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Addressing Taxonomic and Geographic Biases in ethnozoological studies on animal use in Brazil

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ABSTRACT

This study aims to assess the current state of ethnozoological research in Brazil. Sistematic review was conducted using the Web of Science and Scopus databases, encompassing all publications available until December 2022. The selected articles, written in various languages, consist of data obtained directly by the researcher, offering taxonomic descriptions of species and their respective uses. 85 articles were selected to construct a distribution map of ethnozoological studies, categorizing them based on their use. The Spearman's correlation test and the Kruskal-Wallis test, were applied to identify patterns within the data on use, number of studies and zoological class. Spearman's correlation indicated a positive relationship between the sum of uses and the number of studies conducted. The Kruskal-Wallis test revealed variations in the average number of studies and total uses across different zoological classes. The thematic classification of articles included general ethnozoology, specialized ethnozoology, general medicinal use, specific medicinal use, and hunting. Results showed a consistent increase in publications, with the Northeast region and the Caatinga biome featuring prominently. The reviewed papers encompassed 829 species, demonstrating greater representation in the food and medicinal categories. Ichthyofauna and avifauna, exhibited the highest species number. Our study highlights the utilitarian versatility of herpetofauna and mammal fauna. The classes Asteroidea, Bivalvia, Chilopoda, Echinoidea, and Hydrozoa, were identified as having below-average representation in terms of studies and use associations. In conclusion, the revision advocates for investigations with a collaborative bias among research groups from different biomes, to aid in reducing centralized studies in specific geographical areas.

Keywords: Traditional knowledge of fauna; Use of wild animals; Scientometrics.

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SIGNIFICANCE STATEMENT

To evaluate the current state of ethnozoological research in Brazil, we conducted a systematic review encompassing all studies available in the Web of Science and Scopus databases up to December 2022. A total of 85 articles, written in various languages, were selected, each containing primary data on taxonomic descriptions of diverse animal species and their respective traditional uses. From these selections, we created a distribution map of ethnozoological studies categorized by type of use. Additionally, we applied Spearman and Kruskal-Wallis correlation tests to identify patterns within the data regarding usage, number of studies, and zoological classes. Our findings reveal that: 1) there is a positive relationship between the total number of uses and the number of studies conducted; 2) variations exist in the average number of studies and total uses across different zoological classes; 3) there is a steady increase in the number of ethnozoological studies in Brazil, particularly in the Northeast region and the Caatinga biome; 4) the food and medicinal categories were the most frequently considered in the review, with significant emphasis on the utilitarian versatility of herpetofauna and mastozoofauna.

INTRODUCTION

Biodiversity has undergone scrutiny from various perspectives. The scientific emphasis on its utilitarian aspects, along with considerations of local ecological knowledge (CEL) and local zoological knowledge (LZK), has facilitated an understanding of the connections forged between human populations and faunal resources. Studies have documented and disclosed substantial data on management practices, bioprospecting, the discovery of new species, insights into the impact of biological and ecological phenomena, the development of hypotheses, and the application of methodological tests (Alves and Souto 2015; Braga-Pereira et al. 2022; Costa-Neto et al. 2013; Gama 2014; Morado et al. 2021; Rodríguez et al. 2021; Santos et al. 2019c; Serrão et al. 2019; Pozzi and Ladio 2023).

Ethnozoological studies have contributed to the understanding of the identification and classification of animals by humans, taking into account cultural, environmental, and historical contexts (Alves and Souto 2015). These studies reveal that numerous species within the Brazilian fauna serve the diverse needs of populations. They are utilized as source of protein, zootherapy resources, in the manufacturing of artisanal products, in mystical and religious rituals, and pets (Alencar et al. 2012; Santos et al. 2019a, b; Santos et al. 2020; Santos et al. 2021; Soares et al. 2018; Tito and Giraldin 2021). Certain species are also considered significant for people due to their role as predictors of climatic events, conveying either good or bad news, which, in turn, leads to some of them being slaughtered over human aversion (Almeida et al. 2023; Bonfim et al. 2021; Los et al. 2013; Margalida et al. 2014; Santos et al. 2023; Silva et al. 2017).

Despite the growing number of studies and recognition of the area's importance for conservation, knowledge remains fragmented and scattered throughout the literature. There is a need to summarize information regarding the current state of fauna species of utilitarian importance for human, particularly in cultural and biodiversity rich countries, such as Brazil. Although there are reviews regarding ethnozoological knowledge, there is a need to compile data that indicates information such as zoological taxa in greater evidence, areas that require expanding research, and understanding established collaboration networks in studies conducted in Brazil by national and international educational institutions.

When analyzing specific data, systematic reviews can offer syntheses of the knowledge state in a scientific field and future research priorities can be identified, addressing issues that may remain unanswered through individual studies alone (Page et al. 2021). Considering Brazil's pivotal role as a trailblazer in ethnozoological research, with a rich legacy of academic contributions (Oliveira and Lopes 2021), we carried out a scientometric survey to systematically explore the taxa that hold representative significance within human communities residing in Brazilian territory. In addition to assessing the correlation between the total use of animals and developed studies, and the average number of studies per zoological class, as well as identifying national and international collaboration networks that have contributed to this science.

By undertaking this comprehensive examination, we aim to not only contribute to the existing body of knowledge but also to guide and inspire future inquiries, ensuring a nuanced understanding of the intricate relationships between humans and the diverse fauna that share their habitat. We focused on ethnozoological studies and addressed several key questions: 1) What is the current landscape of ethnozoological research in Brazilian territory?; 2) Which zoological groups are most frequently studied?; 3) What utilitarian purposes are predominantly explored?; 4) What are the primary thematic approaches evident in the analyzed papers, and what potential gaps exist that warrant further investigation?; and 5) How have institutional scientific collaboration networks been acting in the development of these studies?

MATERIAL AND METHODS

Search strategies

The research entails a systematic review conducted in accordance with the PRISMA guidelines (2020) (2020) (Page et al. 2021), utilizing the Web of Science database to identify relevant articles (https://www-webofscience.ez15.periodicos.capes.gov.br/wos/woscc/basic-search) and Scopus (https://www-scopus.ez15.periodicos.capes.gov.br/search/form.uri?display=basic#basic).

Our search strategy involved employing the following keywords: Ethnozoology, Ethnomastozoology, Ethno-ornithology, Ethnoherpetology, Ethnoentomology, Ethnoichthyology, Ethnocarcinology, Ethnomalacology, Zootherapy, and Hunting.

Selection of studies

In the initial stage of document identification, we conducted searches using a combination of the aforementioned keywords, pairing them with the term "Brazil". In the case of the term "Hunting", we added the keyword "Ethnozoology" to this combination. This addition was made to account for articles found outside the scope of the research topic, such as "Hunting AND Brazil AND Ethnozoology".

During the tracking stage, we performed a preliminary assessment of located articles by reviewing titles, abstracts, and keywords. Articles that did not reference the keywords used in the search within these fields were disregarded. This exclusion criterion applied particularly to articles structured around secondary data, scientific notes, and duplicates.

