



Hunting and wildlife use in protected areas of the Atlantic rainforest, northeastern Brazil

Caça e uso da fauna silvestre em áreas protegidas da mata atlântica no Nordeste do Brasil

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ABSTRACT: Despite being considered illegal in Brazil, the hunting of wild animals is a very common practice that influences the conservation of several fauna species. As such, the knowledge and practices associated with hunting activities need to be researched. Thus, the present study aimed to investigate, from an ethnozoological approach, the capture, slaughter and use of wild animals in four Conservation Units (protected areas) in the Atlantic Rainforest in the state of Paraíba. 109 hunters were interviewed, and 156 game animals were registered, which were distributed across the categories: mammals (31), birds (93), reptiles (27) and amphibians (05). The use of wild fauna registered in this study is mainly associated with the consumption of meat; however, the use of animals as pets, trade, zootherapy and control hunting were also recorded. Hunting practices have existed for a long time in the study region and are currently, mainly, motivated by subsistence, excluding occurrences of hunters killing animals that they considered to be dangerous. The socioeconomic situation of hunters and their possible dissonance with the laws that regulate wildlife protection are fundamental aspects that contribute to a better understanding of the barriers and possible methods of wildlife conservative management in the region. The catalog of hunted game animals expands our knowledge about the fauna hunted in the state of Paraíba, where research has not yet been performed on hunting activities in Conservation Units (protected areas) in the Atlantic Rainforest, this being the first evaluation. We hope that our results will contribute to the implementation / improvement of public policies aimed at the management of local wildlife, which endeavor to conserve the region's biodiversity.

Keywords: hunting; Atlantic rainforest; conservation areas.

RESUMO: Mesmo sendo considerada ilegal no Brasil, a caça de animais silvestres é uma prática bastante recorrente e que exerce influência sobre a conservação de várias espécies da fauna, portanto, os conhecimentos e as práticas associados às atividades cinegéticas precisam ser pesquisados. Nesse sentido, o presente trabalho objetivou investigar, a partir de uma abordagem etnozoológica, a captura, abate e utilização de animais silvestres em quatro Unidades de Conservação da Mata Atlântica no estado da Paraíba. Cento e nove caçadores foram entrevistados e 156 animais de caça foram registrados, estando distribuídos nas categorias: mamíferos (31), aves (93), répteis (27) e anfíbios (05). O uso da fauna silvestre registrado nessa pesquisa está associado principalmente ao consumo de carne, porém, a utilização para fins de estimação, comércio, zooterapia e caça de controle também foram registradas. As práticas cinegéticas já ocorrem há muito tempo na região e, atualmente, são motivadas sobretudo por demandas de subsistência, exceto quando ocorre o abate de animais considerados perigosos pelos caçadores. A conjuntura socioeconômica dos caçadores e sua eventual dissonância com as leis que regulamentam a proteção da vida silvestre são aspectos fundamentais para compreender melhor as barreiras e os caminhos possíveis para a gestão conservadora da fauna silvestre da região. O catálogo dos animais cinegéticos amplia o conhecimento sobre a fauna caçada no estado da Paraíba, onde ainda não foram realizadas pesquisas acerca das atividades de caça em Unidades de Conservação da Mata Atlântica, sendo este o primeiro trabalho. Almeja-se que nossos resultados colaborem para a implementação / aperfeiçoamento de políticas públicas direcionadas à gestão e manejo da fauna silvestre local, objetivando à conservação da biodiversidade da região.

Palavras-chave: práticas de caça; mata atlântica; unidades de conservação.

1. Introdução

Hunting practices in tropical forest areas are responsible for a significant proportion of the animal protein consumed by local human communities, as well as increasing individual incomes and are profoundly rooted in socio-cultural traditions (Castilho *et al.*, 2017). However, the gradual occupation of areas near the forest, associated with the growth of human populations and the improvement of hunting strategies (Alves *et al.*, 2009a), has resulted in an increased demand for wild animal byproducts, reaching levels of overexploitation in several areas such as the Brazilian Atlantic Forest (Canale *et al.*, 2012).

Despite being highly fragmented in different regions of Brazil, the Atlantic Forest is still one of the most important biodiversity hotspots on the planet (SOS Mata Atlântica, c2021). This biome, since the beginning of Brazil's colonization, has been

suffering from impacts caused by various harmful activities, such as illegal logging, agricultural land use, silviculture and animal husbandry, as well as the hunting of wild animals (Wandscheer, 2016), which has considerably affected the local biodiversity (Dean, 1996; Rezende *et al.*, 2018).

Despite being illegal for the majority of the Brazilian population - Federal Law 9605/98 and Decree 6514/08 (Brasil, 1998; 2008), hunting still occurs in almost every biome across the country (Fernandes-Ferreira, 2014), whether as a subsistence, recreational or professional activity (Souza & Alves, 2014; Barbosa & Aguiar, 2015). Hunting is also performed to provide game meat and commercial, ornamental and medicinal byproducts, as well as providing animals that can be kept as pets (Alves *et al.*, 2009a; Castilho *et al.*, 2013; Nascimento *et al.*, 2013; Carvalho & Morato, 2013; Melo *et al.*, 2014; El Bizri *et al.*, 2015; Morcatty & Valsecchi, 2015; Barbosa *et al.*, 2018). Hunting occurs even in

protected areas such as Atlantic Forest Conservation Units, where the main targets are wild vertebrates (Chiarello, 2000; Canale *et al.*, 2012; Schiavetti *et al.*, 2012).

