

REVIEW

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Use of wild vertebrates for consumption and bushmeat trade in Brazil: a review

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Abstract

Background Bushmeat is a resource exploited by thousands of people around the world, especially in tropical and neotropical regions, constituting an important source of protein and income. But what is known, so far, about the consumption and trade of wild vertebrate meat (hereinafter “bushmeat”) in a megadiverse country like Brazil? This question was answered through a systematic survey of publications on the consumption and trade of wild vertebrate meat made in Brazil between 2011 and 2021.

Methods We selected 63 scientific articles available on “Google Scholar,” “Science Direct,” “Scopus,” “Web of Science” and “Portal de Periódico da CAPES.” The articles were categorized as: exclusive to (1) consumption or (2) bushmeat trade, totals of 54 and three articles, respectively; both (3) consumption and trade bushmeat, totaling six articles. We applied a nonparametric Spearman’s correlation analysis to verify the association between the number of papers and the species richness of wild vertebrates cited for consumption by Brazilian state.

Results The results revealed that the publications were concentrated in the Northeast (36), North (26) and Southeast (1) regions, distributed across 16 states of the federation. These data reinforce the need for more researches in states and other regions of the country. Our research hypothesis was confirmed, since the richness of species cited for meat consumption was positively associated with the amount of work carried out by the states of the federation. We identified a total of 321 species of wild vertebrates mentioned in the categories involving the consumption of bushmeat. We had a greater bird species richness mentioned for consumption (170) to the detriment of mammals (107), reptiles (40) and amphibians (4). Furthermore, in the articles involving the bushmeat trade categories we had 57 species of vertebrates mentioned, with mammals being the most representative in terms of species richness (29), to the detriment of birds (20) and reptiles (8). These data reinforce that birds and mammals have been the groups most used both for consumption and trade in bushmeat in the country’s regions, and it is necessary to mitigate the hunting exploitation of these groups. We recorded that socioeconomic, biological, environmental and sociocultural factors were the most cited predictors of the consumption and trade of bushmeat in the articles. We identified that the bushmeat trade chain is dynamic and ramified, made up of several actors, including specialized and diversified hunters, intermediaries, market sellers, market vendors, restaurant owners and final customers. Public markets and open-air fairs were the most cited places for buying and selling wild meat in commerce.

Conclusions In general, our results indicate that we have made significant advances in publications on the consumption and trade of bushmeat in Brazil over the last few years. However, we highlight the need to better understand the patterns of consumption and trade of bushmeat in different regions of the country, as well as the factors

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associated with the dynamics of the trade chain and uses of wildlife by local communities. We emphasized that a multidimensional understanding of hunting activities is important to face socio-ecological problems and improve the conservation of target species which have continually been explored for uses by populations in different regions of the world.

Keywords Wildlife, Food consumption, Trade chain, Ethnozoology, Conservation

Background

Historically, hunting wild animals played a significant role in the evolution of humanity and the formation of cultures around the world [1, 2]. In the current context, hunting still plays an important role in the survival of human populations, which use wild fauna species as a source of food, medicinal use, commercial, ornaments, clothing, magical-religious, *pets*, social relationships in general, among other purposes [2–7].

The different uses of wild fauna by human societies have encouraged hunting practice, a secular activity of relevant socioeconomic and cultural importance, especially for people from tropical and neotropical forests [8, 9]. Hunting is a practice considered successful in the exploitation of faunal resources; bushmeat, for example, is an important faunal resource used as ensuring food safety and income generation thousands of populations in tropical regions of the world, mainly in Africa, Asia and Latin America [10–13]. In the current context, the use of wild animals for food consumption continues to contribute to the diversification of the diet throughout the world [14–16]. For example, a study by Nielsen et al. [11] estimated that between 230 and 833 million people living in the tropics depend on the meat of wild vertebrates (amphibians, reptiles, birds and mammals) as a source of protein. In urban regions of Central Africa, for example, it is estimated that populations consume more than 4.5 million tons of bushmeat annually in the Congo basin [17, 18].

However, in recent decades, the use of wild animals for their meat has gone from just a source of food and income for rural tropical populations, to a commodity exploited for profit to supply urban areas [19, 20]. This increase of trade urban has increased the prices of bushmeat products, intensified bushmeat harvests and affected hunting patterns and wildlife utilization in the tropics [13, 21, 22]. For example, studies estimate that around 100 million wild animals are traded annually in the tropics, comprising around 6000 species, with an annual global value of US\$7 to US\$23 billion [19, 20].

The increase in the exploitation of wild fauna by populations in the tropics, on the other hand, has made the levels of use of wild animals unsustainable, directly impacting the conservation of biodiversity [23, 24]. The impacts of unsustainable hunting for wild animal meat

threaten the survival of several species that live in the world's tropical forests, mainly primates, large ungulates (such as tapirs and peccaries) and large birds such as curassows, in addition to ecological consequences [23, 25–28].

The practice of hunting in Brazil, despite the context of illegality [29], is permitted only for indigenous peoples and local communities in case of hunger. However, bushmeat hunting continues to be practiced in all regions and biomes [30]. The persistence of hunting in the country has been associated with different socioeconomic, political and cultural contexts, with bushmeat having nutritional importance and generating income for income for several rural and urban populations [31–36]. In the current context, dependence on bushmeat as a nutritional, economic and cultural component for subsistence is still a prevalent reality in many communities in rural and urban areas of Brazil [37–39]. A study by Nyaki et al. [22], for example, estimated that approximately 10 thousand tons of meat from hunting is consumed annually by urban populations residing in the central Brazilian Amazon.

Despite the wide dissemination of hunting and uses of wild fauna and the importance of exploring these resources in Brazil, studies that address hunting are incipient when compared to other parts of the tropics [9, 40, 41]. Most ethnozoological publications carried out in the country have focused on the use of wild animals as a source of meat, traditional medicine and *pets*, mainly due to the greater wealth of species exploited and commercialized for these purposes [7, 14, 42, 43]. Nonetheless, there are several gaps in information about hunting and uses of fauna that need to be filled, mainly about the richness of species exploited for consumption and trade in bushmeat in regions of Brazil [41].

Ethnozoological studies can contribute to the implementation of public policies aimed at the management and conservation of wild fauna [6]. In this context the present evaluated the current situation of publications on the consumption and trade of wild vertebrate meat in the regions of Brazil from 2011 to 2021. More specifically, we sought to identify the richness of animal species exploited for consumption and trade bushmeat in the country's regions and verifying the factors associated with the consumption and trade chain. We tested the

hypothesis that the richness of species cited for bushmeat consumption would be greater in the states of the federation with a greater number of selected consumption publications.

Methods

Data collection

We delimited our review to scientific articles on the theme of consumption and trade of wild vertebrate meat carried out in the federative units of Brazil between the years 2011 and 2021. We searched the following databases: Google Academic, Science Direct, Scopus, Web of Science and Portal de Periódico da CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior). To do this, we used combinations of carefully selected keywords in Portuguese, English and Spanish (Table 1).

We initially selected the scientific publications by reading and analyzing the titles and abstracts, applying the following inclusion criteria: (1) mention of the use of wild vertebrates for consumption and the hunting meat trade in Brazilian federative units; (2) mention of factors driving the consumption of wildmeat vertebrate; (3) mention of aspects of the bushmeat trade chain. In addition, we selected additional papers found in the reference lists of the articles found in the databases and that met the inclusion criteria.

In the second stage all articles initially selected were read in full, and we excluded articles based on the following criteria: (1) use of wildmeat vertebrate only as a source of nutritional value and its relationship with human health; (2) use of bushmeat and the transmission of pathogens and zoonotic diseases; (3) use of bushmeat for zootechnical purposes and associated products; (4) consumption and trade in the meat of aquatic animals (fish, mollusks, crustaceans) and other groups of invertebrates.

We exclude also duplicate works, books, book chapters, conclusion of course works, dissertations, theses, simple or complete abstracts published in proceedings of scientific events, and scientific review articles with data collected in more than 1 year, in order to avoid data overlap. Thus, we classified the selected final articles into three categories: (1) exclusive consumption of bushmeat; (2) consumption and trade bushmeat and (3) exclusive trade of bushmeat (Additional file 1). In our review we followed the guidelines and protocols PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) [44].

In our database searches we identified a total of 7.557 results. In the primary searches we selected 389 articles: Google Scholar ($n=210$), Portal de Periódicos da CAPES ($n=71$), Science Direct ($n=14$), Scopus ($n=34$) and Web of Science ($n=60$). From this total, we excluded

307 duplicate articles. We had 88 articles that had their title and abstract analyzed, and 15 were excluded for not meeting the inclusion criteria. We analyzed the full text of 73 articles, 10 of which were eliminated after applying the exclusion criteria. We additionally selected 26 articles identified from reference lists of articles in the databases. Thus, we included 63 articles in our final quantitative synthesis (Fig. 1).

Data analysis

We used descriptive statistical analyses to compile the following information from the articles: species richness cited for bushmeat consumption and trade, nature or category of the papers, author(s), place and year of publication, type of environment or collection area, phytogeographic domain, drivers of consumption and trade, aspects of the trade chain: places of purchase and sale, forms of commercialization and actors involved, and aspects of wildlife conservation.

We applied a nonparametric Spearman's correlation analysis, after testing the assumptions of normality, to verify whether the richness of wild vertebrate species cited for consumption and trade in bushmeat was associated with the number of studies cited by states of the federation. All statistical analyses were performed using the R *version software* 4.1.2 [45], at a significance level of 5.0% ($p < 0.05$). In parallel, we developed a map to better understand the distribution of the number of papers per federative unit and the richness of species cited for consumption in each state. To prepare the map we used the Geographic Information System tool (SIG) *software QGIS, version* 3.16.

Nomenclature and conservation status of wildlife

The systematic ordering and scientific nomenclature of taxa followed [46] for birds; [47] for mammals, [48] for reptiles and [49] for amphibians. We verified the conservation status of the species through the Red List of Threatened Species of the IUCN (International Union for Conservation of Nature) [50] and Official List of Brazilian Fauna Species Threatened with Extinction [51].