In the eligibility stage, we thoroughly examined the full articles to identify those containing the necessary information for the analyses included in this review. Consequently, we incorporated articles obtained from the search platforms until December 2022. These articles, written in any language, consisted of primary data and involved the taxonomic identification of Brazilian fauna species along with analyses of their utilization.

We extracted the following data from the studies: the publication year of the article, the biome, state, and municipality where each research was conducted, the described species and zoological group, and the utilitarian purpose associated with each animal.

Data Analysis

We generated the distribution map of ethnozoological studies using the geographic coordinates provided in the analyzed articles through the QGis program. In cases where this geographic data was absent, we conducted a search using Google Maps, utilizing information related to the municipality(ies) specified in each search (Figure 3).

Species nomenclature was cross-verified based on the information presented in the articles, and classifications were revised in accordance with the Brazilian Biodiversity Information System. This was particularly crucial in instances where the records diverged due to changes in species nomenclature (SIBBr 2020).

The recorded uses in the analyzed studies were categorized into the following groups: food, medicinal, artisanal (encompassing decorative items and household utensils), pets, magical-religious (pertaining to species used in mystical practices), veterinary (involving the use of animals or their by-products for medicinal treatment of other wild or domestic species), conflict (involving animals considered pests causing damage to plantations, domestic species, or inducing aversion), and bioindication (pertaining to species indicative of meteorological variations and omens, possibly associated with positive news). (Barbosa and Aguiar et al. 2015; Abrantes et al. 2011; Montenegro et al. 2014).

To assess the correlation between the sum of uses and the number of studies conducted, the Spearman's correlation test was employed. In addition, the Kruskal-Wallis test was used to determine whether there was a difference between the average number of studies and the total use (sum of all uses by species) by taxonomic zoological class. These analyses were conducted using R Software (R Core Team 2021).

Lastly, to comprehend the main thematic approaches within the articles, we followed the classification proposed by Ritter et al. (2015), adapting it to ethnozoological studies. This classification includes: General Ethnozoology (encompassing studies addressing the general use of animal resources), Specialized Ethnozoology (covering works focused on the use of fauna for specific purposes such as food or crafts, excluding medicinal purposes, or aimed at a particular zoological group or species), General Medicinal Use (encompassing studies on the general use of medicinal animals), Specific Medicinal Use (including specific studies on the use of medicinal animals within a zoological group or species), and Hunting (encompassing studies on the use of fauna identified using this keyword, not included in other searches). It is worth noting that medicinal categorization is treated separately due to the existence of numerous articles specifically dedicated to this topic.

Bibliometric Analysis

To perform the bibliometric analysis, we used only the papers available on the Web of Science Core Collection and then we used the VOSviewer 1.6.18 software. An analysis of terms frequency and co-occurrence al-

lowed mapping relationships between all the papers and identify main addressed topics. This analysis was conducted in the titles, keywords and abstracts. Analysis of authorship affiliations permitted to map the most active countries/territories in terms of publications. The authorship affiliations analysis used the list of affiliations of the authors and co-authors (Van Eck and Waltman 2010).

RESULTS

Screening of Articles and Profile of Ethnozoological Studies

A total of 513 articles were initially identified across the aforementioned search platforms. However, adhering to the steps outlined by PRISMA, our study narrowed down to the analysis of 85 articles (Figure 1).

The documents retained in the review encompass at least one taxon identified at the genus level, along with its corresponding utilitarian purpose. For instance, consider the study by Barbosa et al. (2022): the authors report on 156 species distributed among mammal fauna (31), avifauna (93), and herpetofauna groups, which include reptiles (27) and amphibians (05), with associated usage citations. However, the document selectively highlights certain scientific identifications, and these animals are included in our database.

Articles that were excluded from the study did not meet the inclusion criteria for various reasons: 1) originating from another country; 2) involving secondary data; 3) lacking mention of animals from the Brazilian fauna; 4) lacking the scientific identification of the species; 5) failing to specify the utilitarian purpose associated with the species; 6) dealing with studies focused on experimental investigations, phytochemical evaluations, and specimen capture techniques.

The publications spanned the years 1999 to 2022, with significant representation observed between 2011 and 2020 (see Figure 2).

Articles are predominantly developed in the Northeast region (76 papers), with a limited number focused on the Central-West and South regions, each comprising only one study (see Figure 3).

Among the Brazilian biomes, the Caatinga (prevalent in the Northeast region) attracts the most significant research investment with 52 papers, followed by the Atlantic Forest (21 papers), the Amazon Forest (8 papers), and the Cerrado (2 papers) (see Figure 3). Some articles were developed in ecotone areas, and others did not specify the biome in which they were conducted. It is important to highlight that, in the case of the Central-West region, the reported research was conducted in collaboration with academics residing in 14 municipalities within the Middle Araguaia region. The extension of study participant allocations resulted in an increased heat spot displayed on the map for the region, which does not accurately reflect the actual number of studies conducted in the area.

Upon evaluating the attributes assigned to species, we observed a greater representation of vertebrates. A total of 829 species were identified, comprising 270 birds, 229 fish, 102 reptiles, 86 mammals, 58 insects, 27 mollusks, 25 crustaceans, 13 amphibians, 9 echinoderms, 7 arachnids, 1 annelid, 1 cnidarian, and 1 kilopod. Although avifauna and ichthyofauna present the highest number of described species, in terms of utilitarian versatility, herpetofauna and mammal fauna stand out. Species such as *Salvator merianae*, *Boa constrictor*, *Crotalus durissus*, *Cayman latirostris*, *Euphractus sexcintus*, *Cerdocyon thous*, and *Tamandua tetradactyla* are associated with seven utility categories (excluding bioindication). The highest number of animals is associated with food use, followed of categories reported in Table 1.

Concerning the applied statistics, Spearman's correlation revealed a positive result between the sum of uses and the number of studies, yielding $S = 4598709$, p-value $< 2.2e\text{-}16$, and rho 0.9515689 (Figure 4).

The Kruskal-Wallis test for the average number of studies per zoological class resulted in a p-value of 8.691e-14 (Figure 5). This outcome demonstrates that the classes Asteroidea (Echinodermata) (4), Bivalvia (Mollusca) (6), Chilopoda (Arthopoda) (9), Echinoidea (Echinodermata) (12), and Hydrozoa (Cnidaria) (14) (Figure 6) are below average.

For the Total uses by zoological class, a p-value of 4.785e-15 was obtained. This result indicates that the classes Asteroidea (4), Chilopoda (9), Echinoidea (12), and Hydrozoa (14) are below average (Figure 6).

The predominant thematic approach in the analyzed articles was Specific Ethnozoology (52 papers), followed by General Medicinal Use (17 papers), Hunting (11 papers), Specific Medicinal Use (4 papers), and General Ethnozoology (1 paper) (Figure 1).