In addition to threatening the conservation of the Atlantic Forest, hunting pressures can change ecosystem ecology (Castilho *et al.*, 2017) and endanger the food security of human populations that rely on wild animal protein for sustenance (Redford, 1992; Nasi *et al.*, 2011). Therefore, environmental protection measures must consider both ecological and sociocultural aspects of the human populations that interact with wild fauna (Alves *et al.*, 2012a; Alves, 2012; Souza & Alves, 2014; Barbosa & Aguiar, 2018).

In an attempt to minimize the threats to vulnerable species in Brazil, national action plans were developed to identify and prioritize conservation practices, with particular attention to the Atlantic Forest (ICMBio, 2011). Some of these Action Plans for endangered species aimed to increase the viability of wild animal populations and improve quality of their habitats. One of these Actions Plans for the state of Paraíba, intends to minimize hunting pressure on target species inside and around the main protected areas - Conservation Units - (ICMBio, 2014).

Despite the importance of studies on hunting, they are still scarce in Brazil (Souza & Alves, 2014; Constantino, 2018). In a review paper, Alves & Souto (2011) listed 28 publications specifically focused on the Amazonian region and on semi-arid areas in Northeastern Brazil (Alves *et al.*, 2009a; 2010a; 2010b; Barbosa *et al.*, 2010; 2011; Fernandes-Ferreira *et al.*, 2012a). Few studies have been carried out on the Atlantic Forest (Hanazaki *et al.*, 2009; Cunha, 2018), and only one has been

performed in the state of Paraíba (Souza & Alves, 2014). However, no studies have been conducted in the Conservation Units of the aforementioned state, where the forest has been reduced and fragmented (Barbosa, 1996; Alves *et al.*, 2017).

The present study characterizes the use of wild fauna in Atlantic Forest conservation units (CUs) in the state of Paraíba and the cynegetic practices related to these uses, evaluating their implications for conservation. Hunting is part of the local culture in the studied region and is likely important for supplementing the diet and income of part of the local population. However, the fact remains that this is an illegal activity, as the relativizations or hunting permits provided through Brazilian environmental legislation do not apply in the context of this study. Therefore, the collection of data on illegal practices in the surrounding areas of a conservation unit is challenging, especially when the participants are aware of the illegality of this practice.

We adapted and applied a method of qualitative analysis of ethnozoological data in studies conducted on hunting, which was recently proposed by Fernandes-Ferreira (2014) (*Use Frequency Value*). The results are expected to support conservation management strategies focused on the most exploited species and also to improve the general comprehension of the factors that influence the hunting practices of the populations living around protected areas.

2. Material and methods

2.1. Study area

This study was carried out in four Atlantic Forest conservation units (CUs) and their surroundings in the state of Paraíba, Brazil:

- 1) National Forest Restinga of Cabedelo (sustainable use CU) - A1, municipality of Cabedelo;
- 2) Benjamim Maranhão Botanical Garden (full

protection CU) - A2, municipality of João Pessoa;

- 3) Engenho Gargaú Private Natural Heritage Reserve (sustainable use CU) - A3, municipality of Santa Rita; and

- 4) Guaribas Biological Reserve (full protection CU) - A4, municipality of Mamanguape), Brazil.

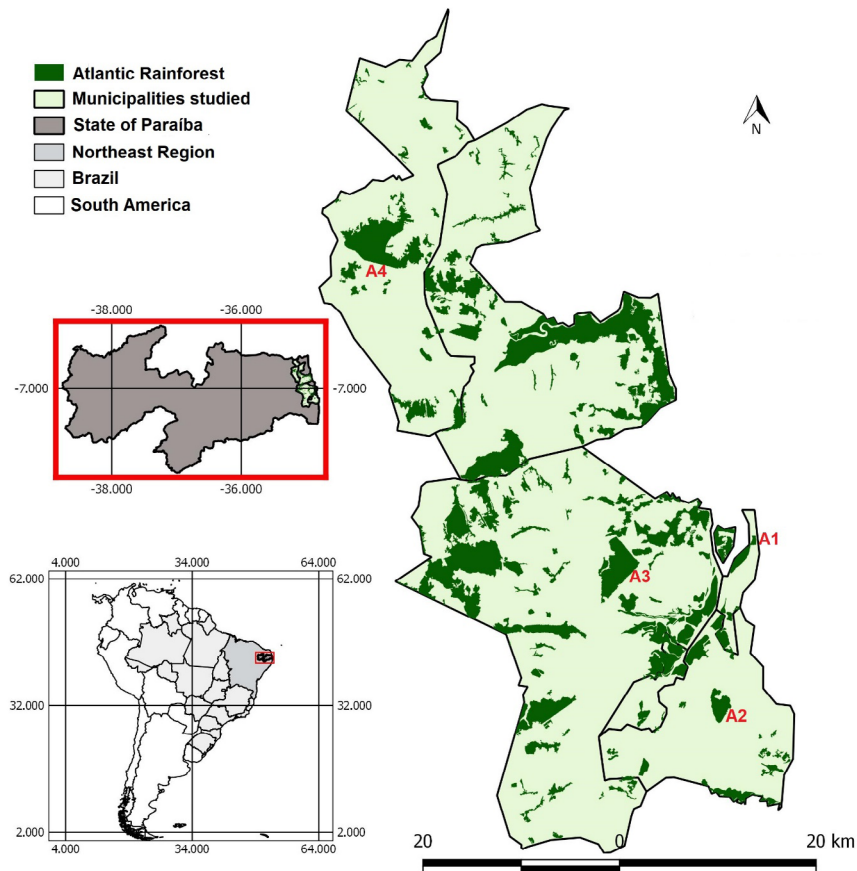


FIGURE 1 – Study area with points marking the Conservation Units.