Results

Overview of research on consumption and trade of bushmeat in Brazil

The 63 scientific publications selected on the consumption and trade of wild vertebrate meat in the regions of Brazil were distributed in greater numbers in the bushmeat consumption category ($n=54$; 85.7%), followed by bushmeat consumption and trade ($n=6$; 9.5%) and exclusively bushmeat trade ($n=3$; 4.7%) (Additional file 1). When analyzing the graph of the temporal distribution of the selected papers, we identified a

Table 1 Results of searches and combinations of keywords applied databases in the period of 2011 to 2021 in Brazil

Keywords	Results GA	Articles selected	Results PPC	Articles selected	Results SC	Articles selected	Results SD	Articles selected	Results WS	Articles selected
<i>Keywords in Portuguese</i>										
"Carne de caça" + consumo + vertebrados + Brasil	160	09	28	0	-	-	-	-	-	-
"Carne de caça" + caça + vida selvagem + Brasil	166	03	47	0	-	-	-	-	-	-
"Carne de caça" + comércio + ilegal + Brasil	561	0	12	0	-	-	-	-	-	-
"Carne de caça" + urbano + rural + Brasil	872	0	13	0	-	-	-	-	-	-
"Carne de caça" + colheita + animais silvestres + Brasil	369	0	90	0	-	-	-	-	-	-
<i>Keywords in English</i>										
"Bushmeat" + consumption + vertebrates + Brazil	248	17	238	0	41	0	73	0	40	0
"Bushmeat" + hunting + wildlife + Brazil	717	07	171	0	25	0	75	0	14	0
"Bushmeat" + trade + illegal + Brazil	528	0	180	0	13	0	122	0	11	0
"Bushmeat" + urban + rural + Brazil	464	0	185	0	39	0	14	0	16	0
"Bushmeat" + harvest + wild animals + Brazil	164	0	158	0	52	0	60	0	04	0
<i>Keywords in Spanish</i>										
"Carne de monte" + consumo + vertebrados + Brasil	97	0	24	0	-	-	-	-	-	-
"Carne de monte" + caza + fauna salvaje + Brasil	420	0	21	0	-	-	-	-	-	-
"Carne de monte" + comercio + ilegal + Brasil	397	0	12	0	-	-	-	-	-	-
"Carne de monte" + urbano + rural + Brasil	351	0	19	0	-	-	-	-	-	-
"Carne de monte" + cosecha + animales silvestres + Brasil	236	0	10	0	-	-	-	-	-	-
Total	5,750	36	1,208	0	170	0	344	0	85	0

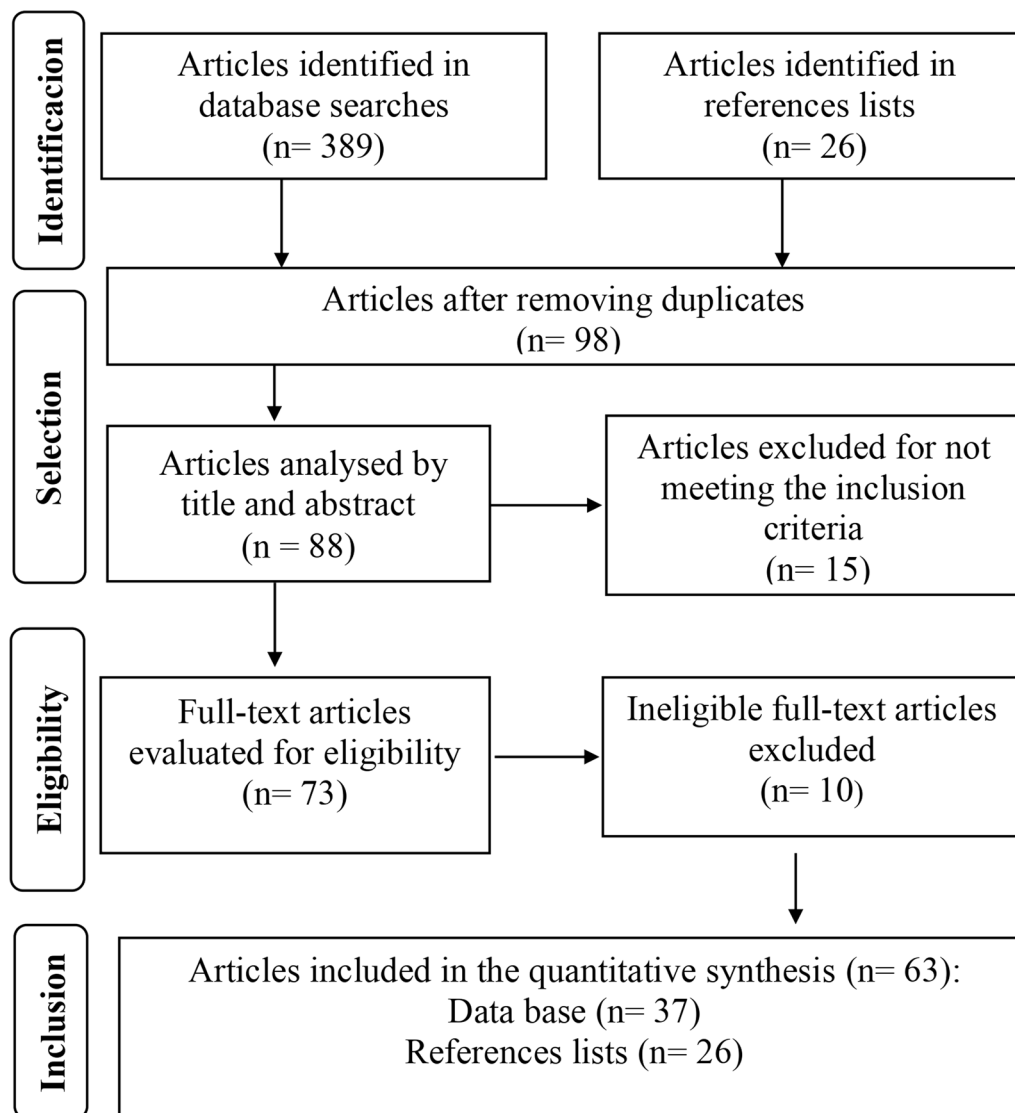


Fig. 1 PRISMA flowchart with the stages of the process of identification and inclusion of articles. *Source:* Authors (2022)

considerable increase in the number of publications, especially in the bushmeat consumption category, in the last 5 years (2017–2021), while the other categories remained stable throughout years (Fig. 2).

Publications registered in 16 states of the federation were selected (i.e., 62% of the total). The majority in the states of the Northeast region of Brazil ($n=36$; 57.1%), followed by the North ($n=26$; 41.2%) and Southeast ($n=1$; 1.6%). On the other hand, in the South or Central-West regions we did not have articles selected in our review.

In terms of phytogeographic domains, the papers were distributed across the following Brazilian biomes: Caatinga ($n=28$; 44.4%), Amazonia ($n=26$; 41.3%),

Atlantic Forest ($n=3$; 4.7%), Cerrado ($n=1$; 1.6%) and two or more biomes ($n=5$; 7.9%). Most articles had data collected in rural areas ($n=40$; 63.4%), urban/rural ($n=8$; 12.6%), urban/peri-urban ($n=5$; 7.9%) and unspecified environments ($n=10$; 15.8%).

Richness of wild vertebrates for consumption for bushmeat

We recorded 321 wild vertebrates species in the 54 papers in the bushmeat consumption category. In this category, birds had the highest species richness ($n=170$; 52.9%), followed by mammals ($n=107$; 33.3%), reptiles ($n=40$; 12.4%) and amphibians ($n=4$; 1.2%) (Additional file 2).

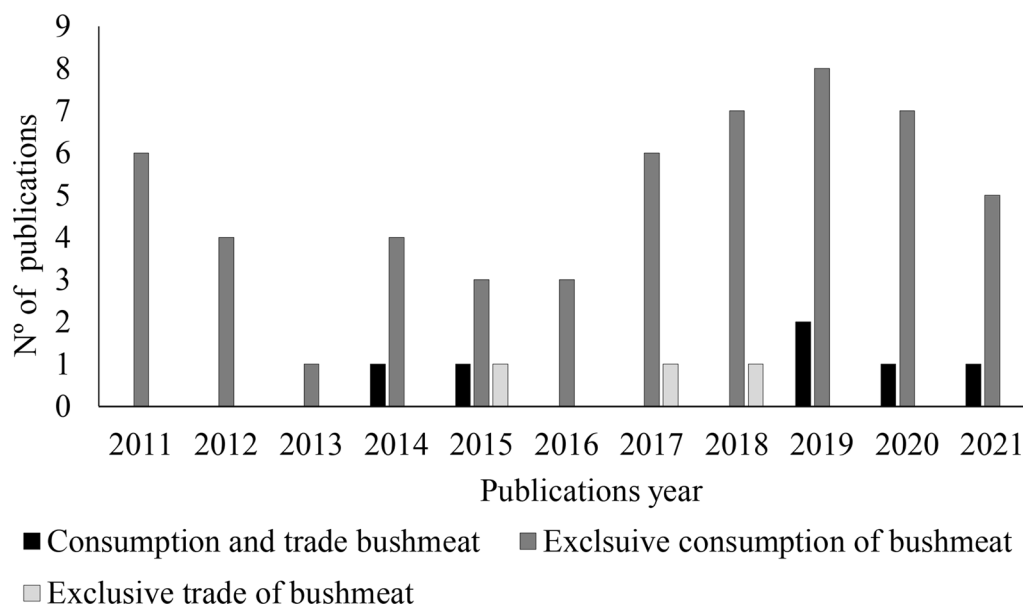


Fig. 2 Temporal distribution of articles in the categories of consumption and trade of bushmeat in Brazil between 2011 and 2021. Source: Authors (2022)

Comparing the richness of birds species mentioned for consumption between regions of the country, we had a higher proportion of species recorded in states in the Northeast region of Brazil ($n=132$; 77.2% of the total), followed by the North ($n=50$; 29.2%) and Southeast ($n=2$; 1.2%). We also had a higher proportion of birds families registered for consumption in the Northeast region of the country ($n=40$ families; 86.9% of the total), followed by the North ($n=13$; 28.3%) and Southeast ($n=2$; 4.3%) (Additional file 2).

In general, the most representative families of birds cited for consumption in terms of species were Columbidae ($n=19$), Cracidae ($n=18$) and Tinamidae ($n=17$). Among the birds species most commonly recorded in Brazil, especially in the northeastern states, we highlight the columbiformes *Zenaida auriculata* (avoante), *Columbina picui* (turtledove), *Columbina minuta* (cinnamon-winged turtledove), *Columbina talpacoti* (purple turtledove), *Leptotila verreauxi* (juriti-pupu) and *Patagioenas picazuro* (white-winged dove). Among the tinamiformes most cited in the papers were *Crypturellus parvirostris* (inhambu-chororó), *Crypturellus tataupa* (inhambu-chintã), *Nothura boraquira* (northeast quail) and *Nothura maculosa* (yellow quail). and among the cracids, the species *Pauxi tuberosa* (Razor-billed Curassow), *Penelope superciliaris* (Rusty-margined Guan) and *Penelope jacquacu* (Spix's Guan) (Additional file 2).

