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Interactions Between People and Birds of Prey in Semi-Arid Regions of Brazil: Ethno-Ornithology and Conservation

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Simple Summary

A total of 19 bird of prey species were identified, with most belonging to the Accipitridae family. Knowledge about these species varied according to several factors, including gender, age, education level, and length of residency. Men, older individuals, and those with more years of residence in the region tended to know more species. Low educational level was linked to greater knowledge, which contrasts with previous studies suggesting that higher educational level leads to more positive conservation attitudes. Birds of prey were culturally linked to omens, which include signs related to weather and ecological events, as well as supernatural beliefs. These beliefs led to negative attitudes and the killing of birds of prey, especially when they attacked livestock. Despite their ecological importance in pest control and nutrient recycling, conflicts between humans and birds of prey often arise due to damage to livestock. More research is needed to understand the socio-cultural drivers of these conflicts and the role of education in promoting coexistence and the conservation of birds of prey.

Abstract

How humans perceive and interact with other animal species is critical in enhancing conservation initiatives. The study recorded and analyzed people's knowledge and perceptions of birds of prey and their interactions in three rural communities in Paraíba, Brazil. The data were collected by face-to-face interviews using semi-structured questionnaires. One hundred ninety-one people were interviewed, and 19 species were recorded. Based on the answers to the questionnaires, the species are considered omens of climatic/ecological and supernatural events. They are important in the maintenance of ecosystems (predation of rodents and snakes and feeding on dead animals). However, most birds of prey are killed because they cause damage by preying upon domestic animals or for being associated with bad omens. The diversity of information listed here shows the need for complex and interdisciplinary studies to understand the human dimensions of knowledge and relationships between people and birds, contributing to species conservation and encouraging coexistence between people and birds of prey.

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Keywords: Caatinga; ethnozoology; human–wildlife coexistence; human–wildlife conflict; traditional knowledge

1. Introduction

Since ancient times, animals, especially birds, have fascinated people around the world [1–4], becoming an integral part of folk tales [5–7] and being used for various purposes, such as pets, traditional medicine, and food [8,9]. In this context, birds of prey have always attracted human interest and admiration as they are associated with symbols of strength, nobility, agility, independence, and precision, as demonstrated through great dexterity [10,11]. These characteristics of birds of prey have been valued by people to this day, influencing their use in falconry and as pets [10,11]. As these birds are apex predators, they are considered one of the most important ecological bioindicators, as they contribute to the balance of trophic chains and signal levels of pollution and changes in habitats, ecosystems, and landscapes. Consequently, they are often used as "key species" in landscape planning and management [12–16].

In the semi-arid region of Northeastern Brazil, which is mainly characterized by the Caatinga ecosystem, birds of prey are widespread in both forested and non-forested areas [17,18]. The resources available in the Caatinga are influenced by seasonality [19], and the impact of anthropogenic activities (deforestation, land degradation, and hunting) has altered the natural environment, reducing forest cover and, consequently, the availability of prey for many raptor species. As a result, many birds of prey have modified their behavior in response to anthropogenic pressures (e.g., deforestation and hunting), often including domestic animals in their diet, which has led to conflicts with the human population living in this ecosystem [20].

While livestock depredation is the leading cause of conflicts between humans and wildlife in many rural areas globally [21–23], research shows that the economic damage caused by birds of prey is relatively minimal [21,22,24]. The persecution and killing of birds of prey are often linked to fear, beliefs, and socio-cultural and economic factors [21,23–25]. Therefore, birds of prey are an interesting model for studying the knowledge and relationships between humans and wildlife in the Caatinga.

While several studies have addressed the knowledge and use of wild birds by traditional communities in the Caatinga, most have focused on trapping techniques, traditional uses, and the conservation impacts of hunting [5,26–29]. Probably because raptors are frequently in conflict with local populations living in this ecosystem, birds of prey have received relatively little attention and are largely absent from these studies.

Given the context of human–wildlife interactions, which can often become conflictual, there is a need for studies aimed at understanding how local populations perceive, categorize, and relate to birds of prey. Such studies can be conducted following the principles of ethno-ornithology [1,6,30–32], a science that seeks to understand traditional knowledge about birds, ranging from species diversity and local classification systems to ecological and socio-cultural factors that influence people's attitudes, perceptions, and usage towards birds.

Given that anthropogenic pressure poses the primary threat to raptor species and that humans play a direct role, it is crucial for managing and conserving biodiversity, this study aimed to capture and analyze aspects of knowledge, perception, and relationships between birds of prey and local populations in three rural communities in the Caatinga biome, in the state of Paraíba, Northeastern Brazil.