LEGEND: A1 - National Forest Restinga of Cabedelo; A2 - Botanic Garden Benjamim Maranhão; A3 - Private Reserve of the Natural Heritage of the Gargaú Plant; A4 - Guaribas Biological Reserve. Paraíba, Brazil.

These CUs are distributed across remaining forest fragments of different sizes to the east of the state, in the Intermediate Geographic Region of João Pessoa, which is the most populated region of João Pessoa (Figure 1).

Area 1 is approximately 1.5km² and is essentially an urban CU and managed by a federal environmental agency. Area 2 is approximately 5km², with a CU fully involved in an urban environment and managed by a local environmental agency. Area 3 is approximately 10km² and is a Private Reserve of the Natural Heritage, which is essentially rural, surrounded by sugar cane (*Saccharum spp.*) plantations. Area 4 is approximately 37km², and is essentially a rural CU, surrounded by diversified agricultural areas and managed by a federal environmental agency.

The vegetation in the CUs is predominantly semi-evergreen forest, with parts of semi-deciduous and savannah forests. The native vegetation of the Atlantic Forest is currently scarce, as it has been replaced, mainly, by sugarcane monocultures (Andrade & Santos, 2015).

2.2. Procedures

The study was conducted between May 2015 and June 2018. Information about hunting and the use of wild fauna were collected through semi-structured questionnaires, supplemented by occasional interviews and casual conversations (Huntington, 2000). The questionnaires contained questions about each hunted species and hunting motives, and respondents could respond by referring to hunting experience accumulated over a lifetime. All the interviewees were informed about the purpose of

this study and officially consented to participate. This research study was approved by the Research Ethics Committee from the Federal University of Campina Grande (Protocol 23096.013946/17-00).

A total of 109 hunters were interviewed (A1 - n=12; A2 - n=27; A3 - n=32; A4 - n=38). All the interviewees were males aged between 18 and 82 (average age of 46.7 years) and all of them lived close to the study areas.

The hunters interviewed in Area 1 and Area 2 were typically urban inhabitants, living in peripheral areas and working in activities such as industry, commerce and provision of services. As a result, their hunting activity was restricted to weekends or periods without work.

The hunters interviewed in Area 3 were mostly agricultural workers in the sugarcane monoculture. They inhabit small communities located between forest fragments and crops, hunting recurrently in these forests.

The hunters interviewed in Area 4 constitute the most heterogeneous group. Despite all the interviewees being rural inhabitants, some of them worked in nearby cities, both in commerce and in the provision of services. Another fraction of this interviewee group was comprised of small family farmers who plant diverse crops such as cereals, tubers and legumes. A portion of the hunters in this area recognized themselves as descendants of the Potiguara Indigenous population. All hunt recurrently, but clandestinely.

The socioeconomic data of the interviewees is summarized in Table 1. Amongst the hunters, key informants (experienced hunters) were chosen based on the “native specialist” criteria, who were self-acknowledged or recognized by the community as culturally competent (Hays, 1976). These key

informants, whenever possible, were monitored during their activities.

After the first few interviews, the other participants were selected using the Snowball (Bailey, 1994) sampling technique. There were attempts to

interview all of the indicated, identified and located local hunters, however, some interviews were cancelled (28.75%) and some interviewees were reluctant to answer questions and thus, provided little information, nonetheless, these interviews were still considered.

All the animal species were identified as such:

1) analysis of the animals or body parts donated by the interviewees (with the approval of the Biodiversity Authorization and Information System – SISBio - Protocol 58.124);

2) analysis of pictures of the animals, which were taken during the interviews or while monitoring an interviewee's activities; and

3) by their common names, along with the help of taxonomists familiar with the studied fauna.

The classification and nomenclature used in this study followed the Brazilian Ornithological Records Committee (Pacheco *et al.*, 2021) for the birds studied; and the Brazilian Society of Herpetology (SBH, 2018a; Segalla *et al.*, 2021) for the reptiles and amphibians. For the mammals, the Mammal Species of the World (GBIF, 2016) database was used. The conservation status of the species registered here followed the IUCN (IUCN, 2021).

2.3. Data analysis

Based on the information from the interviews, statistical analysis were performed using the R Statistic© 3.4.3 software. Initially, the diversity of local cynegetic species was estimated using a Nonparametric estimator (Chao2) which was chosen due to its applicability to incidence data, based

TABLE 1 – Summary of the socioeconomic variables of the interviewees.

Gender		%
Male	109	100
Ages		
18 – 25 years old	12	11
26 – 45 years old	37	33,9
46 – 60 years old	32	29,4
Over 60 years old	28	25,7
Civil Status		
Unmarried	14	12,8
Stable union	23	21,1
Married	66	60,6
Divorced	2	1,8
Widower	4	3,7
Scholarity		
Incomplete elementary school	52	47,7
Complete primary education	34	31,2
Incomplete high school	6	5,5
Complete high school	17	15,6
Monthly income		
Around US\$ 130,00	7	6,4
Around US\$ 260,00	59	54,1
Around US\$ 380,00	36	33
Around US\$ 510,00	5	4,6
Around US\$ 760,00	2	1,8

on the concept that uncommon and rare species carry information about the quantity of absent species in the sample.

$$Chao2 = Sobs + Q_1^2 / 2Q_2$$

LEGEND: Sobs represents the number of registered species, Q1 represents the number of the species present in only one sample and Q2 represents the number of species present in exactly two samples.

