figure 3. Representativeness of reptiles and amphibians described between 1986 and 2022 through environmental monitoring data in different Brazilian biomes.

We found that regions with the highest number of described species are distinct between reptiles and amphibians (represented by the dots in red tone). For reptiles, the regions with the highest density correspond mainly to the Midwest, Northeast and North regions (mainly in the southern part of the Amazon; Figure 4A, a). As for amphibians, the highest density of described species corresponds to the South and Central parts of the Amazon and in the Midwest region (Figure 4B, b). Considering the two groups together, the pattern follows the same as for amphibians, with a higher concentration of the described species also in the southern region of Amazonia and in the Midwest region of Brazil (Figure 4C, c).

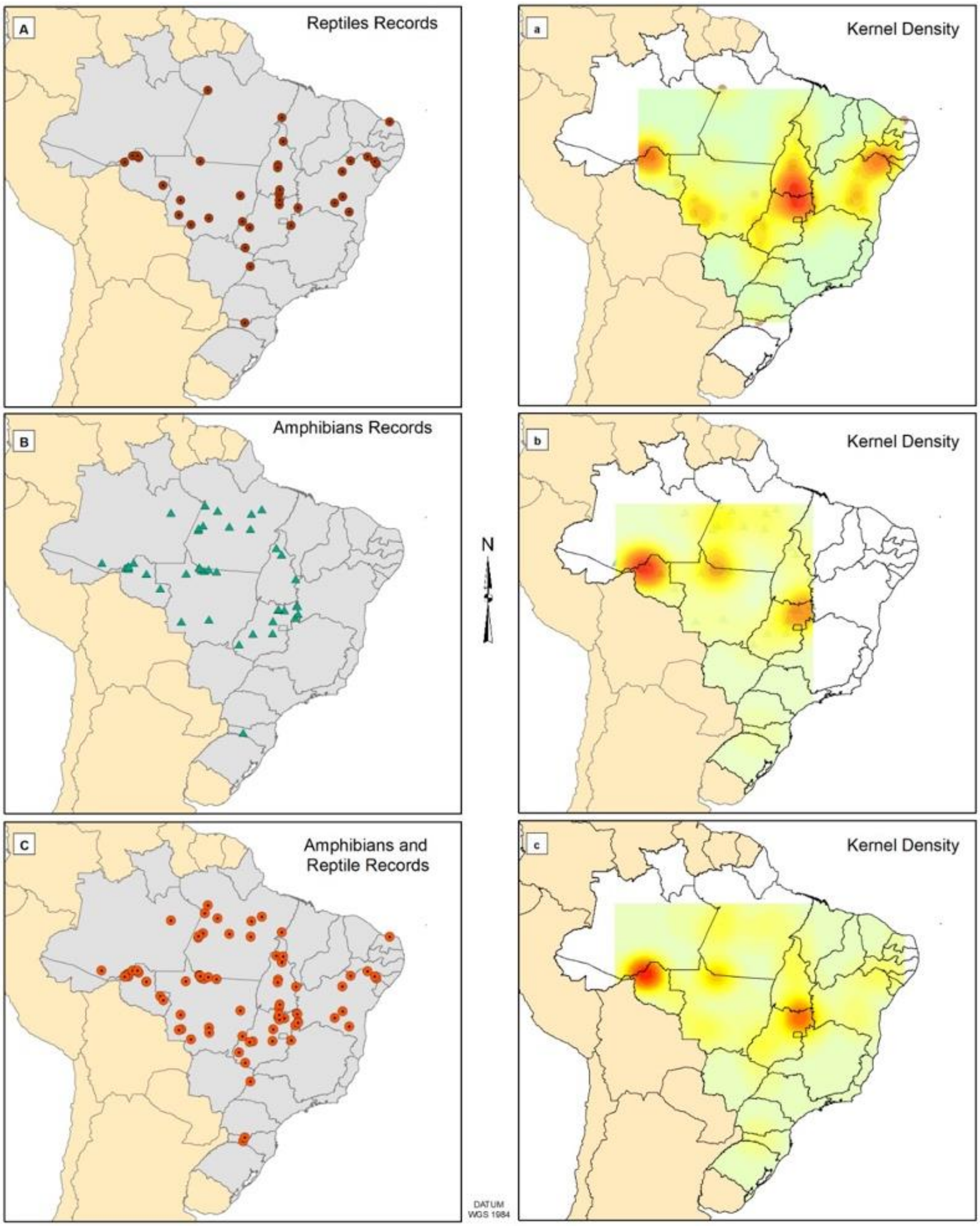

Figure 4. Regions with higher densities of described species gathered in studies with fauna in environmental Brazilian licensing processes. A) Representativeness of reptile species; a) Kernel density demonstrating the sites with the highest concentrations of the reptile species described. B) Representativeness of amphibian species; b) Kernel density demonstrating the sites with the highest concentrations of described amphibians. C) General representativeness (amphibians + Reptiles); c) Kernel Density demonstrating the places with the highest concentrations of amphibians and reptiles described through information from environmental impact studies.

Among amphibians, the Hylidae family stands out as the most representative in terms of the number of species described through information derived from the rescue and monitoring of fauna, responsible for 25.5% (n=12) of the species. This is followed by Aromobatidae and Odontophrynidae (12.76%; both n=6) and Bufonidae and Leptodactylidae, each responsible for 10.63% of the described species (Table 2). Regarding reptiles, the Amphisbaenidae family was responsible for 44.4% (n=16), followed by the family Dipsadidae, which accounted for 25% of the described species (n=9; Table 2).

Table 2. Representativeness of species described based on data from environmental impact studies efforts in Brazil from 1986 to 2022.

Class	Order	Family	Studies number	%