This is the first approach aimed at understanding the knowledge, perceptions, and attitudes of the human population towards birds of prey in semi-arid regions of Brazil. It was guided by the following questions: Which species are locally known? How are these species perceived by the respondents? What are the main attitudes towards birds of prey?

2. Materials and Methods

2.1. Study Area

This study was carried out in the semi-arid region of Paraíba, Northeastern Brazil, specifically in the municipalities of Solânea, Lagoa, and São Mamede (Figure 1). These locations and their respective rural communities were selected based on previous research conducted in the area [8].

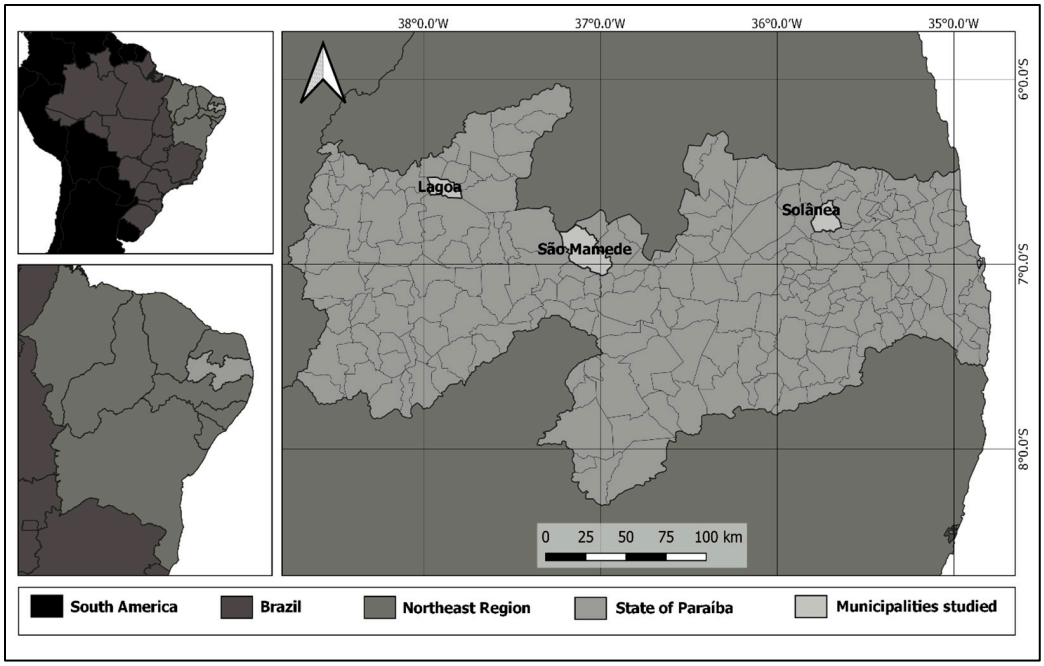


Figure 1. Study area.

Solânea (06° 46′ 40″ S and 35° 41′ 49″ W) is located in the Agreste mesoregion and the Curimataú Oriental microregion, approximately 138 km from the state capital, João Pessoa. It has a population of 26,693 inhabitants, a population density of 115.1 inhabitants/km^2, and a territorial area of 232,970 km^2. The climate is hot and semi-arid, with a mean annual temperature of 27 °C and a dry period that may last up to 11 months [33]. In this municipality, data collection was carried out in the rural community of Capivara, located approximately 15 km from downtown Solânea. This community lies within a riparian forest area crossed by a tributary of the Curimataú River, known as the Capivara stream, which extends across much of the study area. The local economy is based on subsistence agriculture, mainly the cultivation of beans, maize, and cassava.

São Mamede (06°55′37″ S and 37°05′45″ W) is situated in the Borborema mesoregion and the Seridó Ocidental microregion, 283 km from João Pessoa. It has a population of 7748 inhabitants, a population density of 14.60 inhabitants/km^2, and a territorial area of 530,728 km^2. The region's climate is hot semi-arid, with an average annual temperature of 26 °C and drought periods that can last up to 11 months [33]. In this municipality, the data collection was carried out in the rural community Várzea Alegre, located approximately 8 km from downtown São Mamede. This area is part of one of the main desertification hotspots in the state of Paraíba [34]. The local economy primarily relies on

rain-fed agriculture (practiced only during the rainy seasons), especially the cultivation of maize and beans.