The comparison between the registered species and the curve estimator, along with the respective confidence intervals of 95%, allow for the verification of the study's sampling efficiency.

To verify if there was a significant difference between the number of species mentioned according to the age, income and education variables, the collected data was analyzed using a Generalized linear model – GLM (Nelder & Wedderburn, 1972), assuming a Poisson or exponential distribution.

The Kruskal–Wallis H test (Kruskal & Wallis, 1952; 1953) was applied with a significance level

of 5% ($p < 0.05$), to confirm the relationship between the number of species mentioned and the education level of the interviewees. To confirm the relationship between the number of species mentioned and the interviewees' ages and incomes, the Spearman correlation test (Spearman, 1904) was applied.

To determine the cultural value of the cynegetic species registered, we applied the UFV - *Use Frequency Value* (Fernandes-Ferreira, 2014), reformulating its frequency coefficients of “q” use, whose indices are given based on the quantity of mentions made by the interviewees (Table II), “U” is the number of times each use is mentioned for the species, and “n” is the total number of informants that were interviewed.

Therefore, we improved the index, allowing for its application in multiple scenarios of cynegetic fauna analysis, without underestimating the cynegetic potential of any species.

$$UFV = q \cdot (\sum U/n)$$

TABLE 2 – Reformulation of frequency coefficients of use "q" for calculation of *Use Frequency Value*.

Scoring	Consensus Minimum		Type of Use
	Absence of citations	Presence of citations	
q = 0,0	≥ 95%	≤ 05%	Historical / Potential Use *
q = 0,5	≥ 85%	≤ 15%	Rare Use
q = 1,0	≥ 75%	≤ 25%	Moderately Rare Use
q = 2,0	< 50%	> 50%	Frequent Use
q = 4,0	≤ 25%	≥ 75%	Very Frequent Use

SOURCE: Barbosa, 2019 – Adapted.

*It is suggested to substitute the affirmation of locally extinct species of Fernandes-Ferreira (2014), for the inference of the potential use of species.

3. Results

The interviewed hunters (n=109) mentioned a total of 156 species preferably hunted in the study area (supplementary material) which were distributed across four groups. The most frequently mentioned group was the bird group (n=93), followed by mammals (n=31), reptiles (n=27) and amphibians (n=05). These animals were hunted due to five main motivating factors (Food - n=31.2%; Raising - n=25.7%; Commerce - n=20.7%; Wildlife management - n=16.4%; and Medicinal use - n=6%).

The species accumulation curve reached the asymptote for nearly 75 samples and the Chao2 estimator suggested an estimated diversity of 157.4 species, which indicates sufficient effort and sampling efficiency in data collecting (Figure 2).

The average variation in interviewee age by study area was ± 2.54 years. In relation to monthly income, the average variation was ± 0.42 current minimum wage. In study areas 1 and 2 (urban areas) the most common economic activities among respondents were those related to trade and service provision. In study areas 3 and 4 (rural areas), the most common economic activities among respondents were those related to agriculture.

The regression (GLM) demonstrated no significant influence of interviewee average income on the number of mentioned cynegetic species ($E(\log) = -0.019$; $Z = -0.233$; $\Pr(>|z|) = 0.816$). The Spearman correlation showed the same ($\rho = -0.06$, $p < 0.52$), however, we observed that interviewees with an average monthly income lower than US\$ 200 tended to hunt more in order to supplement their diet, whereas those with an average monthly income higher than US\$ 350 hunted as a leisure

activity and eventually commercialized animals and cynegetic byproducts.

In terms of the relationship between interviewee age and the number of mentioned species, however, the results of the regression (GLM) demonstrated that there was an important difference, ($E_{(\log)} = -0.019$; $Z = 14.36$; $\Pr(>|z|) = 2e-16$), with a strong tendency for older interviewees to mention a larger number of cynegetic species. When applying the Spearman correlation ($\rho = 0,50$, $p < 0,01$), this significant relationship was also shown (Figure 3A).

The linear model showed that the interviewees' level of education affected the number of species mentioned (GLM: $Df = 3$; $F = 63.81$; $\Pr < 0.01$), with a reduction in the average number of species mentioned as the years of education increased. The use of the Kruskal–Wallis H test confirmed this relationship (Figure 3B).

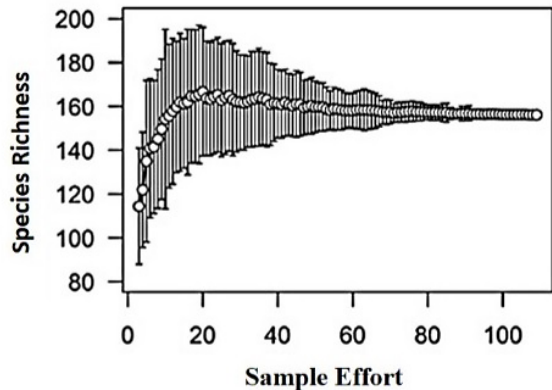


FIGURE 2 – Chao2 Richness Estimator for the sample effort undertaken in this study, with species richness estimated to be 157.4 game animals.

The UFVs varied from zero to 8.59. All 15 species that presented a UFV value of zero could be found still in the study area.