Comparing the richness of mammal species cited for consumption between regions of the country, we had a higher proportion of species recorded in states in the

North region ($n=77$; 72.0% of the total), followed by the Northeast ($n=59$; 55.1%) and Southeast ($n=9$; 8.4%) (Additional file 2). Similar to species richness, we had a higher proportion of mammal families recorded in the states of the North region of the country ($n=24$; 85.7%), followed by the Northeast ($n=21$; 75%) and Southeast ($n=7$; 25.0%).

In general, among the families with the greatest richness of species mentioned, we highlight Cebidae ($n=13$), Atelidae ($n=11$) and Dasyproctidae ($n=8$). Among the species with the most records for consumption in the regions of the country, especially the North and Northeast we highlight *Pecari tajacu* (Collared Peccary), *Dasypus novemcinctus* (Nine-banded Armadillo), *Cuniculus paca* (Paca), *Euphractus sexcinctus* (Six-banded Armadillo), *Tamandua tetradactyla* (Tamandua Gray), *Hydrochoerus hydrochaeris* (capybara), *Tayassu pecari* (Peckerel), *Kerodon rupestris* (Rock cavy) and *Tapirus terrestris* (Tapir) (Additional file 2).

Comparing the richness of reptile species mentioned for consumption between regions of the country, we had a higher proportion of species mentioned in the states of the Northeast region ($n=28$; 70.0% of the total), followed by the North ($n=17$; 42.5%) and Southeast ($n=1$; 2.5%). Similar to wealth, we recorded a higher proportion of families cited for consumption in the Northeast region ($n=14$; 93.3%), followed by the North ($n=4$; 26.7%) and Southeast ($n=1$; 6.7%).

Among the reptile families with the highest species richness mentioned were Alligatoridae ($n=6$),

Podocnemididae ($n=5$) and Cheloniidae ($n=4$). Among the species of reptiles most commonly recorded in articles in the regions of the country, we highlight *Salvator merianae* (tegu), *Iguana iguana* (iguana), *Podocnemis unifilis* (yellow-headed sideneck turtle), *Podocnemis expansa* (Amazonian tortoise), *Podocnemis sextuberculata* (six-tubercled amazon river turtle), *Chelonoidis denticulatus* (yellow-footed tortoises) and *Caiman crocodilus* (common caiman) (Additional file 2). In the group of amphibians we had only 4 species mentioned for consumption, distributed in the families Lepidodactylidae, Ranidae and Bufonidae, all with records in studies from the Northeast region of the country (Additional file 2).

Our hypothesis that the richness of species cited for meat consumption would be positively associated with the amount of work carried out by states of the federation was confirmed (Spearman's $R=0.92$; $p<0.05$). The state of Paraíba had the highest richness of cited

species ($n=119$ spp.) and consequently more publications selected ($n=16$ articles). On the other hand, the state of Sergipe had the lowest representation of species ($n=7$ spp.) and consequently the lowest number of articles ($n=1$) (Fig. 3).

Richness of wild vertebrates in bushmeat trade works

We identified a total of 57 species of wild vertebrates mentioned in articles involving the bushmeat trade categories. The group of mammals presented the greatest richness of species mentioned ($n=29$ spp.; 50.8%), followed by birds ($n=20$; 35.1%) and reptiles ($n=8$; 14.0%). Of the total recorded, we had only 8 species cited exclusively for the bushmeat trade (Additional file 3).

Comparing the number of birds species cited for the bushmeat trade between the regions of the country, we found a higher proportion of records in the Northeast region ($n=11$; 55.0%), followed by the North ($n=10$; 50.0%); we had no records in other regions of the country.

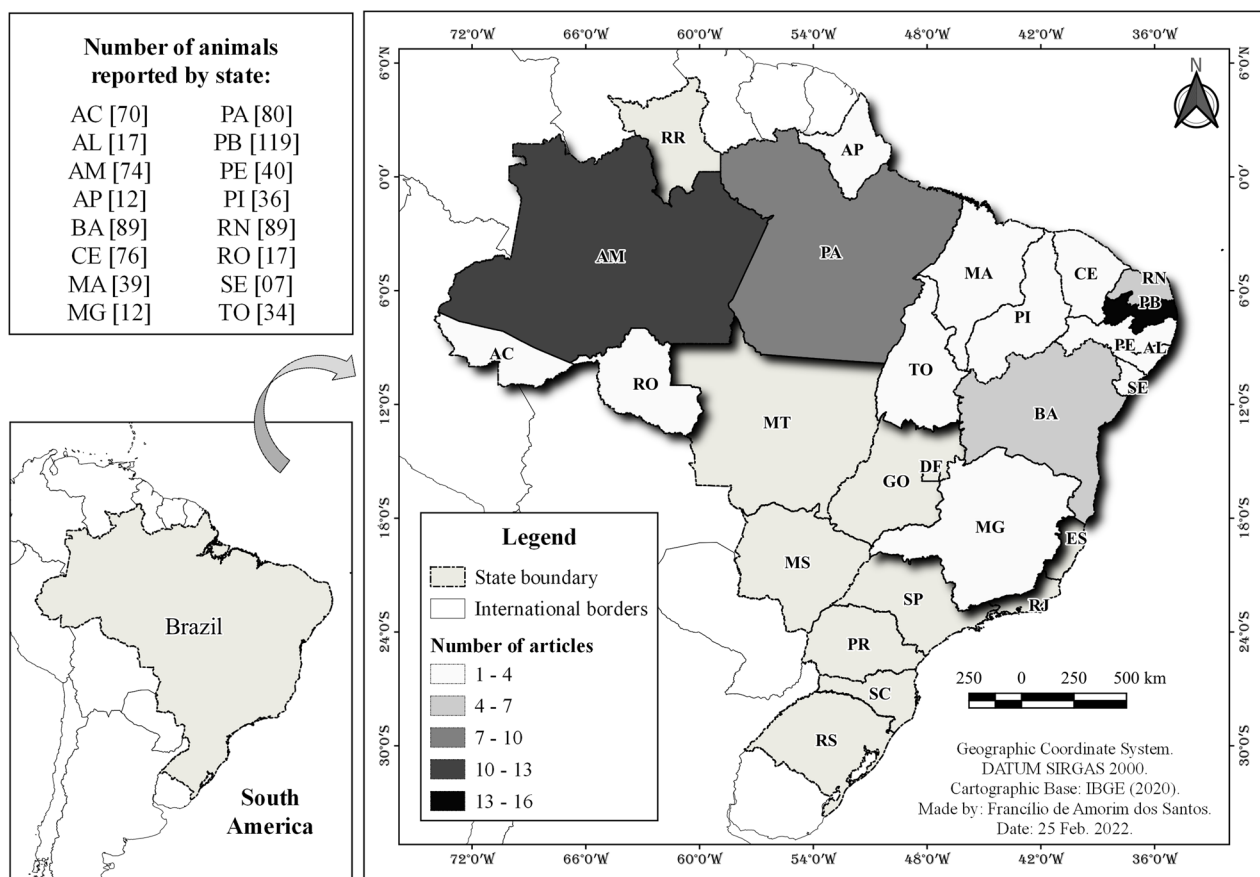


Fig. 3 Distribution map of articles and number of wild vertebrate species cited for bushmeat consumption in Brazilian states in the period from 2011 to 2021. Legends: Brazilian states (AC Acre, AL Alagoas, AP Amapá, AM Amazonas, BA Bahia, CE Ceará, ES Espírito Santo, GO Goiás, MA Maranhão, MG Minas Gerais, MS Mato Grosso do Sul, MT Mato Grosso, PA Pará, PE Pernambuco, PI Piauí, PB Paraíba, PR Paraná, RJ Rio de Janeiro, RR Rondônia, SC Santa Catarina, SE Sergipe, SP São Paulo, TO Tocantins, RN Rio Grande do Norte, RO Roraima, RS Rio Grande do Sul) and federal district (DF Distrito Federal)

In relation to families cited for commerce, the North region had the highest proportion of registrations ($n=4$; 80.0%), followed by the Northeast ($n=3$; 60.0%). Among the most representative birds families in species for trade in the country's regions, we highlight Columbidae ($n=8$), Cracidae ($n=7$) and Tinamidae ($n=3$). Among the species with the highest frequency of records in the regions, we highlight *Crax sp.*, *Pauxi tuberosa*, *Nothura boraquira* (White-bellied Nothura) and *Crypturellus sp.* (Additional file 3).

The region of the country with the highest proportion of mammal species richness cited for trade was the North ($n=19$; 65.5% of the total), followed by the Northeast ($n=12$; 41.4%). In relation to families cited for commerce, the North region had the highest proportion of registrations ($n=13$; 92.8%), followed by the Northeast ($n=8$; 57.1%). Among the families cited for commercialization, we highlight Dasypodidae ($n=5$), Dasyproctidae ($n=4$) and Cervidae ($n=3$) as the most significant species. Among the most frequent species in the articles we highlight *Cuniculus paca*, *Pecari tajacu*, *Tayassu pecari*, *Dasypus sp.*, *Tapirus terrestris*, *Hydrochoerus hydrochaeris* and *Subulo gouazoubira* (brocket deer).

Among reptiles, we identified 8 species cited for the bushmeat trade, with a higher proportion of records in the North region of the country ($n=8$; 100.0%) and Northeast region ($n=1$; 12.5%). Similar to species richness, the highest proportion of family records was in the North region ($n=3$; 100.0%) and Northeast region ($n=2$; 66.7%). The families recorded were Podocnemididae ($n=4$ spp.), Alligatoridae ($n=3$) and Testudinidae ($n=1$). The species *Caiman crocodilus*, *Chelonoidis denticulatus*, *Podocnemis unifilis* and *Podocnemis expansa* were among the most cited in the articles, especially from the northern region of the country. In the selected articles we

did not record any amphibian species mentioned for the bushmeat trade.

Drivers of bushmeat consumption and trade

Of the total articles selected, only 10 mentioned driving factors for the consumption and trade of bushmeat. The majority are in the bushmeat consumption category ($n=8$) and the others ($n=2$) in the bushmeat consumption and trade category. These articles were mainly concentrated in the North ($n=9$; 90.0%) and Northeast ($n=1$; 10.0%) regions of the country. We grouped the consumption and trade drivers cited into 6 categories: socioeconomic factors ($n=7$ articles), biological ($n=4$), environmental ($n=3$), sociocultural ($n=3$), spatial ($n=2$) and demographic factors ($n=1$). In Table 2 we summarize the main types of drivers of hunting meat consumption and trade registered by categories.