The municipality of Lagoa (06°34′25″ S and 37°55′7″ W) is located in the Sertão mesoregion and Catolé do Rocha microregion, 394 km from João Pessoa. It has a population of 4681 inhabitants, a population density of 26.31 inhabitants/km^2, and a territorial area of 177,902 km^2. The region has a hot semi-arid climate, a mean annual temperature of 27 °C, and a dry period that can extend up to 11 months [33]. In this municipality, the rural community of Barroquina was selected as the study site. This rural community is located approximately 1 km from downtown Lagoa and lies within areas of shrub/tree vegetation and forest fragments. Its economy is based on agriculture, notably the rearing of sheep, goats, and cattle, as well as subsistence farming with the cultivation of beans, tobacco, cotton, and maize.

2.2. Data Collection

This research was conducted between 2011 and 2013. All stakeholders in each community (both men and women from each household) were interviewed in Portuguese (Table 1). There was a gender difference between the respondents due to the presence of widows and single men. We tried to avoid the direct influence of other people during the interviews. Therefore, each participant was interviewed individually and at different times [35].

Table 1. Socio-economic profile of the respondents.

Socio-Economic Aspects	Places		
	Lagoa	**São Mamede**	**Solânea**
Gender			
Man	21	20	53
Women	21	18	57
Age			
18–30	4	4	15
31–50	22	14	51
51–70	11	15	33
>70	2	4	4
Not answer	3	1	7
Educational level			
No school attendance	6	2	54
Primary/elementary education	32	28	42
High school/university education	3	5	10
Not answer	1	3	4

Data were collected through face-to-face interviews using semi-structured questionnaires [35] (Appendix A). The interviews were conducted by the researchers (H.K.L.S., V.M.S., and S.S.S.). The questionnaires included open questions addressing the occurrence of species in each locality, as well as participants' knowledge, perceptions, and attitudes towards birds of prey, alongside the biological and ecological aspects of the species. The questions were as follows: What do you consider to be a bird of prey? Which birds of prey do you know? Which birds of prey occur here? Do these birds have any importance? If so, what kind? Are any of these birds used by people? If yes, how? Are there any birds of prey that cause damage or injury to livestock, domestic animals, or people? What do you do when you encounter a bird of prey?

Before each interview, the participants were informed about the objectives of the research and asked to sign an informed consent form, as required by the National Health

Council through the Research Ethics Committee (Resolution 196/96). This study was approved by the Human Research Ethics Committee of the Lauro Wanderley Hospital at the Federal University of Paraíba (protocol CEP/HULW number 297/11, cover sheet number 420/134).

Species were identified using the following methods: (1) direct observation by the researchers (H.K.L.S. and V.M.S.), (2) scientific guides, and (3) the use of photographs (a serial album) of species occurring in the Caatinga and other Brazilian ecosystems, which were shown to respondents during the interviews. The nomenclature followed the taxonomy recommended by the Brazilian Committee of Ornithological Records (CBRO) [18].

2.3. Data Analysis

The data were categorized based on content similarity, following the approach proposed by Bardin [36] and using the technique of thematic content analysis. The semantic categories were established according to the similarity of information obtained during the interviews.

Three main categories were defined. The first category groups the species according to how they are perceived: whether they are considered important or not, dangerous, or associated with natural omens (meteorological ornitho-augurs—birds believed to predict climate changes), and supernatural omens (funereal ornitho-augurs—birds believed to foretell death). The second category concerns the uses attributed to the species, and whether they are perceived as useful or not. The third category relates to the participants' attitudes towards birds of prey, whether positive (e.g., people do not harm the birds) or negative (e.g., people kill birds of prey).

Therefore, a single species may be associated with both positive and negative perceptions and attitudes. For example, some birds were regarded as important for scavenging carcasses, while simultaneously being viewed as pests for preying on domestic animals, such as cattle and lambs.

Quantitative analyses were performed using Microsoft Excel, including the calculation of frequencies of mentions (uses, attitudes, and perceptions) and gender differences. The socioeconomic data of the respondents were categorized into three main groups: gender, education level, and age. Statistical analyses were performed separately for each locality due to the differences in sample sizes. The gender, education level, and age data were subjected to the Shapiro–Wilk test (to assess the normality of the data) and the Levene test (to assess homoscedasticity).