Bibliometric Analysis

Out of the 76 articles predominantly developed in the Northeast region 60 were available in the Core Collection of the Web of Science. The analysis of terms showed the most recurrent terms and the interconnection strength between them over time (Figure 7) and by cluster (Figure 8). The results present the 91 most recurrent terms grouped among 5 clusters, of which the most recurrent terms were "bird", "pet" and "medicine" (51, 45 and 34 times respectively). The clusters were grouped in topics related to health benefits (red cluster), Ecology and Conservation (green cluster), Lo-

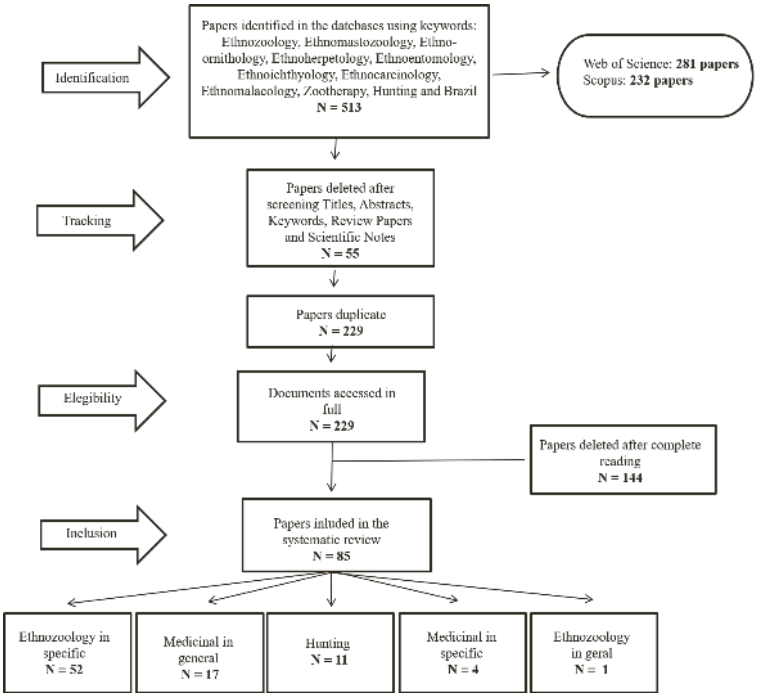

Figure 1. Number of studies selected for the systematic review, following the guidelines proposed by the PRISMA protocol (Page et al. 2021).

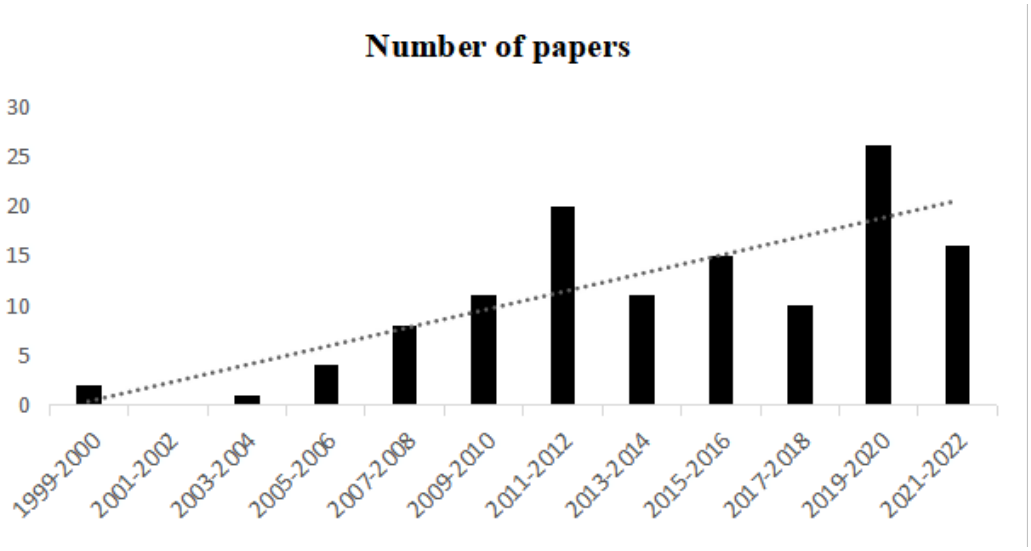

Figure 2. Number of ethnozoological studies available in the Web of Science and Scopus databases per publication year from 1999 to 2022.

cal Knowledge and Techniques (purple cluster), Human Consumption (yellow cluster), and Human Animal Conflicts (blue cluster).

The results of the affiliation analysis show the co-authorship by countries of the published papers (Figure 9). The results show the time in terms of publications and their relationship in publications. All the papers were affiliated to Brazil which is the center of the publications and only a few other countries show up in the research of which the more developed countries present older partnership with Brazil while developing countries present newer partnership (later than 2020).

As for the results of the affiliation analysis of co-authorship by institutions, the institutions from Northeast Brazil were most prominent and have been publishing the longest in this topic (Figure 10). These institutions with more papers are in general older in-