Conversely, more than 20 species showed UFVs higher than 3.0 (Figure 4), which suggests strong cynegetic pressure on these animals, especially on *Salvator merianae* (Duméril & Bibron, 1839) (UFV=8.59), *Crotalus durissus* Linnaeus, 1758 (UFV=5.47), *Dasybus novemcinctus* Linnaeus, 1758 (UFV=5.39), *Euphractus sexcinctus* (Linnaeus, 1758) (UFV=5.39), *Iguana iguana* (Linnaeus, 1758) (UFV=5.03), *Hydrochoerus hydrochaeris* (Linnaeus, 1766) (UFV=4.84), *Cuniculus paca* (Linnaeus, 1766) (UFV=4.77), *Dasyprocta iacki* Feijó & Langguth, 2013 (UFV=4.77), *Amazona amazonica* (Linnaeus, 1766) (UFV=4.70) and *Cyanoloxia brissonii* (Lichtenstein, 1823) (UFV=4.66).

The main hunting motivation in the study area was meat consumption (31.19%). The majority of the interviewees (70.64%) showed a preference for meat from wild animals over meat from domesti-

cated sources, due to their preference for the taste of game meat, its lower monetary cost to obtain and the natural quality of the meat in comparison to beef, pork or poultry.

The hunters' food preferences have been listed, including animals such as *Dasybus novemcinctus* Linnaeus, 1758, *Iguana iguana* (Linnaeus, 1758) and *Penelope superciliaris* Temminck, 1815, which are considered to be clean. The interviewees pointed out some taboos and dietary restrictions related to game meat. Meat from animals such as *Caiman latirostris* (Daudin, 1802), *Cuniculus paca* (Linnaeus, 1766), *Dasyprocta iacki* Feijó & Langguth, 2013, *Leptodactylus vastus* Lutz, 1930 and *Phrynosops geoffroanus* (Schweigger, 1812), for instance, are considered to be potentially harmful to people with a compromised immune system. Other animals as *Euphractus sexcinctus* (Linnaeus, 1758), *Hydrochoerus hydrochaeris* (Linnaeus, 1766) and *Salvator merianae* (Duméril & Bibron, 1839), undergo special treatment before their slaughter, since

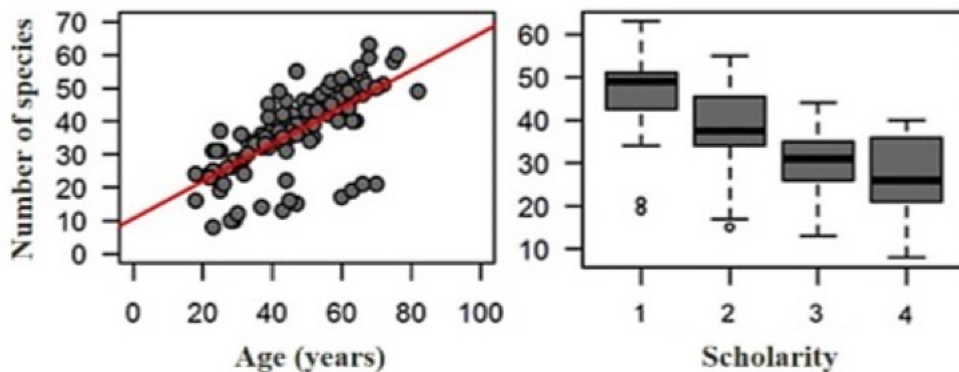


FIGURE 3 – Relationship between the number of game species mentioned with interviewee age (A - left) and their level of education (B - right).
 LEGEND: Scholarity - 1 - Incomplete elementary school; 2 - Complete primary education; 3 - Incomplete high school; 4 - Complete high school.

the hunters believe that the eating habits of these animals make their meat dirty.

In addition to the consumption of meat, the use of animal byproducts in the production of traditional medicines was another common method of utilizing

the local wild fauna. Thirty-nine species that provided raw materials (fat, bones, feathers, viscera, body fluids) for the production of zooterapeutics were mentioned, notably the fat of *S. merianae* (Duméril & Bibron, 1839), which was named by

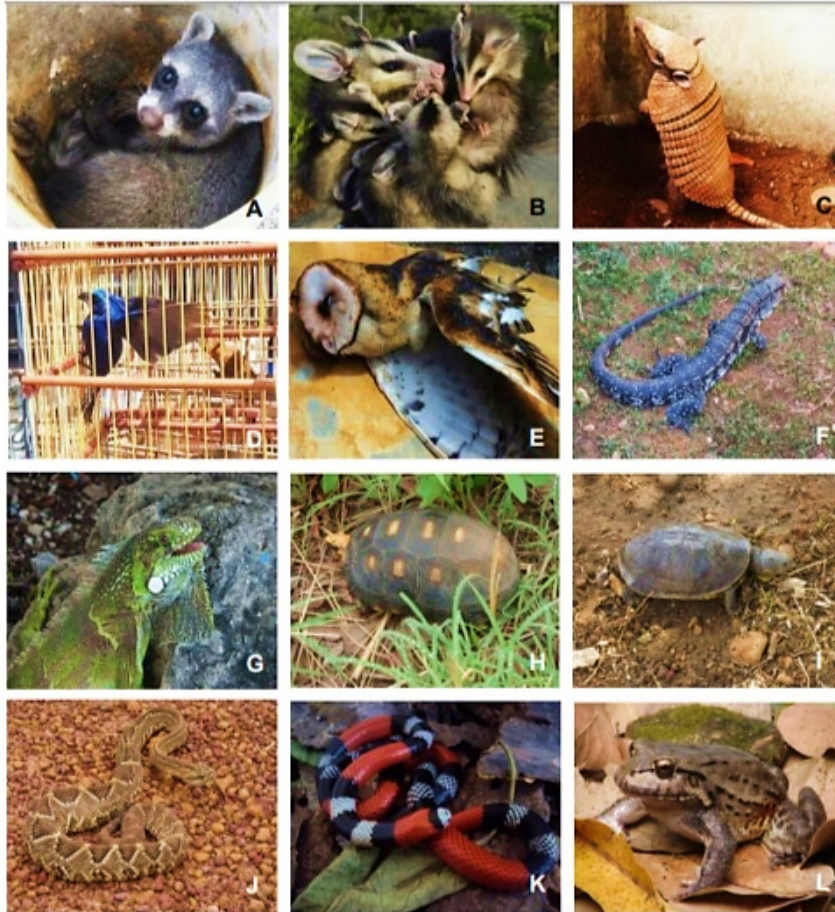


FIGURE 4 – Examples of animals that comprise the game fauna recorded in the present study.