Non-parametric tests were applied to analyze the data. The Mann–Whitney U test was used to assess whether the number of species cited differed significantly by gender within each community. The Kruskal–Wallis test was used to test whether there were significant differences in the number of species cited according to the respondents' education level, age group, and length of residence. Education was categorized as follows: illiterate (no formal education), complete/incomplete primary education, and high school/college. Age was categorized into four groups: 18–30, 31–50, 51–70, and >70. The same classification was applied for both age and length of residence. Dunn's test was used for post hoc pairwise comparisons between age groups, education levels, and lengths of residence. Permutational multivariate analysis of variance (PERMANOVA) was conducted to check whether the species composition differed according to gender, age, education, and length of residence within each community, as well as among the three communities. All PERMANOVA analyses were based on Jaccard distances and 999 permutations. The results of the PERMANOVA were visualized using non-metric multidimensional scaling (NMDS). A significance level of $p < 0.05$ was adopted for all statistical tests. When direct speeches from respondents were presented, they were designated by the letters "DE", followed by their sequential

order in the manuscript (e.g., DE1, DE2 . . .). All statistical analyses were performed using R v. 4.1.0 software [37].

3. Results

3.1. Species Diversity

Nineteen species were identified, distributed across 16 genera and five families. The family Accipitridae had the highest number of species recorded across the three communities (Table 2). The PERMANOVA analysis indicated a significant difference in the composition of recorded species among the communities (Figure 2).

Table 2. Species names, number of mentions per locality, perceptions, and attitudes towards species in the three study areas. C = cleaning, Bc = biological control, R = rearing, F = food.

Species Name/CBRO 2015	Vernacular/English Names	Lagoa	São Mamede	Solânea	Perceptions/Attitudes/Uses **		
Accipitridae					Importance	Kill	Uses
Buteo nitidus	Gavião pedrês/Gray-lined Hawk	5	-	3	2	1	2 (R/F)
Buteo albonotatus	Gavião pequeno/Zone-tailed Hawk	1	-	3	4	2	2 (R)
Buteo brachyurus	Gavião do rabo listrado/Short-tailed Hawk	1	1	3	-	1	6 (R/F)
Urubutinga urubutinga	Gavião preto/Great black Hawk	3	3	3	1 (C)	1	2 (R)
Elanus leucurus	Gavião peneira/White-tailed Kite	1	-	1	1 (Bc)	-	2 (R/F)
Geranoaetus melanoleucus +	Torona/Gavião pé de serra/Black-chested Buzzard Eagle	14	17	20	13 (C/Bc)	16	14 (R/F)
Geranospiza caerulescens *	Gavião azul/Gavião pedrês/ Crane Hawk	6	3	4	5 (Bc)	2	8 (R/F)
Heterospizias meridionalis *	Gavião vermelho/Savanna Hawk	8	10	13	11 (Bc)	13	10 (R/F)
Parabuteo unicintus	Gavião pintado/Harris's Hawk	-	1	2	-	1	1 (R)
Rupornis magnirostris *	Gavião pega pinto/Roadside Hawk	12	29	35	16 (Bc)	29	23 (R/F)
Cathartidae							
Cathartes aura	Urubu de cabeça vermelha/ Turkey Vulture	3	2	3	10 (C)	1	2 (R)
Coragyps atratus+	Urubu de cabeça preta/ Black Vulture	14	30	46	49 (C)	15	20 (R)
Falconidae							
Caracara plancus	Carcará/Crested Caracara	16	21	47	18 (C/Bc)	27	21 (R/F)
Falco femoralis	Gavião de máscara/ Aplomado Falcon	1	-	5	2 (Bc)	1	4 (R)
Falco sparverius	Gavião de coleira/American kestrel	2	4	6	1	2	5 (R)
Herpetotheres cachinnans +*	Acauã/Cauã/Laughing Falcon	4	3	9	3 (Bc)	4	1 (R/F)
Strigidae							
Athene cunicularia +	Coruja buraqueira/Caburé/ Burrowing Owl	1	4	1	-	4	2 (R)
Megascops choliba +	Caburé de orelha/Tropical Screech Owl	2	5	1	1 (Bc)	2	1 (R)
Tytonidae							
Tyto furcata+	Rasga-mortalha/American Barn Owl	10	8	3	2 (Bc)	9	2 (R)
Corujão	Corujão	1	-	1	-	-	-

+ Funeral ornitho-augurs (birds that portend death); * meteorological ornitho-augurs (birds that predict climate changes—rain/dry). ** Sum of the three locations.

The Savannah Hawk (*Heterospizias meridionalis*), Roadside Hawk (*Rupornis magnirostris*), Southern Caracara (*Caracara plancus*), American Kestrel (*Falco sparverius*), and Burrowing Owl (*Athene cunicularia*) were observed in areas with sparse vegetation, anthropized zones, and close to the informants' homes. The Aplomado Falcon (*Falco femoralis*), Laughing Falcon (*Herpetotheres cachinnans*), and Grey Eagle Buzzard (*Geranoaetus melanoleucus*) were recorded in mountainous areas and further from the residences of the respondents.