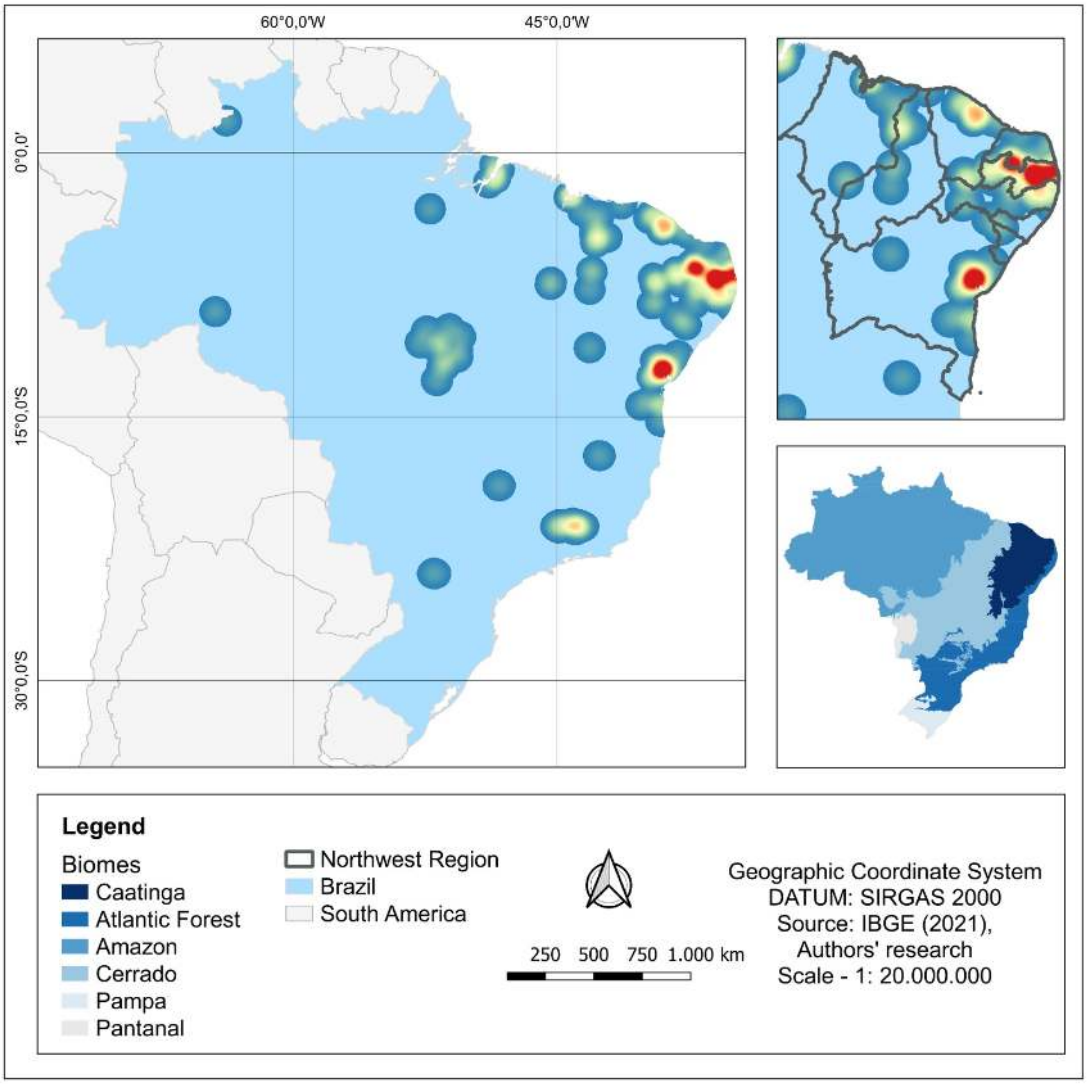

Figure 3. Geographic distribution of ethnozoological research conducted in Brazil available in the Web of Science and Scopus databases from 1999 to 2022.

stitutions while institutions that have only recently started publishing newer institutions. The pattern of co-authorship also shows that the institutions that tend to publish together more and cluster together do so by regions, for instance institutions from the Southeast Brazil are mostly in the same cluster, the ones from the Northeast in another, and also the ones outside Brazil in a separate cluster (Figure 11).

DISCUSSION

Geographic bias

Our review indicates a trend towards increased Brazilian publications in the field over the last decades especially in the Caatinga and Atlantic Forest biomes. Our data align with the findings of the review conducted by Alves and Souto (2011), who, in their analysis of scientific materials on ethnozoology in Brazil, identified exponential growth in research from the early 21st century, particularly between 2001 and 2011, and with the Corrêa et al. (2022), who, when analyzing publications between 1967 and 2017, observed peaks in publications in 2006, 2012, and 2017, but noted a decline in 2017. The authores found that 38% of the studies were conducted in the Caatinga (n = 61), 23% in the Atlantic Forest (n = 38), 19% in the Cerrado (n = 31), 17% in the Amazon Rainforest (n = 27), 2% in the Pampa (n = 3), and 1% in the Pantanal (n = 2). Despite the overall growth in ethnozoological studies in Brazil, this scenario highlights that there are still regions that demand greater investment.

Table 1. Taxonomic classes and their uses categories.

Taxonomic classes	Categories							
	Food	**Medicinal**	**Breeding**	**Magical-religious**	**Conflict**	**Craft purposes**	**Veterinary**	**Bioindication**
Actinopteri	142	45	-	18	4	18	3	-
Asteroidea	-	6	-	4	-	1	-	-
Arachnida	-	4	-	-	2	-	2	-
Aves	161	77	109	49	32	-	5	15
Bivalvia	-	3	-	3	-	-	-	-
Camarondonta	-	1	-	-	-	-	-	-
Cephalopoda	-	1	-	-	-	-	-	-
Chilopoda	-	1	-	-	-	-	-	-
Chondrichthyes	18	17	-	1	6	-	-	-
Clitellata	-	2	-	-	-	-	-	-
Echinoidea	-	2	-	1	-	-	-	-
Gastropoda	1	4	-	17	-	-	-	-
Hydrozoa	-	1	-	1	-	-	-	-
Insecta	6	41	1	2	12	2	7	1
Lissamphibia	3	11	-	3	-	-	1	-
Malacostraca	5	15	-	5	-	10	-	-
Mammalia	50	64	13	29	34	14	12	-
Reptilia	29	58	55	25	41	21	11	-
Total species	415	353	178	158	131	66	41	16
Total (%)	50	42.5	21.4	19	15.7	7.9	4.9	1.9

The prominence of the Northeast region and institutions from the region can be attributed to consolidated research groups in ethnozoology affiliated with academic institutions in this area (Oliveira and Lopes 2021) which facilitates the expansion of research development as newer institutions start to take part during the last few years and hubs of development, even though it is mostly centralized around older institutions. Another contributing factor to the research expansion in the region is the persistent socioeconomic and environmental challenges, despite ongoing development initiatives and government programs providing tax and economic benefits. The northeastern states rank lower in the national Human Development Index (HDI), have the lowest life expectancy in Brazil, lack environmental sanitation in approximately 55% of residences, and face challenges such as irregular rainfall impacting livestock and agricultural practices (ArboControl 2023).

These factors can influence the strengthening of connections between social groups in this territorial extension and the local fauna, thereby directing the focus towards conducting ethnozoological research. Furthermore, certain studies span multiple locations, exemplified by Barboza et al. (2016), who investigated mammal hunting with rural and urban communities in the Caatinga biome across 10 municipalities in four states. Similarly, Barbosa et al. (2022) explored hunting activity in four protected areas of the Atlantic Forest situated in four municipalities. The Southeast region accounted for three articles, while the North region for nine. However, it is noteworthy that several studies were conducted in more than one region.

There necessity of expanding ethnozoological research in biomes with a low concentration of studies, particularly in regions like the Cerrado, which had the fewest studies, and Pantanal, which lacked articles. The Brazilian Cerrado, classified as a global biodiversity hotspot by the Ministry of the Environment (MMA 2023a), emerges as a priority area for stud-

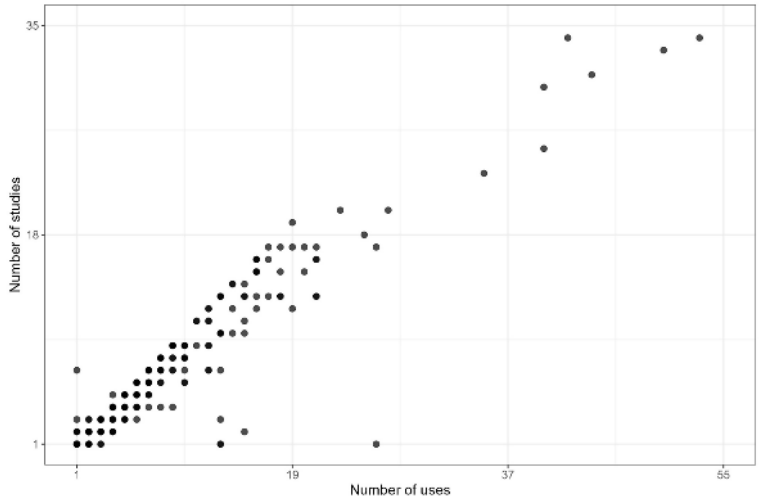

Figure 4. *Scatterplot* of the correlation between the general sum and the number of ethnozoological studies carried out in Brazil available in the Web of Science and Scopus databases from 1999 to 2022.