Aspects of the bushmeat trade chain

We obtained information on aspects of the bushmeat trade chain from 8 of the 9 selected trade papers. In general, we recorded that the trade chain is dynamic and ramified with the presence of several authors, including specialized and diversified hunters, intermediaries, market sellers, restaurant owners and final customers (Table 3).

We identified that negotiations for the purchase and sale of bushmeat can occur directly, involving only hunters, traders, stallholders and end customers, or indirectly through intermediaries who carry out commercial transactions with end customers. Commercial transactions with end customers took place in the hunters own homes, and intermediaries were facilitated by the use of means of transport (e.g., motorcycles) and communication (e.g., cell phones) (Table 3).

Table 2 Description of the factors drivers bushmeat consumption and trade identified in articles published in Brazil between 2011 and 2021

Drivers of bushmeat consumption and trade	Description of factors associated with the consumption and trade of bushmeat	References
Socioeconomic factors	Income, wealth, origin of head of household, level of education, socioeconomic indices (percentage of rural population, HDI, GDP per capita), number of hunters in the family, length of stay in the community, origin of bushmeat, family size, average family age, age of hunter, number of children, poverty probability index (PPI), number of years the head of household has left the rural area	[24, 26, 45, 52–55]
Biological factors	Biomass and species abundance	[24, 45, 52, 55, 56]
Sociocultural factors	Meat flavor preference, social structures: kinship relationships, social marketing: discount coupons, information campaign and engagement to reduce the consumption of wild bushmeat	[45, 50, 52, 55, 56]
Environmental factors	Seasonal variations: dry and rainy season, forest cover, landscape contexts	[54, 56, 57]
Spatial factors	Distance and remoteness from urban center	[54, 57]
Demographic factors	Location, river type, market access: frequency of city trips and boat traffic in communities	[53]

Table 3 Description of the aspects of the wild vertebrate meat trade chain listed in the bushmeat trade papers published

Aspects of the trade chain	Description of the main aspects of the trade chain	References
Main actors and drivers in the trade chain	Specialized and diversified hunters, middlemen/resellers, market traders and vendors, stallholders, street vendors, chopbars/restaurant owners, wholesalers, retailers and consumers from local fairs	[24, 28, 29, 34, 45–48]
Ways of selling bushmeat	Fresh (<i>in natura</i>), frozen, smoked, salted and live animal	[28, 34, 46–48]
Places to buy and sell bushmeat	Markets, street markets, formal and informal restaurants, chopbars, street food stalls, end customer homes, residence of hunters and intermediaries, rural communities, riverboats, ports, family homes	[24, 28, 29, 34, 45–48]
Main end customers and consumers in the trade chain	Urban residents (teachers, merchants, civil servants, wholesalers, family members, friends and neighbors); customers of chopbars and restaurants; settler or mestizo families; indigenous and non-indigenous consumers; tourists and shoppers	[24, 28, 29, 34, 45–48]

In 5 five articles did we mention the ways in which bushmeat was sold. The meat was sold fresh (*in natura*), frozen, salted, smoked or even the animal alive. The main locations for buying and selling wild meat are most mentioned in our study in public markets, book fairs, chopbars, restaurants and residences of hunters, parents and intermediaries. We found that meat was intended mainly for urban residents, such as public officials, such as attackists, customers of small chopbars and restaurants, settler or mestizo families, indigenous and non-indigenous consumers and even tourists (Table 3).

Conservation aspects of wild fauna

Of the 321 specific species in our study, the majority ($n=212$; 77.3%) were included in the Least Concern (LC) category in the Red List of threatened species of the IUCN. Only 41 species were included in the endangered categories: Vulnerable (VU) ($n=29$), Endangered (EN) ($n=10$) and Critically Endangered (CR) ($n=2$) (Additional file 2 and Additional file 3).

In the Endangered (EN) category we register the species of birds: *Crax blumenbachii* (red-billed curassow) and *Crax globulosa* (Wattled curassow). Among the mammals we have the species: *Sylvilagus brasiliensis* (Brazilian rabbit), *Ateles chamek* (Peruvian spider monkey), *Lagothrix poeppigii* (Silvery woolly monkey), *Leontopithecus chrysomelas* (Golden-headed lion tamarin), *Chiropotes satanas* (Black cuxiú) and *Sotalia fluviatilis* (Gray river dolphin) and 2 reptile species: *Chelonia mydas* (Green turtle) and *Lepidochelys olivacea* (Olive ridley turtle). In the category Critically Endangered (CR) we had the species: *Sapajus xanthosternos* (Yellow-breasted monkey) and *Eretmochelys imbricata* (Hawksbill turtle). In List of Brazilian Fauna Species Threatened, we identified 28 species included in threat categories: Vulnerable (VU; $n=21$), Endangered (EN; $n=5$) and Critically Endangered (CR; $n=2$) (Additional file 2 and Additional file 3).

Discussion

Publications on bushmeat consumption and trade in Brazil

The growing in articles on bushmeat consumption and trade observed in recent years in our search is not surprising. Considering that in recent decades we have seen the insertion of new graduate programs in the country, the entry of new researchers, an increase in the number of newspapers that will certainly increase the Ethnological publications in the Brazil [41, 56, 58, 59]. Also, the increase of researchers with specific training in the fields of Ethnobiology and Ethnzoology and the existence of links between Brazilian researchers and from other international countries make Brazil a reference in this field in the Latin American context [56, 58–60].

As we verified, the North and Northeast regions of the country concentrated the largest number of articles selected in our research. The high number of publications in states in the Brazilian Northeast, such as Paraíba, Pernambuco and Bahia, for example, may be associated with research groups in Ethnobiology and related areas that have already consolidated themselves in different networks of scientific collaborations in these regions and in other Brazilian regions with international institutions and research centers [41, 58, 61].

The growth of scientific production in the North of the country may have been favored by the establishment of research centers in the areas of Environmental Sciences and Ecology, for example, such as the Museu Paraense Emílio Goeldi (MPEG) and Instituto Nacional de Pesquisas da Amazônia (INPA) [58]. In these centers experienced researchers have carried out, for example, several investigations into hunting monitoring activities and uses of wildlife by populations in the Amazon regions [22, 37, 39, 43, 62–64].

On the other hand, the low frequency of articles selected in the Southeast, Central-West and South regions of the country is possibly due to the scarcity of studies on hunting carried out in these regions, as pointed out by [41, 58] in publication review research

Ethnozoological and hunting in Brazil, respectively. Thus, we confirm the need for more ethnozoological research in regions of the country that are still little explored. These investigations can provide more accurate information about species hunted for different uses by local communities and contribute to providing important data to be used in management strategies and wildlife conservation policies.

Uses of wildlife for bushmeat consumption

In our research, the group of birds presented the greatest richness of species and families cited for consumption, with emphasis on records in states in the Northeast region of Brazil. These results reflect the trend of birds richness in the Brazilian semi-arid region (Caatinga biome), which is the largest compared to other groups of wild terrestrial vertebrates, with around 548 birds species recorded [65] against 156 mammal species [66] and 224 from reptiles [67].

The preference of populations in the Brazilian semi-arid region for the consumption of small animals with hunting potential, such as birds, may be related to the population decline of medium and large mammals species, such as deer, peccaries, pacas, agoutis, which have been suffering in recent years with the defaunation process [31, 66, 68]. Other aspects related to the greater wealth of birds cited for consumption are due to the way in which species can be captured, both through active hunting (e.g., using shotguns) and through the use of various non-selective hunting techniques [31, 69].

The preference for consuming birds from the families Columbidae, Tinamidae and Cracidae verified in our research reflects the importance of these groups, as they provide sources of proteins essential for the survival of rural and urban populations in Brazilian regions, especially in the semi-Brazilian region (Caatinga biome) [3, 4, 33, 70, 71]. In addition to protein value, aspects for example, meat flavor, abundance and availability, socio-cultural contexts, ease of capture, gregarious behavior of small species (e.g., *Zenaidura macroura*), have been strong determinants for the exploitation of birds species by urban and rural populations in Brazil [34, 52, 72–74].

In our research, the group of mammals also stood out in the richness of species and families cited for consumption of bushmeat, with the majority of citations in the states of the northern region of the country. In the border regions of the Brazilian Amazon, for example, mammals represent the preferred species for consumption compared to reptiles and birds [53, 75–77]. These results also reflect the tropics scenario, in which mammals are the main hunting targets, supposedly because they provide greater protein return (body biomass) and meat supply [54, 57, 76, 78].

The preference for mammal species is not limited to body biomass alone; other aspects have been highlighted in the literature, such as the taste of the meat, abundance and availability of the species, ease of capture, cost–benefit and commercial value [7, 79–84]. For example, the species *Cuniculus paca* is one of the most appreciated for consumption in tropical regions, mainly due to the greater biomass and the flavor of the meat [35, 36, 81, 84, 85]. In South America, armadillos (*Dasypus* sp.), for example, are among the most hunted mammals for food or commercial consumption and their hunting is favored by a widespread perception that meat or products of animal origin are tastier or cleaner than those derived from household products animals [7, 34, 35, 80, 82, 86].

The consumption of reptile species was also highlighted in our research, with a greater incidence in the North region of the country. Previous studies have reported several species of chelonians, especially tortoises (*Chelonoidis denticulatus* and *Chelonoidis carbonaria*) and river tartars (*Podocnemis unifilis*, *Podocnemis sextuberculata* and *Podocnemis expansa*) being the most commonly hunted for consumption and trade in rural and urban regions of the Brazilian Amazon [35, 64, 87, 88]. According to [89], freshwater chelonians have been used as a food resource in the Amazon since the pre-Columbian period. Several historical records made by naturalists and colonizers attest to a significant exploitation of adult individuals and eggs of twelve-water chelonians in the Amazon, with emphasis on the genus *Podocnemis* [90, 91].

Currently, the consumption and trade of chelonian species to meet the demands of regional and even international markets is already significant. A recent study by [64] estimates that approximately 1.7 million turtles and tortoises can be consumed annually in urban centers in the central Amazon. Another recent study by [92] identified that turtle species, especially *Podocnemis unifilis* and *Podocnemis sextuberculata*, were among the main species whose meat and eggs were consumed and sold by hunters in tropical areas of the Eastern Amazon. In this context, we highlight the need to reinforce protection, inspection and awareness measures among local populations, in order to guarantee the sustainable management of Amazonian chelonian species, without putting them at risk of extinction.

The hunting importance of the *Salvator merianae* and *Iguana iguana* species highlighted in our study has also been widely recorded in different regions of the world, especially in Latin American countries [4, 93–95]. In addition to meat, other animal body parts (e.g., fat) have been used in traditional medicine to treat various diseases and illnesses, as evidenced by previous neotropical studies [42, 55, 96–98].