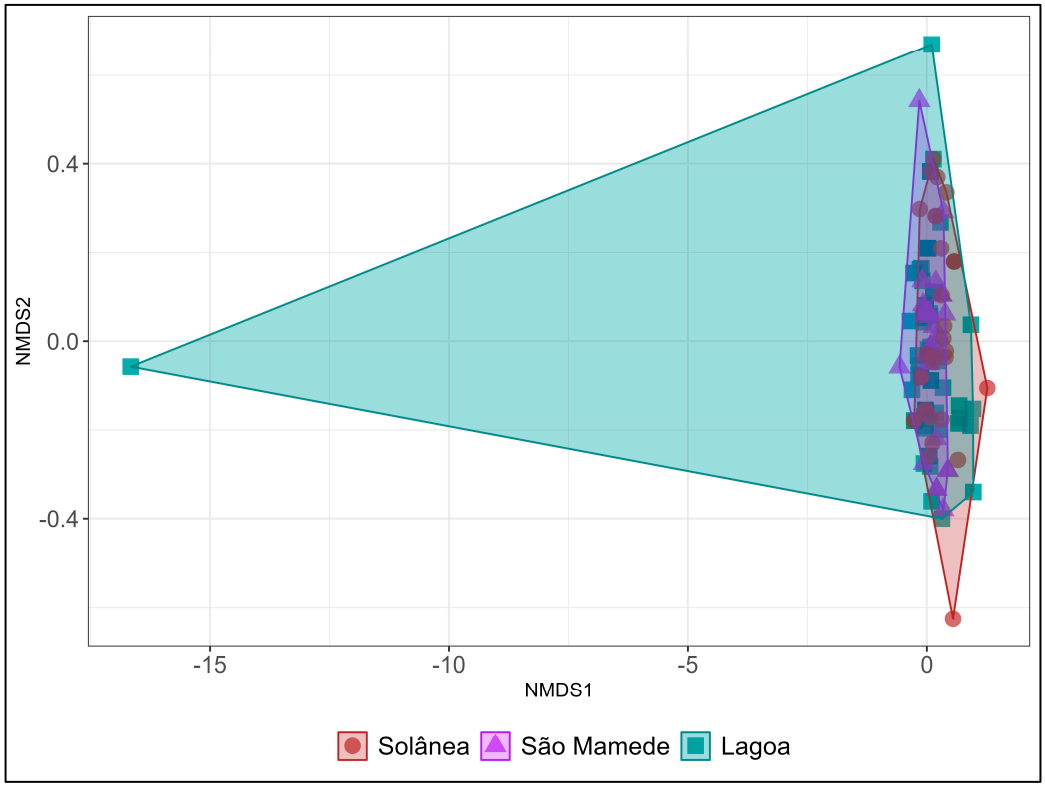


Figure 2. Differences between compositions of recorded species in Lagoa, São Mamede, and Solânea.

3.2. Knowledge and Perceptions About the Species

Men named more species than women in all three study areas, as follows: Solânea—men cited 19 species (mean = 2.41 ± 1.81 SD; nº = 53) and women cited 13 species (mean = 1.33 ± 1.32 SD; nº = 57); São Mamede—men cited 14 species (mean = 4 ± 2.15 SD; nº = 20) and women cited 14 species (mean = 2.94 ± 1.66 SD; nº = 18); and Lagoa—men cited 17 (mean = 4.47 ± 1.59 SD; nº = 21) and women cited 11 (mean = 1.14 ± 1.59 SD; nº = 21). The Mann–Whitney U test showed a significant difference in the number of species cited by gender in Lagoa (U = 221, $p < 0.001$) and Solânea (U = 252, $p < 0.05$). No significant difference was found in São Mamede ($p > 0.05$).

The Kruskal–Wallis H-test indicated a significant difference between the number of species cited and the respondents' educational level only in Lagoa (H = 8.5934, df = 2, $p < 0.05$; Dunn's post hoc test, $p < 0.001$ between illiterate—primary/elementary education, illiterate—high school/college and primary/elementary education—high school/college) (Figure 3a). A significant difference related to age was observed only in São Mamede (H = 13.272, df = 3, $p < 0.01$; Dunn's post hoc test, $p < 0.001$ between 19–30/51–70, 19–30/>70, 31–50/51–70, and 31–50/>70). No significant differences were found between young adult–adult and senior–elderly (Figure 3b). A significant difference was observed in the number of species cited based on the length of residence in Solânea (H = 13.436, df = 3, $p < 0.01$; Dunn's post hoc test, $p < 0.001$ between 18–30/31–50, 18–30/51–70, and 18–30/>70 and $p < 0.01$ between 31–50 and 51–70), and São Mamede (H = 8.3868, df = 3, $p < 0.05$; Dunn's post hoc test, $p < 0.001$ between 18–30/31–50, 18–30/51–70, and 18–30/>70, and $p < 0.05$ between 31–50 and51–70) (Figure 3c,d).