Amphibia	Anura	Aromobatidae	6	7.23
		Bufonidae	5	6.02
		Craugastoridae	1	1.2
		Dendrobatidae	2	2.41
		Hylidae	12	14.46
		Leptodactylidae	5	6.02
		Microhylidae	2	2.41
		Odontophrynidae	6	7.23
		Phyllomedusidae	1	1.2
		Strabomantidae	5	6.02
	Caudata	Plethodontidae	1	1.2
	Gymnophiona	Siphonopidae	1	1.2
Reptilia	Squamata	Amphisbaenidae	16	19.28
		Anomalepididae	1	1.2
		Dipsadidae	9	10.84
		Elapidae	1	1.2
		Gymnophthalmidae	4	4.82
		Leptotyphlopidae	1	1.2
		Mabuyidae	1	1.2
		Teiidae	2	2.41
		Tropiduridae	1	1.20
Total			**83**	**100**

Regarding the type of enterprise, the hydroelectric dam accounted for 81.92% (n=71), followed by road construction (7.22%; n= 6; Table 2) to describe new species of amphibians and reptiles.

Table 3. Species described by type of enterprise in Brazil between 1986 and 2022.

Type	**N**	**%**
Tannery	1	1.20
Hidroelectric	68	81.92
Transmition line	1	1.20
Minering	5	6.02
Eolic Park	1	1.20
Road	6	7.22
Vegetation supression	1	1.20
Total	**83**	**100**

DISCUSSION

Several animal groups, especially amphibians and reptiles, are highly sensitive to environmental changes (Guibbons et al., 2000; Vredenburg and Wake, 2007), resulting in an increased number of globally (IUCN, 2023) and nationally (MMA, 2022) threatened species. Understanding biodiversity is essential to ensure the survival of these species in the face of biodiversity loss at a global scale. In Brazil, approximately 30% (260 million hectares) of the territory is occupied by agricultural crops such as pastures, soybeans, sugarcane, and forests (Joly et al., 2011). In the past 10 years, over 1 million environmental licenses have been issued in the country (PNLA, 2023). Considering that environmental licensing aims to monitor activities with potential environmental impacts (Carmo et al., 2013), it is essential to establish mechanisms to integrate the data collected during these studies for licensing purposes.

The description of new species in Brazil is fundamental for understanding the country's biodiversity but faces important limitations (Marques and Lamas, 2006). Brazil is recognized as one of the most biodiverse countries, housing numerous unique and unknown species (Lewinson and Prado, 2002; Franke et al., 2005). However, many of these species remain undescribed or insufficiently documented due to a range of challenges and limitations.