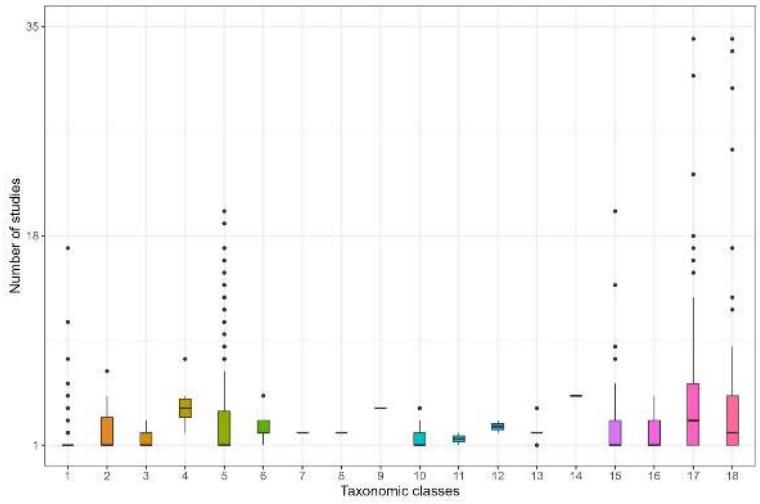

Figure 5. *Boxplot* of the sum of zoological classes and the number of ethnozoological studies carried out in Brazil available in the Web of Science and Scopus databases from 1999 to 2022. Caption: 1. Actinopteri; 2. Lissamphibia; 3. Arachinida; 4. Asteroidea; 5. Aves; 6. Bivalvia; 7. Camarondonta; 8. Cephalopoda 9. Chilopoda; 10. Chondrichthyes; 11. Clitellata; 12. Echinoidea; 13. Gastropoda; 14. Hydrozoa; 15. Insecta; 16. Malacostraca; 17. Mammalia; 18. Reptilia.

ies aiming to comprehend the socio-environmental and socioeconomic dynamics at play. The Pantanal, recognized as the world's largest continuous floodplain with a rich presence of traditional and native communities, has been impacted by human activities, especially agricultural practices (MMA 2023b), necessitating increased investment in ethnozoological research.

Another ecoregion in the Central-West of Brazil requiring expanded study is the Chaco. Affected by soybean production, the area has experienced health and social conflicts among communities residing near plantations (Yousefi et al. 2018). Lacking official government recognition as a biome, the Chaco is often overlooked in public policies (Campos 2023). The consolidation of data in these locations may enhance their visibility by identifying weaknesses and potentialities related to social, environmental, and economic dimensions, which, in turn, can provide directions for necessary conservation and restoration strategies.

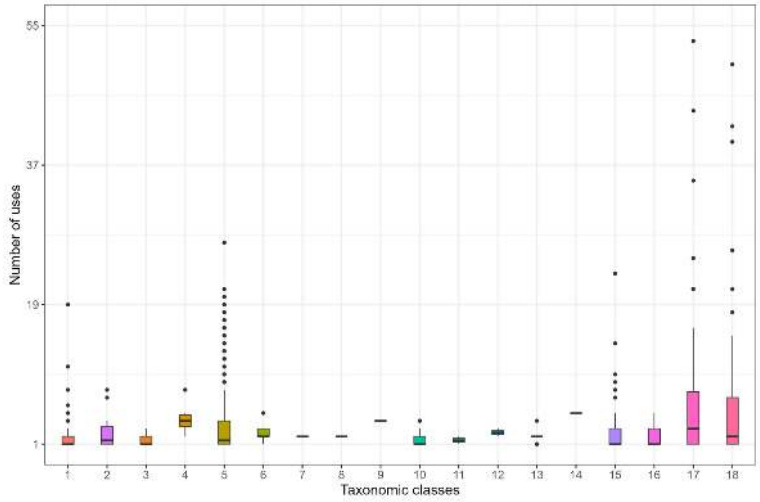

Figure 6. *Boxplot* of the sum of zoological classes and the number of ethnozoological studies carried out in Brazil available in the Web of Science and Scopus databases from 1999 to 2022. Caption: 1. Actinopteri; 2. Lissamphibia; 3. Arachinida; 4. Asteroidea; 5. Aves; 6. Bivalvia; 7. Camarondonta; 8. Cephalopoda 9. Chilopoda; 10. Chondrichthyes; 11. Clitellata; 12. Echinoidea; 13. Gastropoda; 14. Hydrozoa; 15. Insecta; 16. Malacostraca; 17. Mammalia; 18. Reptilia.

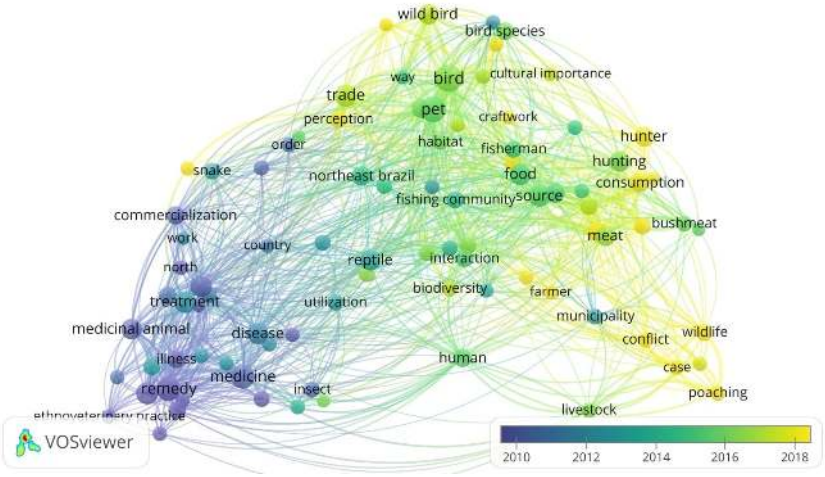

Figure 7. The image shows the 91 (60% most relevant terms that occurred at least 5 times) out of the 1896 recurrent terms across 60 papers acquired from Web of Science. The most occurrent terms were "bird", "pet" and "medicine" (51, 45 and 34 times respectively). Colors represent the time period the term was most recurrent according to label and circle sizes the relative occurrences. Lines represent coocurrences between terms and lines' thicknesses the relative times terms coocurred.

Animal use bias

Research indicates that factors influencing people's habits include sociocultural and economic considerations, taboos, utilitarian preferences, and/or ecological and biological aspects of the species. This results in the individual or multiple use of animals, contributing valuable data to their conservation efforts (Alves et al. 2021; Barbosa et al. 2022; Barboza et al. 2016; Landim et al. 2023; Marques et al. 2022; Santos et al. 2021; Silva et al. 2023; Soares et al. 2018; Soares et al. 2020).

In the analyzed articles, various purposes are attributed to the identified species, including food, medicinal use, pet keeping, magical-religious significance, conflict resolution, artisanal, veterinary applications, and bioindication, with the first two being the most recurrent.