Although men named more species in all three communities, the PERMANOVA analysis indicated a significant difference in the composition of recorded species between genders only in São Mamede ($p < 0.01$) (Figure 4a). The analysis also indicated a significant difference in the composition of recorded species among educational levels only in Solânea ($p < 0.01$) (Figure 4b).

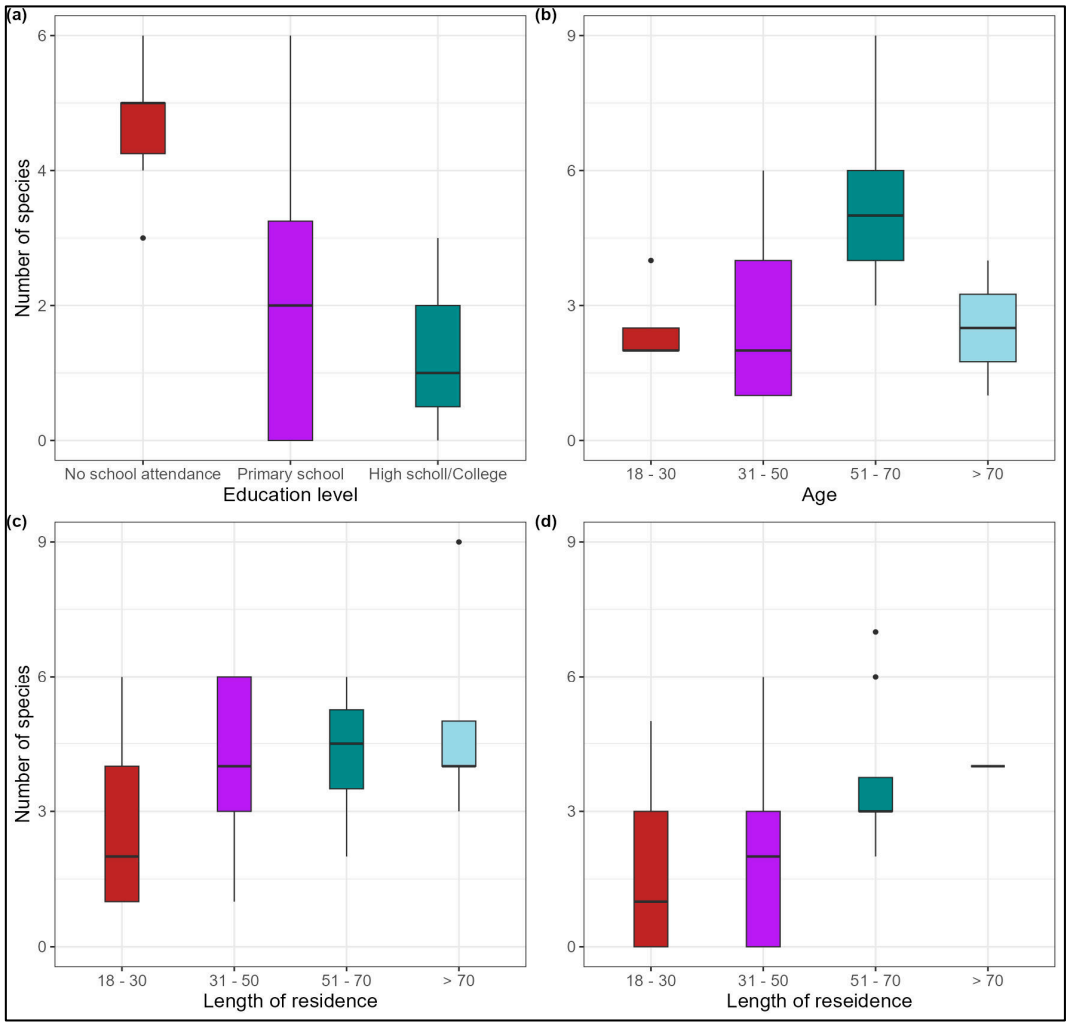


Figure 3. Differences between known species and socio-economic factors in Lagoa (**a**), São Mamede (**b**,**c**), and Solânea (**d**).