The low number of amphibian species for consumption found in our research may be associated with factors such as availability of other sources of animal protein, lack of eating habits, disease transmission, aversion and fear of the toxicity of these small animals in local populations [99, 100]. In this sense, these sets of factors make amphibians less attractive as a food source for local populations. Furthermore, in the literature there are few studies on the use of amphibians for consumption in the Neotropical regions of the world, including Brazil [101–103].

Therefore, our results reflect that in the current context, hunting and the consumption of game meat in Brazil are still common activities and play an important socioeconomic role. As we have shown, many species of wild vertebrates continue to provide a crucial source of protein for several rural and urban families, especially in the North and Northeast regions of the country, which do not have other sources of domestic protein.

Wildlife uses in the bushmeat trade

Most of the scientific production on the use of wild fauna in the wild meat trade has been concentrated in the Northern region of Brazil, mainly because urban wild meat markets are already more established in Amazonian cities on the triple border (Brazil–Peru–Colombia), with a large volume of wild animals being sold [12, 35, 103, 104]. For example, there are significant urban wild meat markets in cities such as Pompéia, Ecuador [105], Abaetetuba in Pará, Brazil [106] and the cities of Letícia, Tabatinga, Benjamin Constant and Caballococha in the Amazon triple border region [12].

Since the trade of bushmeat is common in many Amazonian markets, it is difficult to obtain more information on the commerce of wild animal meat, mainly because the purchase and sale of wild animals is carried out illegally [107]. Furthermore, most of the information on bushmeat sold in South American cities derives largely from confiscations by environmental agencies [108] and, therefore, the quality of these data can be questioned in terms of its representativeness global trade.

The greater exploitation of mammal species in the bushmeat trade has also been recorded in other Neotropical studies [13, 109–112]. Our results showed a greater record of mammal species traded mainly in regions of the Brazilian Amazon. A study by [22], for example, identified the species *Tayassu pecari* (peccary) and *Tapirus terrestris* (tapir), together with chelonians (*Podocnemis unifilis* and *Podocnemis sextuberculata*) as responsible for 71.8% of the amount of bushmeat consumed in urban markets in the Central Amazon. Another recent study by [92] found that the meat of the species *Hydrochoerus hydrochaeris* (capybara) was the most widely cited among

the species traded by local communities living in floodplain areas in the Brazilian Amazon.

Compared to mammals, the diversity of birds species exploited for the bushmeat trade in our study was lower. Although birds make up the smallest proportion of meat sold in markets, many species, including columbiformes, tinamiformes and cracids, are still hunted and traded as shown in neotropical literature [109–111, 113]. In the Brazilian Amazon basin, for example, a large volume of cracids (e.g., *Crax sp.*; *Penelope sp.*) have been illegally traded in urban and rural markets [12, 22, 37, 87, 90].

The reptile group had a greater participation of species cited for the bushmeat trade in the Northern region of Brazil. These results reflect the fact that in regions of the Brazilian Amazon, for example, several species of tortoises and turtles to the families Podocnemididae (e.g., *Podocnemis unifilis*, *Podocnemis expansa*) and Testudinidae (e.g., *Chelonoidis denticulatus*) are frequently consumed and valued as a local cultural delicacy [22, 35, 54, 114]. A recent study by [92], for example, identified 6 species of turtles of the genus *Podocnemis* as responsible for around 71% of the species cited for bushmeat trade in lowland communities in the eastern Amazon.

In the current context of increasing human populations, the bushmeat trade has increased dramatically over the last three decades in the tropics [13, 22, 112]. This increase in the illegal trade of wild animals for meat may have reached unsustainable levels, as the natural regenerative capacity of wildlife populations may not be high enough to meet the demand for bushmeat [112]. Against this background, unsustainable harvesting of wild meat in many tropical forests continues to threaten the survival of a wide range of wild species, as well as the food security of populations that depend on these resources as a means of survival [23, 26].

Drivers of bushmeat consumption and trade

We identify a wide range of socioeconomic, biological, environmental and sociocultural factors associated with bushmeat consumption and trade. Interactions between humans and wildlife are affected by complex factors including income source, taste preference, culture, lack of alternative meat, meat price and wealth that regulate the ways in which local populations utilize wildlife resources [18, 38, 115–117].

However, hunting factors and bushmeat consumption are complex and can vary between different socioecological contexts and depending on usage patterns by local populations. For example, proximity to urban centers and local forest cover can affect the demand and supply of bushmeat. According to [35] found a relationship between remoteness from urban centers and a decrease

in the availability of domestic sources of protein, resulting in high prices and a high demand for bushmeat.

Bushmeat consumption is also influenced by meat flavor preferences, as well as health, cultural and spiritual reasons [18, 115, 118]. Neotropical studies have demonstrated that cultural associations drive the consumption of game meat, as pointed out in the study by [38], which highlighted a strong association of beliefs (*taboos*), attitudes and social norms in understanding the consumption and preference of bushmeat among people urban inhabitants of the Brazilian Amazon. The study by [119], for example, in Bata, Equatorial Guinea highlighted ethnicity and nationality as the main key determinants of consumption. In this sense, understanding the socio-cultural context and economic determinants of wildlife consumption and trade is critical to inform appropriate policy interventions to prevent overexploitation and promote the sustainable use of wildlife resources [57].

Aspects of the bushmeat trade chain

Our results point to a dynamic bushmeat trade chain made up of several actors, similar to that described in studies carried out in countries in West Africa and Congo [120–122]. The existence of a diverse and dynamic trade chain highlights the complexity and extent of the problem of illegal wildlife trade. This chain involves different actors, from local hunters to intermediaries, international traffickers and end consumers, as shown in tropical studies [12, 37, 43, 87, 123].

In the current context, hunters represent true repositories of knowledge about fauna and the dynamics of exploitation of faunal, as they are directly involved in the capture and distribution of faunal products, in addition to evidently using animals for local uses [9, 124, 125]. Therefore, recognizing the importance of hunters' knowledge can be an important step toward the conservation and sustainable management of wildlife species.

The incorporation of new hunting technologies, including transportation (e.g., motorbikes, outboard boats) and communication (cell phones) by hunters, has facilitated wildlife trade transactions between different actors in the trade chain in the tropics [22, 27, 126]. On the other hand, the insertion of new technologies changed the patterns of consumption and trade of wild fauna in the tropics, increasing the demands for consumption and sale of wild animals, and consequently catalyzed contemporary processes of defaunation, with signs of reduction, extirpations and extinctions of faunal species [23, 43]. In this context, understanding the illegal wildlife trade chain and identifying the actors involved are key elements for developing effective conservation strategies to combat this problem on a global scale.

The diversification of ways of commercializing bushmeat observed in our research reflects the fact that wild animal meat has become an extremely versatile product, which can be obtained, transported, consumed immediately, stored, preserved for future consumption or even sold [52, 78, 80]. Salting and freezing are conservation methods widely used in many cultures around the world and in South American countries. The study carried out by [12], for example, found that bushmeat is commonly sold fresh in Colombia, smoked in Peru and salted or frozen in Brazil. In this context variations in the ways in which bushmeat is sold may reflect cultural differences, traditional food preparation and preservation practices, as well as regional consumption preferences.

Similar to what was found in regions of Central and West Africa, we highlight public markets and open-air markets as the main places for buying and selling bushmeat. In regions of Africa, for example, bushmeat markets are found in almost every city and play an important role as wildlife collection and trading centers [13, 109, 112].

In the current context, markets in the Brazilian Amazon basin also play an important role in the commercialization of wildlife products. In these markets, bushmeat is sold openly in open-air markets and can even be sold in the homes of hunters and intermediaries themselves, and there is, therefore, an intense commercial flow between Amazonian cities [22, 43, 62, 123, 127]. Therefore, understanding the patterns and dynamics of the bushmeat trade is an important step toward informing conservation policies, sustainable natural resource management and decision-making related to wildlife conservation and sustainable development of tropical regions and neotropics.

Implications and challenges for wildlife conservation

Although most of the species recorded in our research were listed in non-endangered categories on international and national lists, there are several aspects that need to be considered regarding faunal conservation. For example, although a species may be classified as non-threatened on global and national lists, it may be locally threatened due to factors such as loss of habitat in specific areas, illegal hunting, use of wild meat by local populations, climate change and /or other human impacts [25, 26, 128, 129].

In our research, we listed two species of cracids in categories of threat of extinction at an international level. Special attention has been given to cracid populations, one of the most threatened birds families in the Americas [130, 131]. The loss of forest habitat and excessive hunting are considered key factors in the decline in populations of some cracid species such as the Wattled Muttonbird.

(*Crax globulosa*), White-browed Guan (*Penelope jacucaca*) and other galliformes [130–132].

In our research, Primates species also stood out in the number of species listed in endangered categories. A recently carried out study found that 68% of the world's Primates species for which data are available are listed in some category of threat of extinction and 93% are in population decline [133]. Most populations of Primates species are declining and threatened with extinction worldwide due to anthropogenic pressures resulting in habitat deforestation and fragmentation, increased urbanization, hunting for meat and other by-products [133–135].

Therefore, our results reflect an urgent need to implement conservation policies for populations of threatened species, such as primates, ungulates, marsupials and large birds (e.g., cracids) that have been excessively exploited to provide meat or other animal products in the tropics [23, 26, 34, 71, 73]. Furthermore, wildlife conservation requires an integrated approach to the various aspects involved in hunting activities, whether biological, political, economic, ecological or sociocultural. It is also essential to understand the dynamics and use relationships between local communities and wildlife in order to establish effective conservation strategies adapted to local needs and realities.

Conclusions

Although the keywords used to search for publications on the consumption and trade of game meat in Brazil may produce biases and limitations to the generalization of conclusions, we consider that the articles reviewed may be a representative sample of the current situation of publications on the topic under study.

Our review study showed significant advances in publications on the consumption and trade of bushmeat in Brazil in recent years, with the majority of them concentrated in the North and Northeast regions of the country. We highlight the need for more research in regions that are still little explored, such as the South, Southeast and Central-West. Such investigation could provide greater information on the richness of target species for consumption and trade, directing more effective conservation strategies for target species.

In our research, we identified the group of birds and mammals as the most representative in terms of proportion of species richness and families cited for both consumption and trade of bushmeat in the regions of Brazil. In our research, we identified the group of birds and mammals as the most representative in terms of proportion of species richness and families cited for both consumption and trade of bushmeat in the regions of Brazil. These results reinforce the importance of game species

from these groups, which are widely distributed and used for different uses by populations in urban and rural areas of the country, especially in the Brazilian semi-arid regions (Caatinga biome).