LEGEND: A - *Procyon cancrivorus* (G. Cuvier, 1798), B - *Didelphis albiventris* Lund, 1840, C - *Euphractus sexcinctus* (Linnaeus, 1758), D - *Cyanoloxia brissonii* (Lichtenstein, 1823), E - *Tyto furcata* (Temminck, 1827), F - *Salvator merianae* (Duméril & Bibron, 1839), G - *Iguana iguana* (Linnaeus, 1758), H - *Chelonoidis carbonaria* (Spix, 1824), I - *Mesoclemmys tuberculata* (Luederwaldt, 1926), J - *Crotalus durissus* Linnaeus, 1758, K - *Micrurus ibibocca* (Merrem, 1820), L - *Leptodactylus vastus* Lutz, 1930.

87 interviewees as being helpful for the treatment of diseases that affect the respiratory tract, as well as the musculoskeletal and auditory systems.

Another great hunting motivation was the potential use of many local species as pets and commercializing. A total of 80 species (66 birds, 12 mammals and 2 reptiles) were listed as being pets and/or commercialized in the region. We noted that the capture of animals for use as pets and commercialization were closely linked to cultural recreational habits, and also help to increase the average monthly income of the hunters. According to some interviewees, these practices can even be responsible for the majority of their income. However, three species that are commercialized in the area - *Leopardus tigrinus* (Schreber, 1775), *Touit surdus* (Kuhl, 1820) and *Herpsilochmus pileatus* (Lichtenstein, 1823) - are classified as vulnerable on international conservation lists (IUCN, 2021).

The wild animals of this region are also hunted when perceived as threats to people or to livestock. Reptiles stand out in the wildlife management category (50% of mentions), particularly snakes (*Bothrops leucurus* Wagler, 1824, n=103; *Micrurus ibiboboca* (Merrem, 1820), n=101; *Crotalus durissus* Linnaeus, 1758, n=97; *Philodryas nattereri* Steindachner, 1870, n=83), which are considered to be potentially harmful to people. Mammals and birds, such as *Cerdocyon thous* (Linnaeus, 1766) (n=90), *Didelphis marsupialis* Linnaeus, 1758 (n=36) and *Caracara plancus* (Miller, 1777) (n=34) are also killed for preying on livestock.

4. Discussion

The sampling in the present paper is much

more ample compared to other studies that investigate the use of fauna in Atlantic Forest fragments in Northeastern Brazil (Souza & Alves, 2014; Alves *et al.*, 2017). However, a considerable proportion of the cynegetic species mentioned in this paper have been previously registered in other studies on the use of fauna (Ferreira *et al.*, 2009a; 2009b; Alves *et al.*, 2009a; 2009b; 2010a; 2010b; 2011; Pereira & Schiavetti, 2010; Souto *et al.*, 2011; Barbosa *et al.*, 2011; Bezerra *et al.*, 2011; 2012a; 2012b; Barbosa & Aguiar, 2015; 2018), which highlights the dissemination of this practice and suggests a pattern of the most hunted cynegetic vertebrate species in the Northeastern Region of Brazil (Alves *et al.*, 2012a).

However, while the diversity of hunted species in one area reflects the aspects of the local faunal composition (Altrichter, 2006; Van Vliet *et al.*, 2015), which is expected to be richer in Conservation Units as indicated in our study, this also highlights the ease of access and preference for these resources (Barboza *et al.*, 2016; Van Vliet *et al.*, 2016; Policarpo *et al.*, 2019). This is contrary to the most basic aims of CU establishments (Melo *et al.*, 2014; Wandscheer, 2016), highlighting the existence of flaws, whether in the process of establishing these CUs (Risso, 2014), in the inclusion of its inhabitants as conservation activists (Diegues, 2000; Quinteiro, 2017) or in the education policies and awareness focused on conservation aspects (Fischer *et al.*, 2017).

Our results indicate a greater hunting effort directed towards birds, mammals and reptiles, as shown in other studies that investigate general aspects of hunting in the American continent (Redford & Robinson, 1987; Robinson & Bodmer, 1999; Lopes & Ferrari, 2000; Peres & Nascimento, 2006; Pereira & Schiavetti, 2010; Castilho *et al.*, 2017).

This is further reinforced by the illegal trade and pet raising, especially of birds, due to the greater return on products and byproducts that mammals and birds provide humans (Bodmer & Lozano, 2001; Silvius *et al.*, 2004; Alves & Alves, 2011; Alves *et al.*, 2013; Souza & Alves, 2014; Barbosa & Aguiar, 2015), as well as the greater occurrence of hunting for population control associated with reptiles (Robinson & Bodmer, 1999; Barbosa & Aguiar, 2012; Fernandes-Ferreira *et al.*, 2012b).