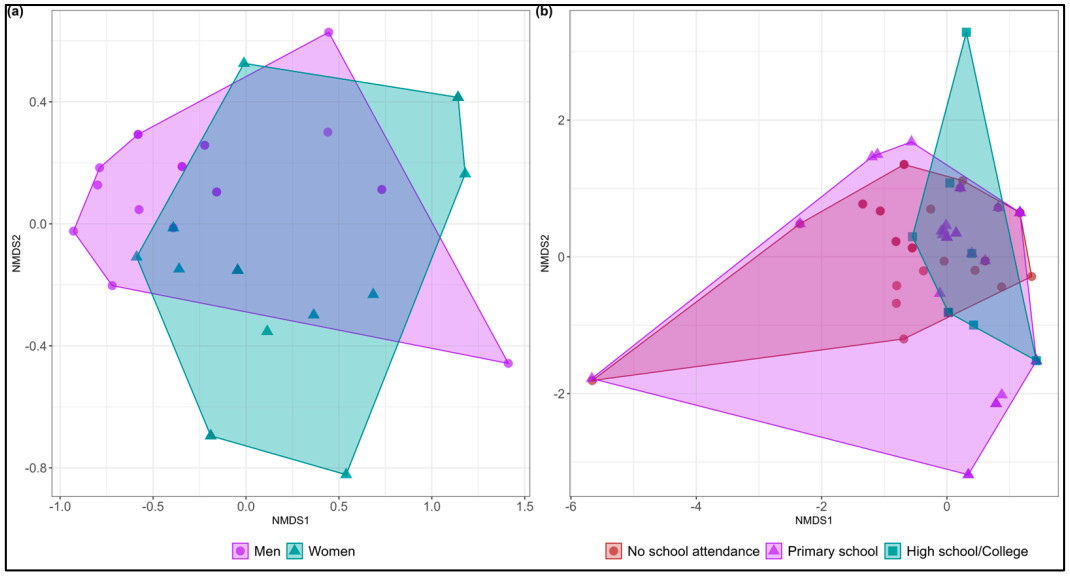


Figure 4. Differences between composition of recorded species for gender in São Mamede (**a**), and for education levels in Solânea (**b**).

Species identification, local nomenclature, and classification were primarily based on morphological characteristics such as color (e.g., Crane Hawk (*Geranospiza caerulescens*) and Great Black Hawk (*Urubitinga urubitinga*)), behavior (e.g., White-Tailed Kite (*Elanus leucurus*)), and habitat (e.g., Burrowing Owl and Grey Eagle Buzzard) (Table 2). Birdsong was another commonly cited factor, particularly for species such as the Laughing Falcon and Barn Owl.

According to 33 respondents (13 (31%) in Lagoa, 12 (11%) in Solânea, and 8 (21%) in São Mamede), nine species are culturally regarded as augurs of climatic or ecological events (meteorological ornitho-augurs) and/or as omens of bad luck or death (funereal ornitho-augurs) (Table 2). Among the meteorological ornitho-augurs, the Laughing Falcon was the most cited species across the three communities (13 mentions in total) (Table 2). Among the funeral ornitho-augurs, the Barn Owl was the species most frequently cited in the three communities (16 mentions in total). Across all three sites, birdsong and reproduction were the most common signs used for predicting weather conditions (17 mentions each), while birdsong (26 mentions) and presence (1 mention) were cited as signs of death (Table 2).

> "When the Cauã (Laughing Falcon) vocalizes in a green tree, it is a sign of good rainy season. If it vocalizes in a dry tree, it means drought for sure." (DE1, 71 years old—Lagoa)

Sixty-seven respondents (37 (34%) in Solânea, 21 (55%) in São Mamede, and 9 (21%) in Lagoa) stated that birds of prey are important for nature because they perform essential ecosystem functions, such as "cleaning up" by feeding dead animals and carcasses, a role mainly attributed to the Black Vulture (*Coragyps atratus*) (28 mentions in Solânea, 16 in São Mamede, and 5 in Lagoa) and the Turkey Vulture (*Cathartes aura*) (7 mentions in Lagoa, 2 in São Mamede and 1 in Solânea). Nine respondents (five (4.5%) in Solânea, three (8%) in São Mamede, and one (2.3%) in Lagoa) also mentioned pest control (e.g., rats, insects, and snakes) as another important function performed by these birds (Table 2).