Our results also highlighted the need for more understanding on the part of research on the factors that drive the consumption and trade of bushmeat in different regions of the country, since few selected studies made mention of these factors. We also identified that the game meat trade chain is still poorly understood in Brazil, with detailed information on this trade only in the northern region of the country.

It is hoped that the information contained in this research can serve as a basis for future research and projects involving interactions between local communities and wild animals. We reinforce the urgent need for conservation measures and wildlife management strategies that have been continuously explored in hunting activities in different regions of the world.

Abbreviations

CAPES	Coordenação de Aperfeiçoamento de Pessoal de Nível Superior
IBGE	Instituto Brasileiro de Geografia e Estatística
INPA	Instituto Nacional de Pesquisas da Amazônia
IUCN	International Union for Conservation of Nature
MPEG	Museu Paraense Emílio Goeldi
MMA	Ministério do Meio Ambiente
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
SIG	Sistema de Informação Geográfica

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s13002-023-00628-x>.

Additional file 1. List of articles on bushmeat consumption and trade selected in our study by category in our systematic review.

Additional file 2. List of wild vertebrate species cited in works on bushmeat consumption by regions in Brazil.

Additional file 3. List of wild vertebrates species cited in articles on consumption and trade bushmeat and exclusive trade bushmeat.

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Author contributions

JAAS carried out a survey of publications and collected the data. JAAS and WMSS performed the literature review. JAAS interpreted the data and wrote the manuscript. LMSS, FSF, ABS and WMSS critically reviewed and re-wrote sections of manuscript. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

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References

- Alves RRN, Souto W, Fernandes-Ferreira H, Bezerra D, Barboza R, Vieira W. The importance of hunting in human societies. In: Alves RRN, Albuquerque UP, editors. *Ethnozology animals in our lives*. London: Elsevier; 2018. p. 98–119.
- Alves RRN, van Vliet N. Wild fauna on the menu. In: Alves RRN, Albuquerque UP, editors. *Ethnozology animals in our lives*. London: Elsevier; 2018. p. 167–94.
- Alves RRN, Rocha L. Fauna at home: animals as *pets*. In: Alves R, Albuquerque U, editors. *Ethnozology animals in our lives*. London: Elsevier; 2018. p. 303–49.
- Alves RRN, Gonçalves MBR, Vieira WLS. Caça, uso e conservação de vertebrados no semiárido Brasileiro. *Trop Conserv Sci*. 2012;5:394–416.
- Policarpo IS, Barboza RRD, Borges AKM, Alves RRN. Mammalian fauna used in folk medicine among hunters in a semiarid region of Brazil. *Environ Dev Sustain*. 2019;21:1533–42.
- Alves RRN, Souto WMS. *Ethnozology: a brief introduction*. *Ethnobiol Conserv*. 2015;4:1–13.
- Souto WMS, Lima RN, Sousa BFCF. Illegal bushmeat hunting and trade dynamics in a major road-hub region of the Brazilian Mid North. *Indian J Tradit Knowl*. 2019;8(2):402–11.
- Alves RRN. Relationships between fauna and people and the role of ethnozology in animal conservation. *Ethnobiol Conserv*. 2012;1:1–69.
- Alves RRN, Albuquerque UP. *Ethnozology: animals in our lives*. 1st ed. Amsterdam: Academic Press; 2018. p. 552.
- Fa JE, Olivero J, Real R, Farfán MA, Márquez AL, Vargas JM, et al. Disentangling the relative effects of bushmeat availability on human nutrition in central Africa. *Sci Rep*. 2015;5:81–68.
- Nielsen MR, Meilby H, Smith-Hall C, Pouliot M, Treue T. The importance of wild meat in the global south. *Ecol Econ*. 2018;146:696–705.
- van Vliet N, Quiceno-Mesa M, Cruz-Antia D, Aquino L, Moreno J, Nasi R. The uncovered volumes of bushmeat commercialized in the Amazonian trifrontier between Colombia, Peru & Brazil. *Ethnobiol Conserv*. 2014;3:1–11.
- Lindsey P, Balme G, Becker M, Begg C, Bento C, Bocchino C, et al. Illegal hunting and the bushmeat trade in savanna Africa: drivers, impacts and solutions to address the problem. New York: Wildlife Conservation Society; 2015.
- Oliveira WSLD, Luna MDSO, Souto WMS, Alves RRN. Interactions between people and game mammals in a Brazilian semiarid area. *Indian J Tradit Knowl*. 2017;16:221–8.
- Powell B, Thilsted SH, Ickowitz A, Termote C, Sunderland T, Herforth A. Improving diets with wild and cultivated biodiversity from across the landscape. *Food Secur*. 2015;7:535–54.
- van Vliet N, Nebesse C, Nasi R. Bushmeat consumption among rural and urban children from Province Orientale, Democratic Republic of Congo. *Oryx*. 2015;49:165–74.
- Nasi R, Taber A, van Vliet N. Empty forests, empty stomachs? Bushmeat and livelihoods in the Congo and Amazon Basins. *Int For Rev*. 2011;13:355–68.
- Chausson AM, Rowcliffe JM, Escouffaire L, Wieland M, Wright JH. Understanding the sociocultural drivers of urban bushmeat consumption for behavior change interventions in Pointe Noire, Republic of Congo. *Hum Ecol*. 2019;47:179–91.
- Coad L, Fa J, Abernethy K, van Vliet N, Santamaria C, Wilkie D, et al. Toward a sustainable, participatory and inclusive wild meat sector. 2019.
- Nguyen M, Jones TE. Predictors of support for biodiversity loss countermeasure and bushmeat consumption among Vietnamese urban residents. *Conserv Sci Pract*. 2022;4(12):e12822.
- Nyaki A, Gray SA, Lepczyk CA, Skibins JC, Rentsch D. Local-scale dynamics and local drivers of bushmeat trade. *Conserv Biol*. 2014;28(5):1403–14.
- El Bizri HR, Morcatty TQ, Valsecchi J, Mayor P, Ribeiro JES, Vasconcelos Neto CFA, et al. Urban wild meat consumption and trade in central Amazonia. *Conserv Biol*. 2020;34:438–48.
- Ripple WJ, Abernethy K, Betts MG, Chapron G, Dirzo R, Galetti M, et al. Bushmeat hunting and extinction risk to the world's mammals. *R Soc Open Sci*. 2016;3:160498.
- Vanthomme H, Bellé B, Forget PM. Bushmeat hunting alters recruitment of large-seeded plant species in central Africa. *Biotropica*. 2010;42(6):672–9.
- Abernethy KA, Coad L, Taylor G, Lee ME, Maisels F. Extent and ecological consequences of hunting in Central African rainforests in the twenty-first century. *Philos Trans R Soc B Biol Sci*. 2013;368(1625):20120303.
- Benítez-López A, Alkemade R, Schipper AM, Ingram DJ, Verweij PA, Eikelboom JAJ, et al. The impact of hunting on tropical mammal and bird populations. *Science*. 1979;207(356):180–3.
- Scabin AB, Peres CA. Hunting pressure modulates the composition and size structure of terrestrial and arboreal vertebrates in Amazonian forests. *Biodivers Conserv*. 2021;30(12):3613–32.
- Harrison RD, Sreekar R, Brodie JF, Brook S, Luskin M, O'Kelly H, Velho N. Impacts of hunting on tropical forests in Southeast Asia. *Conserv Biol*. 2016;30(5):972–81.
- Brasil. Lei no 5.197, de 3 de janeiro de 1967. Dispõe sobre a proteção à fauna e dá outras providências. 1967. Available in: https://www.planalto.gov.br/ccivil_03/leis/15197.htm.
- Fernandes-Ferreira H. A História da Caça no Brasil. Tese. Paraíba: Universidade Federal da Paraíba; 2014.
- Alves RRN, Mendonça LE, Confessor MV, Vieira WL, Lopez L. Hunting strategies used in the semi-arid region of northeastern Brazil. *J Ethnobiol Ethnomed*. 2009;5(1):1–16.
- van Vliet N, Quiceno-Mesa MP, Cruz-Antia D, Tellez L, Martins C, Haiden E, Nasi R. From fish and bushmeat to chicken nuggets: the nutrition transition in a continuum from rural to urban settings in the Tri frontier Amazon region. *Ethnobiol Conserv*. 2015. <https://doi.org/10.15451/ec2015-7-4-6-1-12>.
- Da Silva JS, do Nascimento ALB, Alves RRN, Albuquerque UP. Use of game fauna by Fulni-ô people in Northeastern Brazil: implications for conservation. *J Ethnobiol Ethnomed*. 2020;16:18.
- Mendonça LET, Vasconcelos A, Souto CM, Oliveira TPR, Alves RRN. Bushmeat consumption and its implications for wildlife conservation in the semi-arid region of Brazil. *Reg Environ Change*. 2016;16:1649–57.
- Chaves WA, Wilkie DS, Monroe MC, Sieving KE. Market access and wild meat consumption in the central Amazon, Brazil. *Biol Conserv*. 2017;212:240–8.
- Torres PC, Morsello C, Parry L, Pardini R. Forest cover and social relations are more important than economic factors in driving hunting and bushmeat consumption in post-frontier Amazonia. *Biol Conserv*. 2021;253:108823.
- van Vliet N, Cruz D, Quiceno-Mesa MP, Aquino L, Moreno J, Ribeiro R, Fa J. Ride, shoot, and call: wildlife use among contemporary urban hunters in Três Fronteiras, Brazilian Amazon. *Ecol Soc*. 2015;20(3):1–12.
- Morsello C, Yagüe B, Beltreschi L, van Vliet N, Adams C, Schor T, et al. Cultural attitudes are stronger predictors of bushmeat consumption and preference than economic factors among urban Amazonians from Brazil and Colombia. *Ecol Soc*. 2015;20:21.