One of the main limitations in describing new species in Brazil is the scarcity of qualified taxonomic experts (Hopkins et al., 2002; Marques and Lamas, 2006). Taxonomy is the science responsible for species identification, naming, and classification, but the training of taxonomists has been insufficient to deal with the country's vast biological diversity (Wilson, 2004). The lack of trained experts results in delays in identifying and describing new species, making it difficult to include them in studies and conservation programs. Currently, there are just over 542 taxonomists in the country (Marques and Lamas, 2006), and training programs in this field have significantly declined in recent years, with most research concentrated in three states (São Paulo, Rio de Janeiro, and Minas Gerais) (Marques and Lamas, 2006). In 2006, Brazil had just over 20 postgraduate programs in Zoology, with 14 of them offering doctoral courses, mostly located in states where the largest scientific collections are concentrated (Marques and Lamas, 2006).

Lack of adequate funding is also a significant limitation (Marques and Lamas, 2006) for discovering new species in Brazil. Taxonomic research requires financial resources for fieldwork, laboratory analyses, publication of results, and maintenance of scientific collections. Unfortunately, investment in this area has been insufficient, hindering comprehensive and in-depth studies (Hopkins et al., 2002). The lack of resources also affects access to remote and unexplored areas, where many new species may be found. In this regard, the results of our research highlight the importance of integrating data from environmental consulting firms to improve knowledge of the country's biodiversity.

In addition to resource scarcity, the vast geographical extent of Brazil, encompassing a variety of ecosystems from the Amazon rainforest to coastal biomes, needs to be considered. This geographic diversity makes it challenging to conduct comprehensive surveys in all regions, resulting in knowledge gaps about biodiversity in less explored areas (Martins and Oliveira, 2011). These remote regions often harbor endemic and threatened species that have yet to be discovered or documented (Costello et al., 2013; Tedesco et al., 2014).

Another limitation is related to scientific infrastructure. The lack of adequate laboratories and institutions hampers high-quality taxonomic research. The absence of modern equipment and technology hinders precise sample analysis and comparison with existing scientific collections (Vivo et al., 2014). Additionally, the lack of access to digital resources and databases limits the ability to share information about new species quickly and comprehensively.

Our results indicate a significant increase in the number of studies published on amphibians and reptiles since 1986, consistent with other studies that have observed the same pattern (Rossa-Feres et al., 2011). This increase is observed in both the number of described species and the years in which they were described. In the case of amphibians, there has been a progressive increase in the number of discovered and described species over time, driving greater interest and research production in this group. Similarly, although the correlation is weaker than in the case of amphibians, there is also an increase in the number of described reptile species over the years, suggesting that the number of studies and publications on reptiles is growing, albeit to a lesser extent. When considering all species (amphibians and reptiles), the positive correlation between publication years and the numb er of described species remains significant, indicating a consistent overall trend of increasing research and publications in both groups.

Considering the large number of environmental licenses issued in recent years, we should also consider the species described through studies conducted for environmental licensing. In this regard, the results are similar, with a significant increase in published studies on amphibians and reptiles. The inclusion of species collected during these environmental monitoring activities is particularly relevant, as they often represent new species to science (Fonseca et al., 2010) and are screened by experts, resulting in descriptions of new species, on average, 12 years after their inclusion in a scientific collection (Guedes et al., 2020). This highlights the importance of these conservation efforts not only in protecting and mitigating impacts on fauna but also in obtaining valuable data for scientific research and species discovery. Furthermore, the use of this information has been crucial in identifying priority conservation areas and making decisions related to land-use planning (Toledo et al., 2017). It is important to emphasize that species recognition is essential in conservation approaches, as undescribed taxa are often excluded from planning, management, and decision-making processes (Costello et al., 2013; Tedesco et al., 2014).