For food purposes individuals are prepared and consumed based on individual preferences for prepa-

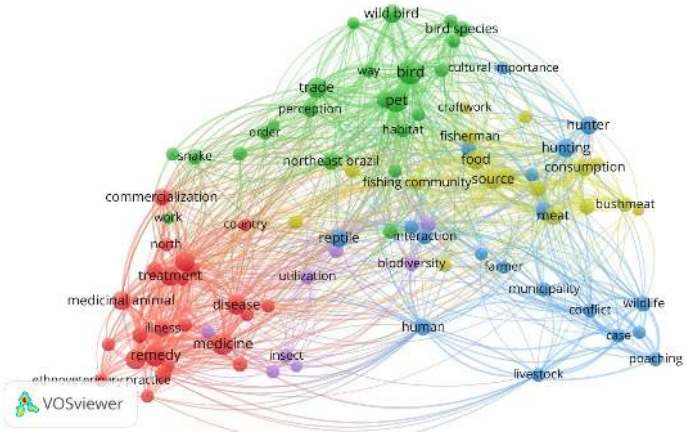

Figure 8. The image shows the 91 (60% most relevant terms that occurred at least 5 times) out of the 1896 recurrent terms across 60 papers acquired from Web of Science. The most occurrent terms were "bird", "pet" and "medicine" (51, 45 and 34 times respectively). Colors represent clusters of terms that most occurred together. Lines represent coocurrences between terms and lines' thicknesses the relative times terms coocurred.

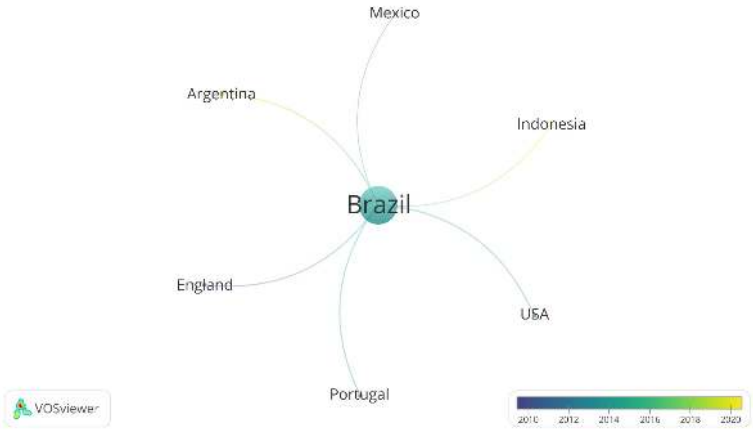

Figure 9. The image shows the sis countries across the 60 papers acquired from Web of Science. The country affiliated to the most papers was Brazil (with 60 papers) followed by Argentina, England, Portugal, and USA (with two papers each) and Indonesia and Mexico (with one paper each). Colors represent the time period the country published the most according to label and circle sizes the relative number of papers affiliated to it. Lines represent co-authorship between countries and lines' thicknesses the relative times countries co-authored papers.

ration of people (e.g. Alves et al. 2012a; Barros and Azevedo 2014; Bonifácio et al. 2016; Magalhães et al. 2006; Pinto et al 2013; Rocha-Mendes et al. 2005; Santos et al. 2022; Santos and Alves 2016). Certain social groups, such as fishermen, despite having access to protein sources like beef, often turn to fish as their main protein source, contributing to their food security (e.g. Pinto et al. 2017). Future assessments should list species genuinely useful for subsistence, in conjunction with other analyses such as studies on the biology and ecology of species, to propose strategies for the sustainable use of these resources.

Several species are used in medicinal practices, with 584 species described for Latin America (Alves and Alves 2011) and for Brazil alone 354 animal species (Alves et al. 2013). Many of these medicinal practices involve the use of live animals, parts of their bodies (e.g., skin and feathers), by-products resulting from their metabolic actions (body secretions such as fat), and materials constructed by them (nests or cocoons). These uses are linked to the treatment of various pathologies, for instance respiratory (e.g. Alves et al. 2012a; Alves and Pereira Filho 2007; Bezerra et al. 2017; Costa-Neto et al. 2002; Modro et al. 2009; Seger et al. 2019). It is important to specify the type of use and condition to be treated during

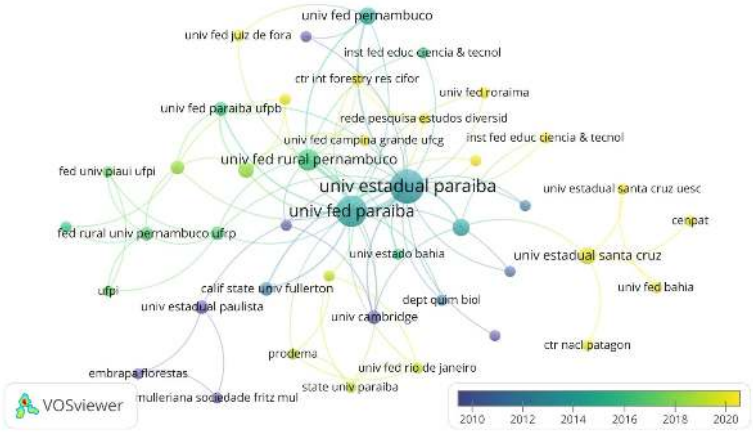

Figure 10. The image shows the 43 interconnected institutions out of the 57 across the 60 papers acquired from Web of Science, the other 14 institution did not have any connections with other institutions. The institutions affiliated to the most papers were Universidade Estadual Paraíba, Universidade Federal Paraíba and Universidade Federal rural de Pernambuco (with 39, 29 and 9 respectively). Colors represent the time period the institution published the most according to label and circle sizes the relative number of papers affiliated to it. Lines represent co-authorship between institutions and lines' thicknesses the relative times institutions co-authored papers. The 14 institutions that do not appear in the map do not have connections with any other institution.

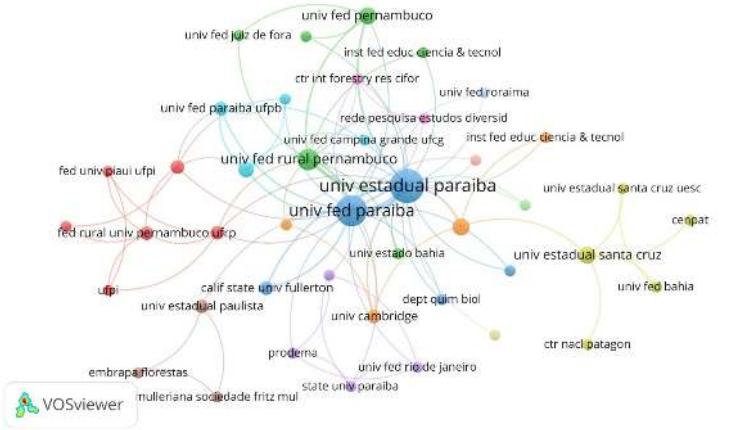

Figure 11. The image shows the 43 interconnected institutions out of the 57 across the 60 papers acquired from Web of Science, the other 14 institution did not have any connections with other institutions. The institutions affiliated to the most papers were Universidade Estadual Paraíba, Universidade Federal Paraíba and Universidade Federal rural de Pernambuco (with 39, 29 and 9 respectively). Colors represent clusters of institutions that most co-authored papers together and circle sizes the relative number of papers affiliated to the institution. Lines represent co-authorship between institutions and lines' thicknesses the relative times institutions co-authored papers. The 14 institutions that do not appear in the map do not have connections with any other institution.

data collection, as it aids in the development of conservation actions (Alves and Alves 2011; Moura and Marques 2008).