The positive correlation between interviewee age and the number of mentioned species can be explained by strong historical and oral traditions, through which knowledge about hunting is shared between hunters and who subsequently pass such knowledge, accumulated through years of experience, on to younger hunters. Throughout history, oral transmission has been greatly responsible for the transference of traditional knowledge about the environment in areas of Northeastern Brazil (Aguiar & Barbosa, 2013), and as such, this knowledge has accumulated and shaped the perceptions and practices in the natural environment in this region.

Considering the negative relationship between higher education level and the number of mentioned species, it is possible to notice the influence of age on education level, as the interviewees with a higher education level were usually the younger ones. However, the fact that good education policies play an important role in the awareness of conservation implications cannot be denied and are often extremely efficient when implemented as the foundation for environmental actions (Fischer *et al.*, 2017; Quinteiro, 2017; Martins *et al.*, 2017).

The present study corroborates Alves *et al.*'s (2012a) findings where they found that hunting motivations can change depending on the average

monthly income of interviewees. In a study about hunting in the semi-arid region of Northeastern Brazil, these authors observed that average monthly income was one of the criteria that influenced the registered hunting patterns, where interviewees with lower incomes stated that they hunted for subsistence.

However, in tropical rainforests and in nearby urban and semi-urban settings, such as the ones here studied, hunting motivations are diverse (Fischer *et al.*, 2013; Van Vliet *et al.*, 2015; 2016; Barboza *et al.*, 2016; Lau, 2016; Oliveira *et al.*, 2017; Lund & Jensen, 2017), and there is an increase in techniques and technologies related to cynegetic practices (El Bizri *et al.*, 2015; Castilho *et al.*, 2017; Duda *et al.*, 2017) that are not intended to supplement the nutritional needs of the hunters. Thus, average monthly income is one of the many variables that require further investigation and analysis.

A pertinent example of this is the possibility that hunters with higher levels of education are hunting for fun, since hunting has historically been mentioned as a sociocultural representation of leisure, particularly among more affluent human populations (Lima *et al.*, 2020).

In relation to the species that presented low or zeroed UFVs, it is possible to infer that behavioral and cultural changes have occurred in hunting communities (Barbosa *et al.*, 2018), based on the survey-type data gathered in Conservation Units. However, the possibility that there has been a reduction in animal populations cannot be ruled out, and thus, additional zoological and ecological studies focused on these populations are necessary.

As all species that presented zero UFV could be found in the study area, updating the list of locally extinct species, described by Fernandes-Fer-

reira (2014), through the inference of its historical use/ potential use when the UFVs are equal to zero, is justified.

Regarding the species that presented a high UFV (above 3.0), there is a strong indication that these animals, although still present in the region, are being overexploited (Fernandes-Ferreira, 2014; Barbosa *et al.*, 2018).

Concerning the high levels of game meat consumption in this study, we must consider that mammals, due to their bigger size and potential energetic return, are the preferred food target sources in the American continent (Souza & Alves, 2014; Barbosa & Aguiar, 2015; Barboza *et al.*, 2016; Castilho *et al.*, 2017), although birds also stand when considering the diversity of species used as food source (Bezerra *et al.*, 2011; 2012a; 2012b; Bezerra, 2015). This fact seems to reflect the diversity of faunal groups in the Atlantic Forest, with 850 bird species and 270 mammalian species (MMA, s.d.).

A very similar trend with regard to the preference for game meat was reported by Souza & Alves (2014). They recorded that in areas of the Atlantic Forest this preference was justified by the taste and healthiness of the meat and by the feeling of accomplishment, pride and conquest that the hunters felt when they were successful in a hunt.

Food taboos all over the world (Ross *et al.*, 1978), including in the tropical forests of Brazil (Begossi *et al.*, 2004), should be taken into consideration when investigating the specific habits adopted in the study region and their relationship to the consumption of animals. These taboos are often related to hunting (Simoons, 1978; Cawthorn & Hoffman, 2015) and may possibly constitute a means of food safety and protection (Begossi, 1992; Begossi &

Braga, 1992; Begossi & Richerson, 1993; Van Vliet *et al.*; 2016), as well as aiding in the avoidance of potentially harmful nutritional risks (Bolton *et al.*, 1972; Van Vliet *et al.*, 2017). Therefore, recording and understanding hunting motivations is essential for ensuring the quality of what is consumed by human populations.

In relation to the record of cynegetic species and their byproducts used in traditional health treatments, it is necessary to consider that in Brazil this practice has been recognized as a therapeutic option since its colonization, and is widely disseminated and available across the whole country (Alves *et al.*, 2011; 2016). Many people still use medicines of animal origin as an alternative or as a supplement to pharmaceutical drugs (Alves & Rosa, 2006; 2007; Santos, 2017), and this scenario is common among hunters from Northeastern Brazil, as an attempt to maximize the resources made available from captured animals (Moura & Marques, 2008; Barbosa & Aguiar, 2015; Barbosa *et al.*, 2018).

In regard to raising pets, we must consider that although this practice dates back to the most ancient societies (Alves, 2012), integrating the local culture and tradition of these populations (Alves & Albuquerque, 2018) and the increasing use of wild vertebrates to serve this purpose, has stimulated the illegal wildlife trade and it is now vital that this trade be considered in conservation policies (Andrews, 1990; Broad, 2001; Alves *et al.*, 2012b).