39. Parry L, Barlow J, Pereira H. Wildlife harvest and consumption in Amazonia's urbanized wilderness. *Conserv Lett.* 2014;7:565–74.
40. Braganolo C, Gama GM, Vieira FA, Campos-Silva JV, Bernard E, Malhado AC, Ladle RJ. Hunting in Brazil: What are the options? *Perspect Ecol Conserv.* 2019;17(2):71–9.
41. Fernandes-Ferreira H, Alves R. The researches on the hunting in Brazil: a brief overview. *Ethnobiol Conserv.* 2017. <https://doi.org/10.15451/ec2017-07-6.6-1-7>.
42. Souto WMS, Barboza RRD, Fernandes-Ferreira H, Júnior AJCM, Monteiro JM, Abi-chacra ÉA, et al. Zootherapeutic uses of wildmeat and associated products in the semiarid region of Brazil: general aspects and challenges for conservation. *J Ethnobiol Ethnomed.* 2018;14:60.
43. van Vliet N, Quiceno MP, Cruz D, Jonhson Neves de Aquino L, Yagüe B, Schor T, et al. Bushmeat networks link the forest to urban areas in the trifrontier region between Brazil, Colombia, and Peru. *Ecol Soc.* 2015;20:21.
44. Page M, McKenzie J, Bossuyt P, Boutron I, Hoffmann T, Mulrow C, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Syst Rev.* 2021;10:1–11.
45. R Core Team. R: a language and environment for statistical computing. Vienna: R Foundation for Statistical Computing; 2020.
46. Pacheco J, Silveira L, Aleixo A, Agne C, Bencke G, Bravo G, et al. Annotated checklist of the birds of Brazil by the Brazilian Ornithological Records Committee—second edition. *Ornithol Res.* 2021;29:94–105.
47. Abreu E, Casali D, Costa-Araújo R, Garbino G, Libardi G, Loretto D, et al. Lista de Mamíferos do Brasil (2022-1) 2022. [Data set]. <https://doi.org/10.5281/zenodo.7469767>.
48. Bernéris R, Costa H. Brazilian reptiles List of species (versão 2018). 2018. <http://www.sbherpetologia.org.br>.
49. Segalla M, Berneck B, Canedo C, Caramaschi U, Cruz C, Garcia P, et al. Brazilian amphibians: list of species. *Herpetol Bras.* 2021;10:122–226.
50. IUCN. The IUCN Red List of Threatened Species (version 2021–3). 2021. <https://www.iucnredlist.org>. Accessed 20 Aug 2023.
51. MMA. Ministério do Meio Ambiente. Lista Nacional de Espécies Brasileiras Ameaçadas de Extinção. 2022. <https://in.gov.br/en/web/dou/-/portaria-mma-n-148-de-7-de-junho-de-2022-406272733>. Accessed 20 Aug 2023.
52. Souza JB, Alves RRN. Hunting and Wildlife use in an Atlantic Forest Remnant of Northeastern Brazil. *Trop Conserv Sci.* 2014;7:145–60.
53. Trinca CT, Ferrari SF. Game populations and hunting pressure on a rural frontier in southern Brazilian Amazonia. *Biol Geral Exp.* 2007;7(1):5–16.
54. Robinson J, Redford K. The use and conservation of wildlife. In: Robinson J, Redford K, editors. *Neotropical wildlife use and conservation*. Chicago: University of Chicago Press; 1991. p. 215–44.
55. Ferreira FS, Brito SV, Ribeiro SC, Almeida WO, Alves RRN. Zootherapeutics utilized by residents of the community Poço Dantas, Crato-CE, Brazil. *J Ethnobiol Ethnomed.* 2009;5:1–10.
56. Oliveira AMV, Lopes WH. Trends in scientific publication on ethnozoology: Brazil's highlight in international science. *Rev Ibero-Am Ciências Ambient.* 2021;12(1):691–8.
57. Cawthorn D-M, Hoffman LC. The bushmeat and food security nexus: a global account of the contributions, conundrums and ethical collisions. *Food Res Int.* 2015;76:906–25.
58. Alves RRN, Souto WMS. Ethnozoology in Brazil: current status and perspectives. *J Ethnobiol Ethnomed.* 2011;7:1–18.
59. Alves R, Silva J, Chaves L, Albuquerque U. Ethnozoology: An overview and current perspectives. In: Alves R, Albuquerque U, editors. *Ethnozoology animals in our lives*. London: Elsevier; 2018. p. 513–21.
60. Ladislau DS, Souza PL, Aride PHR, Oliveira AT, Gubiani ÉA. Current situation and future perspectives of ethnoichthyology in Brazil. *Ethnobiol Conserv.* 2021;10:1–35.
61. Sidone OJG, Haddad EA, Mena-Chalco JP. A ciência nas regiões brasileiras: evolução da produção e das redes de colaboração científica. *Transinformação.* 2016;28:15–32.
62. El Bizri HR, Morcatty TQ, Ferreira JC, Mayor P, Vasconcelos- Neto CFA, Valsecchi J, et al. Social and biological correlates of wild meat consumption and trade by rural communities in the Jutai River Basin, Central Amazonia. *J Ethnobiol.* 2020;40:183–201.
63. Chaves WA, Valle DR, Monroe MC, Wilkie DS, Sieving KE, Sadowsky B. Changing wild meat consumption: an experiment in the central Amazon, Brazil. *Conserv Lett.* 2018;11:e12391.
64. Chaves WA, Valle D, Tavares AS, Morcatty TQ, Wilcove DS. Impacts of rural to urban migration, urbanization, and generational change on consumption of wild animals in the Amazon. *Conserv Biol.* 2021;35:1186–97.
65. Araújo HFP, Silva JMC. The avifauna of the Caatinga: biogeography, ecology, and conservation. In: Silva JMC, Tabarelli M, Leal IR, editors. *Caatinga: the largest tropical dry forest region in South America*. New York: Springer; 2017. p. 181–210.
66. Albuquerque UP, Araujo EL, El-Deir ACA, Lima ALA, Souto A, Bezerra BM, Severi W. Caatinga revisited: ecology and conservation of an important seasonal dry forest. *Sci World J.* 2012;1–18:2012.
67. Garda AA, Lion MB, Lima SMDQ, Mesquita DO, Araujo HFPD, Napoli MF. Os animais vertebrados do Bioma Caatinga. *Ciência Cult.* 2018;70(4):29–34.
68. Fernandes-Ferreira H, Mendonça SV, Albano C, Ferreira FS, Alves RRN. Hunting, use and conservation of birds in Northeast Brazil. *Biodivers Conserv.* 2012;21:221–44.
69. Bezerra DMM, Araujo HFP, Alves RRN. Captura de aves silvestres no semiárido brasileiro: técnicas cinegéticas e implicações para conservação. *Trop Conserv Sci.* 2012;5(1):50–66.
70. Bezerra DMM, Araujo HFP, Alves RRN. Understanding the use of wild birds in a priority conservation area of Caatinga, a Brazilian tropical dry forest. *Environ Dev Sustain.* 2020;22:5297–316.
71. Loss A, Neto E, Flores F. Aves silvestres utilizadas como recurso trófico pelos moradores do povoado de Pedra Branca, Santa Teresinha, Bahia, Brasil. *Gaia Sci.* 2014;2:1–14.
72. Borges AKM, Ribeiro BDP, Alves RRN. Hunting, capture, and wildlife use by communities in a semi-arid region of Northeastern Brazil. *Hum Dimens Wildl.* 2021;26:1–11.
73. Teixeira PHR, Thel TN, Ferreira JMR, de Azevedo SM, Junior WRT, Lyra-Neves RM. Local knowledge and exploitation of the avian fauna by a rural community in the semi-arid zone of northeastern Brazil. *J Ethnobiol Ethnomed.* 2014;10:1–10.
74. Santos S. Conhecimento tradicional e utilização da fauna silvestre em São José da Lagoa Tapada, Paraíba, Brasil. *Rev Ethnobiol.* 2019;17:31–48.
75. Redford KH. Robinson JGA game of choice: patterns of Indian and colonist hunting in the Neotropics. *Am Anthropol.* 1987;89:650–67.
76. Mesquita G, Barreto L. Evaluation of mammals hunting in indigenous and rural localities in eastern Brazilian Amazon. *Ethnobiol Conserv.* 2015;4:1–14.
77. Valsecchi J, Amaral PV. Perfil da caça e dos caçadores na Reserva de Desenvolvimento Sustentável Amanã, Amazonas-Brasil. *Sci Mag UAKARI.* 2009;5(2):33–48.
78. van Vliet N, Nasi R, Taber A. From the forest to the stomach, bushmeat consumption from rural to urban settings in Central Africa. In: Schakleton S, Schakleton C, Stanley P, editors. *Non-timber forest products in the global context*. Berlin, Heidelberg: Springer; 2011. p. 129–45.
79. Lima J, Santos S, Lucena R. Uso de recursos faunísticos em uma comunidade rural do semiárido da Paraíba-Brasil. *Rev Ethnobiol.* 2018;16:36–53.
80. Barboza RRD, Lopes SF, Souto WMS, Fernandes-Ferreira H, Alves RRN. The role of game mammals as bushmeat in the Caatinga, northeast Brazil. *Ecol Soc.* 2016;21:2.
81. Santos S, Soares H, Soares V, Lucena R. Traditional knowledge and use of mammals in a rural community in the Sertaneja Depression (Paraíba State, Northeast Brazil). *Indian J Tradit Knowl.* 2019;18:94–1013.
82. Chaves LS, Alves RRN, Albuquerque UP. Hunters' preferences and perceptions as hunting predictors in a semiarid ecosystem. *Sci Total Environ.* 2020;726:138494.
83. Silva Neto BC, Nascimento ALB, Schiel N, Alves RRN, Souto A, Albuquerque UP. Assessment of the hunting of mammals using local ecological knowledge: an example from the Brazilian semiarid region. *Environ Dev Sustain.* 2017;19:1795–813.
84. Torres PC, Morsello C, Parry L, Barlow J, Ferreira J, Gardner T, et al. Landscape correlates of bushmeat consumption and hunting in a post-frontier Amazonian region. *Environ Conserv.* 2018;45:315–23.
85. Valsecchi J, El Bizri HR, Figueira JEC. Subsistence hunting of *Cuniculus paca* in the middle of the Solimões River, Amazonas, Brazil. *Braz J Biol.* 2014;74(3):560–8.