Within the classes Amphibia and Reptilia, certain families have contributed more to the described species. In the case of amphibians, the family Hylidae is the most represented, followed by Aromobatidae, Odontophrynidae, Bufonidae, and Leptodactylidae. Among reptiles, the family Amphisbaenidae stands out as the largest contributor, followed by Dipsadidae. These results could provide information about the taxonomic groups that have received greater attention in recent years and may reflect their ecological and conservation importance. Hylidae amphibians are found in a variety of habitats, including tropical forests and savannahs, and have been the subject of many studies due to their ecological and behavioral diversity (e.g., Savage et al., 1968; Martin and Watson, 1971). Similarly, the family Amphisbaenidae includes many species of fossorial lizards that inhabit underground environments and have developed specific morphological characteristics over time for this way of life (Castro-Mello, 2000; Mott et al., 2008; Galdino et al., 2015; Oliveira et al., 2008). Amphisbaenids are fossorial animals and difficult to record (Colli et al., 2016). In recent years, they have been recorded during dam filling or vegetation suppression activities, when their burrows are flooded, forcing them to emerge (e.g., Hoogmoed and Ávila-Pires, 1991; Vanzolini, 1996, 1997; Castro-Mello, 2000, 2003; Ribeiro et al., 2008; Ribeiro et al., 2012; Teixeira et al., 2014; Ribeiro et al., 2016; Oliveira et al., 2018). Additionally, the installation of pitfall traps in areas required by environmental agencies has led to increased sampling and study of these animals, resulting in several new descriptions in recent years, as this type of trap can capture species that are rarely sampled by other methods (e.g., Amphisbaenidae) (Campbell and Christman, 1982; Cechin and Martins, 2000).

When analyzing regional distribution patterns, differences can be observed between amphibians and reptiles. The Amazon Rainforest is the most representative biome in terms of amphibian diversity, followed by the Cerrado. This can be attributed to the complexity and diversity of habitats found in these regions, providing favorable conditions for a wide variety of species (Klink and Machado, 2005; Menin, 2007). On the other hand, reptile descriptions are concentrated in the Central-West, Northeast, and North regions of Brazil, with a special focus on the southern part of the Amazon. This distribution may be influenced by factors such as the availability of food resources and climatic variations in different regions (Rodrigues, 2005; França et al., 2017; Oliveira et al., 2019). These results corroborate our finding that the majority of studies describing new species from this data originate from hydropower plants. The Amazon region, in general, has enormous potential for electricity generation through its numerous large rivers. In the case of amphibians, most descriptions came from the Jirau Hydropower Plant, Belo Monte Hydropower Plant, and Santo Antônio Hydropower Plant, all located in remote regions of the Amazon. Similarly, in the case of reptiles, descriptions from the Central-West region stand out, originating from various studies conducted in large (UHE) and small (PCH) hydropower plants.

CONCLUSION

This study highlights the various limitations and challenges faced in describing and understanding the biodiversity of amphibians and reptiles in Brazil. The scarcity of qualified specialists in taxonomy, the lack of adequate funding, the lack of scientific infrastructure and the vast geographical extension of the country are factors that make it difficult to identify and describe new species, as well as to obtain a comprehensive knowledge of biodiversity.

However, despite these limitations, it is encouraging to observe a significant increase in the number of studies and publications on amphibians and reptiles over the years. This increase reflects a greater interest and recognition of the importance of these groups in ecology and conservation. In addition, the inclusion of species collected during environmental licensing activities and consultations has proven to be a valuable source of discovery of new species.

It is essential that measures are taken to overcome the challenges mentioned. This includes investing in training more qualified taxonomists, providing adequate funding for taxonomic research, strengthening scientific infrastructure, improving access to digital resources and databases, and establishing strict control over data collected by environmental consultancies. In addition, it is necessary to expand research efforts in less explored regions and promote partnerships between scientific institutions, environmental agencies and companies to boost the discovery and description of new species.

By overcoming these challenges, we can gain a better understanding of Brazil's rich amphibian and reptile biodiversity, which is essential for developing effective conservation and management strategies. The identification and description of new species not only contribute to science, but also play a crucial role in protecting these endangered groups and preserving the ecosystems they inhabit.

Although our results indicate that few described species originated from data collected by environmental consulting firms, it is important to highlight the potential of this data. For this, it is essential to establish rigorous control of this information by environmental agencies, requiring companies to provide feedback on the material deposited in collections. Additionally, it is necessary to stimulate research in the country by improving laboratory structures and promoting the training of new taxonomists.

In the world context of accelerated loss of biodiversity, Brazil plays a fundamental role due to its immense biological diversity. Therefore, it is imperative that measures be taken to strengthen taxonomic research and conservation of the amphibian and reptile fauna, thus ensuring the preservation of these animals for future generations.

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