Concerning the use of wildlife fauna in commercial practices, as recorded here, it is necessary to take into consideration that the illegal wildlife trade is one of the most profitable illegal business in the world, generating around US\$ 15 billion annually (Barber-Meyer, 2010; van Uhm & Moreto, 2017) and involves several participants – hunters,

intermediaries, dealers, traders, consumers; many steps – hunt, capture, transportation, selling; and diverse motivations – food, pets, ornamentation, clothing, medicinal purposes (Wyatt, 2013; Moreto & Lemieux, 2015; Leberatto, 2016). This practice demonstrates a pattern of animals going from developing to developed countries (Duffy, 2010; van Uhm & Moreto, 2017), which suggests that Brazil may potentially be affected by this trade, due to its high biodiversity.

The high frequency of commercialized bird records (86.7%) in the present study can be explained by the fact that the country possesses one of the richest avifauna in the world, with over 1900 recorded species (CBRO, 2015). Many of these birds are appreciated for their beauty, however, they are especially valued for their singing, and are often kept as pets or used for different purposes and consequently encourages the hunting of this animal group (Nobrega *et al.*, 2012; Bezerra, 2015). It is important to note that such targeting may result in serious ecological and conservation consequences, such as population declines, species extinction, a decrease in pollinators or seed dispersers which are important for the maintenance of plant diversity, and the possibility of an increase in pest insects (Fernandes-Ferreira *et al.*, 2012a; Sreekar *et al.*, 2015; Bezerra, 2015).

Souza and Alves (2014), in a study about hunting and the use of fauna in Atlantic Forest remnants in Northeastern Brazil, recorded a low level of hunting aimed at birds when compared to other areas in Brazil. This record is probably due to the lack of studies on hunting and the use of fauna in the Atlantic Forest in the state of Paraíba. The present paper supports the research of the aforementioned authors by presenting a more

ample sample both for the number of interviewees and for the size and conservation statuses of the study fragments. Our results highlight the need to ensure continuous research on this issue, in order to provide a better evaluation of the real impact of avifauna exploration.

Hunting as a means to control animal populations, especially snakes, seems to be a trend in studies on hunting activities in the Northeastern region of Brazil (Barbosa *et al.*, 2011; Alves *et al.*, 2012c; Souza & Alves, 2014; Barbosa & Aguiar, 2015; Alves *et al.*, 2017). Since serpents often occupy the trophic level of top predators, the killing of snakes can affect food chain dynamics in local ecosystems, resulting in increased prey populations, which when out of control, can act as pests and negatively impact agricultural production, the rearing of livestock and the natural environment (Sotolu *et al.*, 2017).

Many hunters presented sufficient empirical knowledge about venomous snakes. Others, however, considered all snakes to be potentially dangerous and admitted to killing them indiscriminately. A similar fact has already been recorded in different ecosystems in Northeastern Brazil (Mendonça *et al.*, 2012; Alves *et al.*, 2012c; Souza & Alves, 2014; Alves *et al.*, 2017), which is worrying in terms of herpetofauna conservation and their interaction with other species.

Although the action plans proposed for the Atlantic Forest (ICMBio, 2011) in the state of Paraíba (ICMBio, 2014) represent an advance in terms of local forest preservation, through the prioritization of conservation practices, these plans have limitations, especially regarding the identification of the majority of threatened species. Studies that list the main animal species that are threatened by hunting and discuss how the socioeconomic aspects

of hunters influence cynegetic practices, can be useful as auxiliary documents in the development of conservation strategies by the competent bodies (Barbosa *et al.*, 2020).

Another important limitation of the aforementioned management plans is the fact that these documents do not consider the importance of including human populations in the forest surroundings as indispensable agents for the success of conservation strategies, especially populations that directly use natural resources, including wildlife (Barbosa, 2019). However, we know that for the effective maintenance of biodiversity and efficient management of protected areas where hunting still occurs, it is essential to include local human communities in environmental conservation programs (Andriuguetto-Filho *et al.*, 1998).

5. Conclusion

The present study has demonstrated that hunting and the use of vertebrates in the researched areas is still a recurring practice, as well as in different regions of the country. This confirms that the current conservation strategies adopted in Brazil have not been effective, and that the establishment of Conservation Units as protected areas, as they occur today, is incipient with regards to cynegetic issues, and should consequently be reconsidered.

Socioeconomic factors certainly motivate hunting in the study regions, which are backed by cultural traditions and mostly, by the fragility of law enforcement. Conversely, there is the added challenge of imposing conservation strategies in regions where the wild fauna has historically been seen as an essential natural resource, as in the study area.

We suggest that in order to reduce the contrasting ethical conflicts between the conservation of wildlife and human needs (use and management of wild fauna), that the establishment, monitoring, standardization and modernization of these conservation policies should consider the social and cultural aspects of the local human populations, as well as being delimited by the development of environmental education strategies.

The aim of this study is not to condemn the management of the study protected areas, much less to encourage the conflict between Brazilian environmental legislation and the traditions of human communities. We do, however, suggest that in sustainable use CUs (Areas 1 and 3), subsistence hunting activities should be included in management plans compatible with environmental protection. In full protection CUs (Areas 2 and 4), we suggest that environmental inspection be effective, however, where possible, specific and targeted inspection approaches and strategies should be used, considering the socioeconomic situation of the surrounding population. We expect that by meeting these standards, the anthropogenic impacts on overexploited species can be minimized.

Any progress regarding the improvement of the management plans in the study Conservation Units will only be possible through the consideration of advances in research. The present study was limited to listing the main hunted species, the most common hunting motivations and the relationship of this scenario with some socioeconomic aspects of the interviewed hunters. However, further research that considers:

a) the importance of hunting for the food and economic security of hunters;

- b) local ecological knowledge about the most exploited game species;
- c) the evaluation of the impacts of hunting on the exploited fauna populations is necessary.

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