Regarding the animals as pets, these studies contain crucial information, including data on commercial networks and species management for commercial purposes (e.g. Alves et al. 2012a; Alves et al. 2016a; Alves et al. 2019; Bezerra et al. 2017, 2020; Fernandes-Ferreira et al. 2012; Licarião et al. 2013; Oliveira et al. 2018; Oliveira et al. 2020; Soares et al. 2020; Sodré-Andre et al. 2022; Souto et al. 2017; Teixeira et al. 2014). "Pet" is one of the most mentioned term in the term map, right along with birds and in the same category as "trades", which is also a topic

that is being used more often in the last decade. This shows the importance of surveillance of animal trafficking since it has negative impacts on the environment (Sollund 2013; Duarte et al. 2021). Conscientization of the impacts of having wild animals as pets could have impacts in the demands for such animals, which in turn would lead to less poaching and trafficking, decreasing the offers (Sollund 2013).

To fulfill the purpose magical-religious, live animals or products of animal origin are used and/or sold (e.g. Alves et al. 2012a; Alves and Pereira Filho 2007; Bezerra et al. 2013; Fernandes-Ferreira et al. 2012; Léo Neto et al. 2012). Alves et al. (2012b), when investigating animals used for spiritual and religious purposes by followers of the Afro-Brazilian religion Candomblé, identified the most cited animals in the terreiros, including *Monetaria caputserpentis*, *Monetaria moneta*, *Monetaria annulus*, *Gallus gallus*, *Columba livia*, *Chelonoidis denticulata*, *Numida meleagris*, and *Capra hircus*. Some of these species are domesticated and even brought from other continents and are also raised for human consumption. However, some of the species used for religious purposes are only found in the wild. The authors also found an extensive commercial network involving collectors, middlemen/distributors, store owners, and consumers focused on the commercialization of animal products. Traders cited *Hippocampus reidi*, *Boa constrictor*, *Sotalia fluviatilis*, and *Crotalus durissus* as the most traded species. Product use must be identified by spiritual guides, with information provided by spiritual entities. Regarding the use of live animals, these are sacrificed and offered to the orixás in the terreiros.

In the mystical use of animal resources, some species are employed in crafting handmade objects. For instance, Bonifácio et al. (2016) describe the use of the horn and paws of *Subulo gouazoubira* in the form of keychains and paws kept in homes, respectively, serving as a protective amulet or to expel bad moods. These peculiarities are fundamental characteristics to be analyzed in ethnozoological studies, as conservation and management strategies must integrate the cultural and spiritual values associated with the species.

Conflict situations with animals are also reported by some studies (e.g. Carvalho et al. 2019; Costa et al. 2021; Diniz 2019; Silva et al. 2020a; Fernandes-Ferreira et al. 2012; Lima et al. 2016; Lima et al. 2020; Saiki et al. 2009). Lima et al. (2020) found that motivations for people to kill species considered conflicting, such as *Boa constrictor*, *Panthera onca*, and *Rupornis magnirostris*, include a natural aversion to wildlife, reduction and prevention attacks on livestock, and upon others domestic animals, respectively. Other significant reasons include viewing some animals as disease carriers, such as *Cerdocyon thous* (Silva et al. 2020b), and causing economic losses to people. Carvalho et al. (2019) reported economic losses triggered by wild animals, mainly by *Psittacara leucophthalmus*, which attacked corn and fruit crops. Lima et al. (2016) recorded that the species *Planococcus* sp., *Aphis gossypii*, *Bemisia tabaci*, and *Diabrotica speciosa* are insects considered pests of okra. It is necessary to outline control strategies for the management of pest species.

The use craft was reported in some research (e.g., Alves et al. 2012a; Blásquez et al. 2009; Mariz et al. 2020; Mendonça et al. 2014; Santos et al. 2019b; Silva et al. 2020a). Santos et al. (2019b) identified that species from the carnivore group (*Cerdocyon thous*, *Puma yagouaroundi*, *Leopardus pardalis*, *Puma concolor*, *Galictictis cuja*, *Procyon cancrivorous*) obtained a significant number of citations for craft purposes, with leather commonly cited as a material used in making musical pieces, such as tambourines and drums, motorcycle seats, chair covers, car seats, shoes and boot soles, bags, hats, keychains, belts, among others. The authors also discuss the use of *Kerodon rupestris* stomach in cheese production, something also observed by Alves et al. (2012a). Mariz et al. (2020) highlight the capture of fish and crustaceans (for example, *Panulirus* spp., *Carpilius corallinus* e *Ucides cordatus*) intended to produce handicrafts. The species with the highest rates of capture were *Balistes vetula* and *Megalops atlanticus*, with the most cited materials being the whole body or taxidermized body parts and skin, used to make jewelry and souvenirs.

For veterinary use, medicines are crafted using various products and by-products, including bile, bone, fat, feathers, gizzards, heads, homemade butter, honey, horns, leather, meat, milk, rattles (from rattlesnakes), saburá (fermented pollen), skulls, stingers, tails, urine, and viscera, or the live animal. These are intended for the treatment of inflammatory and dermatological diseases or conditions (e.g., respiratory problems, rheumatism, throat problems, furunculosis, dermal nodules, wounds, and swelling), as well as obstetric disorders (prolapse of the uterus) (e.g., Barboza et al. 2007; Confessor et al. 2009; Souto et al. 2011a; Souto et al. 2011b; Souto et al. 2012a; Souto et al. 2012b). Souto et al. (2011b) identified that these practices have a strong relationship with traditional human medicine, presenting converging information on species used, prevalence of use, modes of administration, and techniques applied.

The bioindication category, the species are described as foreshadowing events, such as good or bad news, indicative of bad luck or death, and climate predictions (e.g., Costa-Neto 2006; Galvagne-Loss and Costa-Neto 2017; Melo et al. 2014). In the case of birds, their vocalization and body parts, such as feathers, respectively, aid in classifying the predicted event

and protecting against unpleasant events (e.g., Bezerra et al. 2013). Furthermore, the authors recorded that, in some cases, people believe that keeping certain birds as pets helps to avoid unpleasant events, as they can predict such occurrences, as is the case with *Cyanocorax cyanopogon*.

These articles contain valuable information about people's relationships with wild animals. While these practices are considered important for populations, they can result in irreparable damage to fauna. Therefore, they must be scrutinized to identify species requiring attention regarding the intensification of studies, aiming to provide data focused on the sustainability of these resources. It is also crucial for these studies to engage with other scientific areas, such as political ecology, to develop plausible alternatives for addressing emerging socio-environmental problems, promoting actions aimed at building a sustainable future. In this context, the creation of public policies can be crucial tools in preventing environmental damage, considering the importance of fauna for people.

Taxonomic Bias

Most studies focus on the vertebrate group, which includes animals of large or medium size such as mammals, birds, and fish. In aquatic systems, fish are the most addressed. This pattern can be explained mainly by people's dietary dependence on the resource, but it can also be related to researchers' interest in these groups.