86. Santos SL, Alves RRN, Mendonça LET. Fauna silvestre utilizada em comunidades rurais no semiárido paraibano. *Biodivers Bras*. 2018;8:149–62.
87. Morcatty TQ, Valsecchi J. Social, biological, and environmental drivers of the hunting and trade of the endangered yellow-footed tortoise in the Amazon. *Ecol Soc*. 2015;20:3.
88. Lopes GP, Valsecchi J, Vieira TM, Amaral PV, Costa EWM. Hunting and hunters in lowland communities in the region of the middle Solimões, Amazonas, Brazil. *Sci Mag UAKARI*. 2012;8:7–18.
89. Prestes-Carneiro G, Béarez P, Bailon S, Py-Daniel AR, Neves EG. Subsistence fishery at Hatahara (750–1230 CE), a pre-Columbian central Amazonian village. *J Archaeol Sci Rep*. 2016;8:454–62.
90. Pantoja-Lima J, Aride PH, Oliveira AT, Félix-Silva D, Pezzuti JC, Rebêlo GH. Chain of commercialization of *Podocnemis* spp. turtles (Testudines: Podocnemididae) in the Purus River, Amazon basin, Brazil: current status and perspectives. *J Ethnobiol Ethnomed*. 2014;10:8.
91. Fiori MM, Santos CFM. A carne, a gordura e os ovos: colonização, caça e pesca na Amazônia. EDIPUCRS, Porto Alegre, Brazil. 2015. p. 109.
92. Da Silva AB, Pereyra PE, El Bizri HR, Souto WMS, Barboza RSL. Patterns of wildlife hunting and trade by local communities in eastern Amazonian floodplains. *Ethnobiol Conserv*. 2022. <https://doi.org/10.15451/ec2022-07-11.16-1-19>.
93. Jugli S, Chakravorty J, Meyer-Rochow VB. Zootherapeutic uses of animals and their parts: an important element of the traditional knowledge of the Tangsa and Wancho of eastern Arunachal Pradesh, North-East India. *Environ Dev Sustain*. 2020;22:4699–734.
94. Hussain JF, Tynsong H. Ethnozoological study of animals-based medicine used by traditional healers of North-east India. *Asian J Ethnobiol*. 2021. <https://doi.org/10.13057/asianjethnobiol/y040101>.
95. Fitzgerald LA. Tupinambis lizards and people: a sustainable use approach to conservation and development. *Conserv Biol*. 1994;8(1):12–5.
96. Fernandes-Ferreira H, Mendonca SV, Cruz RL, Borges-Nojosa DM, Alves RRN. Hunting of herpetofauna in montane, coastal, and dryland areas of Northeastern Brazil. *Herpetol Conserv Biol*. 2013;8:652–66.
97. Alves RRN, Neta ROS, Trovão DMB, Barbosa JEL, Barros AT, Dias TLP. Traditional uses of medicinal animals in the semi-arid region of northeastern Brazil. *J Ethnobiol Ethnomed*. 2012;8:1–7.
98. Alves RRN, Alves HN. The faunal drugstore: animal-based remedies used in traditional medicines in Latin America. *J Ethnobiol Ethnomed*. 2011;7:1–43.
99. Pazinato DMM, Corrêa LLC, Silva DE, Araujo LEB. Conhecimento etnoherpetológico no município de Caçapava do Sul, sul do Brasil. *Rev Ciências Ambient*. 2021;15(1):1–12.
100. Oliveira MA, Rodrigues APVC, Messias MR, Doria CRC. The consumption of the White-lipped Frog (*Leptodactylus macrosternum* Leptodactylidae Anura) in the state of Rondônia in the Brazilian Amazon. *Biotemas*. 2021;34(3):4.
101. Campos F, Neto E, Costa-Neto E, Ferreira F. Rural populations of alagoinhas and herpetofauna: knowledge, uses and interactions. *Res Square*. 2021. <https://doi.org/10.21203/rs.3.rs-211463/v2>.
102. Barbosa JAA, Aguiar JO. Conhecimentos e usos da fauna por caçadores no semiárido brasileiro: um estudo de caso no estado da Paraíba, Nordeste do Brasil. *Biotemas*. 2015;28:137.
103. Mohnke M, Onadeko A, Petersen M, Rodel MO. Dried or fried: amphibians in local and regional food markets in West Africa. *Traffic Bull*. 2010;22:117–28.
104. van Vliet N, Quiceno M, Moreno J, Cruz D, Fa JE, Nasi R. Is urban bushmeat trade in Colombia really insignificant? *Oryx*. 2017;51(2):305–14.
105. WCS. El tráfico de carne silvestre en el Parque Nacional Yasuní: caracterización de un mercado creciente en la Amazonía norte del Ecuador. *Bol Wildl Conserv Soc Programa Ecuador*. 2007;2:1–8.
106. Baia Júnior PC, Guimarães DAA, Le Pendu Y. Non-legalized commerce in game meat in the Brazilian amazon: a case study. *Rev Biol Trop*. 2010;58:1079–88.
107. Bodmer RE, Lozano EP, Fang TG. Economic analysis of wildlife use in the Peruvian Amazon. In: *People in nature: wildlife conservation in South and Central America*. Columbia University Press; 2004. p. 191–208.
108. OTCA (Organización del Tratado de Cooperación Amazónica). Monitoreo y control del tráfico de fauna y flora en la Amazonia. Primer informe de avance. Proyecto ATN/OC-9251-RG. OTCA, Brasília, Brazil. 2009.
109. Petrozzi F, Amori G, Franco D, Gaubert P, Pacini N, Eniang EA, Luiselli L, et al. Ecology of the bushmeat trade in West and Central Africa. *Trop Ecol*. 2016;57(3):545–57.
110. Consumption W. Bushmeat and fetish trade of birds in West Africa: a review. *Vie et milieu-life aNd eNViroNmeNt*. 2018;68(1):51–64.
111. Fa JE, Seymour S, Dupain J, Amin R, Albrechtsen L, Macdonald D. Getting to grips with the magnitude of exploitation: bush meat in the Cross—Sana'a Rivers region, Nigeria and Cameroon. *Biol Conserv*. 2006;129:497–510.
112. Lindsey PA, Balme G, Becker M, Begg C, Bento C, Bocchino C, Zisadza-Gandiwa P, et al. The bushmeat trade in African savannas: Impacts, drivers, and possible solutions. *Biol Conserv*. 2013;160:80–96.
113. Gonçalves FM, Luís JC, Tchamba JJ, Cachissapa MJ, Chisingui AV. A rapid assessment of hunting and bushmeat trade along the roadside between five Angolan major towns. *Nat Conserv*. 2019;37:151–60.
114. Alves RRN, Vieira KS, Santana GG, Vieira WLS, Almeida WO, Souto WMS, Pezzuti JCB. A review on human attitudes towards reptiles in Brazil. *Environ Monit Assess*. 2012;184:6877–901.
115. Souza JDM, Lins Neto EM, Ferreira FS. Influence of the sociodemographic profile of hunters on the knowledge and use of faunistic resources. *J Ethnobiol Ethnomed*. 2022;18(1):1–13.
116. Nunes AV, Oliveira-Santos LGR, Santos BA, Peres CA, Fischer E. Socio-economic drivers of hunting efficiency and use of space by traditional Amazonians. *Hum Ecol*. 2020;48:307–15.
117. Brashares JS, Golden CD, Weinbaum KZ, Barrett CB, Okello GV. Economic and geographic drivers of wildlife consumption in rural Africa. *Proc Natl Acad Sci*. 2011;108(34):13931–6.
118. Van Vliet N, Mbazza P. Recognizing the multiple reasons for bushmeat consumption in urban areas: a necessary step toward the sustainable use of wildlife for food in central Africa. *Hum Dimens*. 2011;16:45–54.
119. East T, Kumpel NF, Milner-Gulland EJ, Rowcliffe JM. Determinants of urban bushmeat consumption in Rio muni, Equatorial Guinea. *Biol Conserv*. 2005;126(2):206–15.
120. Cowlshaw G, Mendelson S, Rowcliffe J. The bushmeat commodity chain: patterns of trade and sustainability in a mature urban market in West Africa. *ODI Wild Life Policy Brief*. 2004;7:1–4.
121. Dupain J, Nackoney J, Mario Vargas J, Johnson PJ, Farfán MA, Bofaso M, et al. Bushmeat characteristics vary with catchment conditions in a Congo market. *Biol Conserv*. 2012;146:32–40.
122. van Vliet N, Nebesse C, Gambalemoke S, Akaibe D, Nasi R. The bushmeat market in Kisangani, Democratic Republic of Congo: implications for conservation and food security. *Oryx*. 2012;46:196–203.
123. Quiceno M, Cruz-Antia D, Moreno J, van Vliet N. Descripción de la cacería y consumo de carne de monte en el río Loretoyacu y el lago Tarapoto, Puerto Nariño—Amazonas, Colombia. In: Trujillo F, Duque S, editors. *Los humedales de Tarapoto: Aportes al conocimiento sobre su biodiversidad y uso*. Fundación Omacha: Bogotá; 2014.
124. Alves RRN, Lima JRD, Araujo HFP. The live bird trade in Brazil and its conservation implications: an overview. *Bird Conserv Int*. 2013;23:53–65.
125. Souto WMS, Torres MAR, Sousa BFCC, Lima KGGC, Vieira LTS, Pereira GA. Singing for cages: the use and trade of passeriformes as wild pets in an economic center of the Amazon—NE Brazil Route. *Trop Conserv Sci*. 2017;10:194008291768989.
126. Dounias E. From subsistence to commercial hunting: technical shift in cynegetic practices among southern Cameroon forest dwellers during the 20th century. *Ecol Soc*. 2016;21(1):13.
127. Chaves WA, Monroe MC, Sieving KE. Wild meat trade and consumption in the central Amazon, Brazil. *Hum Ecol*. 2019;47:733–46.
128. Maxwell SL, Fuller RA, Brooks TM, Watson JEM. Biodiversity: the ravages of guns, nets and bulldozers. *Nature*. 2016;2016(536):143–5.
129. Benítez-López A, Santini L, Schipper AM, Busana M, Huijbregts MA. Intact but empty forests? Patterns of hunting-induced mammal defaunation in the tropics. *PLoS Biol*. 2019;17(5):e3000247.
130. Brooks DM, Fuller RA. Biology and conservation of cracids. In: Cancino L, Brooks DM, editors. *Conserving cracids: the most threatened family of birds in the Americas*. Houston: Misc. Publ. Houston Museum of Natural Science; 2006. p. 11–26.
131. Barrio J. Hunting pressure on cracids (Cracidae: Aves) in forest concessions in Peru. *Rev Peru Biol*. 2011;18:225–30.

132. Luna-Maira L, Alarcón-Nieto G, Haugaasen T, Brooks DM. Habitat use and ecology of Wattled Curassows on islands in the lower Caquetá River, Colombia. *J Field Ornithol.* 2013;84(1):23–31.
133. Estrada A, Garber PA, Gouveia S, Fernández-Llamazares Á, Ascensão F, Fuentes A, et al. Global importance of Indigenous Peoples, their lands, and knowledge systems for saving the world's primates from extinction. *Sci Adv.* 2022;8:2927.
134. Estrada A, Garber PA, Rylands AB, Roos C, Fernandez-Duque E, Di Fiore A, et al. Impending extinction crisis of the world's primates: why primates matter. *Sci Adv.* 2017;3:e1600946.
135. Estrada A, Garber PA, Mittermeier RA, Wich S, Gouveia S, Dobrovolski R, et al. Primates in peril: the significance of Brazil, Madagascar, Indonesia and the Democratic Republic of the Congo for global primate conservation. *PeerJ.* 2018;6:e4869.

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