Classes like Asteroidea, Echinoidea, Hydrozoa, and Chilopoda fall below the average when correlated with the mean of developed studies and uses. This is due to the limited number of studies conducted with animals from these taxa. Consequently, further evaluations are imperative to gain a more nuanced understanding of this indicator, employing a specific approach tailored to each zoological theme.

The results of the Kruskal-Wallis test for the average number of studies per zoological class can be attributed to the greater concentration of studies involving rural farming communities, a social group with no direct contact with certain organisms. However, even other populations involved mention these species with low frequency.

The classes with the largest number of included species were Actinopteri, Chondrichthyes, and the Aves group. In addition to ichthyofauna and avifauna, the mammalian group and reptiles are described as animals with great utilitarian importance. The use of these animals may be associated with their geographic distribution and population density, as noted by Santos et al. (2019c) in their investigation, where the authors found that the perceived abundance of mammal fauna influenced the capture of the collected animals by the studied community.

Mendonça et al. (2016) also observed this dynamic, emphasizing that in areas where larger animals are absent, people intensify the collection of species with a greater perceived spatial distribution. The flavor of the species is another factor influencing people's choices, as well as low income and education, contributing to animal slaughter and consumption. On the other hand, seasonality did not predict consumption intensity.

The results for the Total uses by zoological class reflects the low diversity of use described for the species present in the taxa (asteroidea, chilopoda, echinoidea, and Hydrozoa), a favorable situation for these animals since the versatility of use, together with their biological conditions and environmental factors, can favor their population decline.

Main thematic approaches

The high representation of articles focusing on specialized Ethnozoology (61%) can be attributed to several factors. Firstly, there is an evaluative focus in research, exemplified by studies such as Sodré Neto et al. (2022), which assesses local customs and practices specifically related to birdlife. Second, a focus on a particular zoological taxon, as seen in Silva et al. (2020b), who directs their investigation to the ecology, interactions, and human perceptions of *Cerdocyon thous* in rural landscapes. Lastly, studies addressing a specific category of use, such as the research by Santos et al. (2020), which identifies conflicts between humans and wildlife.

Specific approaches investigated revealed a lower number of studies that delved into the peculiarities of management practices. For instance, Costa-Neto et al. (2002) explored *in situ* management of fish and crustaceans for capturing specimens, while Soares et al. (2020) described *ex situ* maintenance practices involved in breeding wild birds kept in captivity for commercialization, fights, or appreciation of bird songs. Oliveira et al. (2018) highlighted care practices for maintaining birds, including providing food, medicines, and, in some cases, training to improve singing or learn songs from other species. Santos et al. (2021) emphasized the increasing importance of this approach for other zoological groups, potentially leading to the incipient process of animal domestication.

The Medicinal approach also demonstrated significant relevance, encompassing research on lists of all species known and used by populations (20%) and specific zoological groups (5%), totaling 21 articles (25%). Example include studies by Alves et al. (2006; 2007; 2007a; 2007b; 2008; 2009; 2010; 2016b), Alves and Santana (2008); Andrade and Costa-Neto (2005), Bar-

ros et al. (2012), Brito et al. (2019), Costa-Neto (1999; 2011), Costa-Neto and Oliveira (2000), Costa-Neto and Resende (2004), Ferreira et al. (2009), Nascimento et al. (2016) Oliveira et al. (2010), among others. These findings underscore the importance of zootherapy in various sociocultural environments.

Despite the wealth of information on medicinal use, Alves et al. (2021) recently evaluated zootherapy information from a new hypothetical and methodological perspective. This research sought to understand the influence of ecological and evolutionary factors on the medicinal use of wild mammals, revealing that phylogenetically close species are used to treat similar pathologies. This emphasizes the need for new perspectives to comprehend the relationship between people and animals, considering cultural dynamism and the specific biological and ecological characteristics of each species.

Hunting, as an approach, represented 13% of the analyzed manuscripts (e.g., Alves et al. 2012c; Barbosa et al. 2018; Barbosa et al. 2022; Barboza et al. 2016; Fernandes-Ferreira et al. 2013; Marques et al. 2022; Mendonça et al. 2016; Oliveira et al. 2017; Souto et al. 2019; Souza and Alves 2014; Souza et al. 2022). Despite its illegality in Brazil, the studies indicate its prevalence in various municipalities, with records of commercialization of products and by-products derived from hunted species. The activity is often associated with purposes such as medicinal use, crafting, and breeding as pets. Fernandes-Ferreira and Alves (2017), in their analyses on the topic, emphasize the necessity to expand studies concerning the complexity of hunting, including factors influencing the consumption of animals and the sustainability of the fauna involved in the practice.

On the other hand, the General Ethnozoology approach had the lowest representation (1%), featuring only one article by Torres et al. (2009). Their study aimed to analyze aspects of the interaction between human populations and biodiversity in the Genipabu Environmental Protection Area (APA-Genipabu) on the coast of the state of Rio Grande do Norte. This scarcity of research highlights the limited number of studies with a broad focus on understanding all zoological groups considered important by people in a particular location. Expanding studies to all groups requires greater involvement among regional and global institutions, enabling the strengthening of collaborative research networks.

CONCLUSION

The prevalence of ethnozoological research in Brazil has been notable, with a significant focus on data compilation in the Northeast region, particularly within the Caatinga biome. Regions like the Central-West and South demand increased investment in researches to enhance comprehension of the dynamics between people and the fauna in these areas.

Despite the escalating number of articles produced in Brazilian territory, certain zoological classes receive limited attention, necessitating expansion. Vertebrates stand out as the zoological groups with the highest number of species spotlighted for their importance food and medicinal, with a particular emphasis on avifauna and ichthyofauna. However, herpetofauna and mammal fauna exhibit greater versatility of use, warranting more in-depth assessments capable of gauging the impact stemming from these relationships. In general terms, these studies address popular knowledge about species, without extending to investigations that involve, for example, hypothesis testing. Achieving this requires alignment between ethnozoological studies and other scientific analyses, such as ecological assessments focusing on the biology and ecology of species, as well as political ecology.

Bibliometric analyses demonstrate the need to expand collaboration among national and international research networks, providing a pathway to address the scarcity of studies in biomes such as the Cerrado and Pantanal, and consequently enhancing the understanding of species requiring conservation actions and the development of political strategies for populations that regularly interact with fauna, relying on these resources for their subsistence. Established research groups in northeastern Brazil may play a relevant role in nucleating new research nodes in other regions.

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DATA AVAILABILITY

For access to the specific date supporting the findings of this study, interested parties can contact the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The authors affirm that no conflicts of interest exist in relation to this study.

CONTRIBUTION STATEMENT

Conceptualization: SSS, RFPL.
Data curation: SSS.
Formal analysis: SSS, HKLS, DGN, FOR.
Investigation: SSS, HKLS, RFPL.
Methodology: SSS, HKLS, RFPL, DGN, FOR.
Visualization: SSS, HKLS, HFM, EMCN, RFPL, DGN, FOR.
Writing – original draft: SSS.
Writing – review and editing: SSS, HKLS, HFM, EMCN, RFPL, DGN, FOR.

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