3.3. Uses and Attitudes Towards Birds of Prey

Fifty-one respondents (33 (30%) in Solânea, 11 (27%) in Lagoa, and 7 (18%) in São Mamede) reported that birds of prey can be kept as pets. However, only one inhabitant (in Lagoa) reported keeping the Southern Caracara and Aplomado Falcon (Table 2) for this purpose. All respondents stated that this activity was only feasible when the birds were caught as juveniles, allowing them to become accustomed to domestic animals and avoid preying on them. In addition, six respondents mentioned the use of nine species for food purposes (Table 2). Another six respondents (three (3%) in Solânea and three (7.1%) in Lagoa) mentioned that birds of prey can be used as food.

A total of 134 respondents (86 (78%) in Solânea, 39 (93%) in Lagoa, and 9 (24%) in São Mamede) reported killing these birds with firearms when encountered. This action is justified by perceived threats to domestic animals, particularly sheep, goats, and chickens. The Roadside Hawk, Southern Caracara, and Grey Eagle Buzzard were the most frequently cited species in the three communities (Table 2). Species like the Barn Owl (nine mentions in total) and the Laughing Falcon (four mentions in total) (Table 2) are often killed due to beliefs that they signify misfortune or death, leading to feelings of disgust and fear among respondents.

> "The caracara is a very cruel animal. It only eats the lambs' eyes and leaves the animal blind." (DE2, 82 years old—Solânea)

4. Discussion

All species recorded in our study are widely distributed throughout the Caatinga ecosystem, as well as in other regions of Brazil [13,18]. Species such as the Aplomado Falcon, Laughing Falcon, Harris' Hawk (*Parabuteo unicinctus*), Great black Hawk, Crane Hawk, Grey Eagle Buzzard, and Zone-Tailed Hawk (*Buteo albonotatus*) possess ecological and behavioral traits, including long life spans, late sexual maturity, and specific environmental requirements (dependence or semi-dependence on forested habitats) that make them particularly vulnerable to anthropogenic pressures and deforestation [38].

Our findings indicate that the number of species recognized by respondents varies according to gender, age, education level, and resident time. Numerous ethnozoological studies have demonstrated that socio-demographic variables affect ecological knowledge, particularly regarding the use of animals [39–41], the number of species recognized [39], and perceptions and attitudes towards wildlife [42,43].

In terms of gender, some studies have shown that the sociocultural structures differ between men and women, which can lead to distinct perceptions and attitudes towards wildlife [44,45]. There is no straightforward explanation for this without considering gender roles in rural areas of the Caatinga. Kellert and Berry [45] argue that perceptions, behaviors, and attitudes towards animals differ between genders due to contrasting socialization experiences, which shape the ethical and moral values of men and women. In general, in rural communities within the Caatinga, most outdoor activities (e.g., hunting, wood harvest, and agriculture) are typically carried out by men [39,40]. These patterns were also observed in the areas covered by the present study, where men typically learn about agriculture practices and fieldwork from an early age, whereas women are generally socialized to take care of domestic duties and child-rearing.

In terms of age, our results indicate that older respondents (aged over 51) tend to recognize more species than younger respondents (aged up to 50). Many factors related to globalization, rural depopulation, and rapid socio-economic and environmental changes have contributed to the erosion of traditional knowledge [46]. In the specific context of the Caatinga region, the expansion of electricity and internet access has improved local livelihoods and increased access to communication platforms such as social media (e.g., YouTube and Facebook) [40]. However, Santos et al. [40] suggest that easy access to digital information and entertainment may reduce younger people's interest in outdoor activities, leading to weaker empirical knowledge of local biodiversity.

Another factor that may explain the broader knowledge of species held by older respondents is "memory"—an integral process within socio-ecological systems [39]. As memory is shaped by time and life experience, it is expected that older people, having lived longer in rural areas, would have more opportunities to interact with the environment [39,47]. Furthermore, they are generally less exposed to external influences such as social media [40]. This aligns with our findings, where in the three locations, respondents aged up to 50 years often work in urban areas while residing in the countryside, whereas older respondents (>51 years) have lived and worked in rural settings since birth. These findings suggest a need for further research to assess whether the observed generational differences are due to a loss or interruption in the transmission of ecological knowledge, and how environmental and social factors influence this process. As noted by Souza et al. [39], limited engagement with the environment increases the likelihood of knowledge erosion.

In relation to the level of education, our results indicate that respondents with lower levels of formal education (including illiteracy) tend to recognize more birds of prey than respondents with primary, secondary, or higher education. Overall, people with higher levels of education living in the rural areas of the Caatinga possess less knowledge about wildlife than those with only a primary education or no formal education at all

(illiterate) [40]. According to Santos et al. [40], people with limited formal education in these areas tend to rely more heavily on natural resources, including wildlife, which may explain their broader ecological knowledge. These findings contrast with other studies suggesting that schooling is a key factor in promoting species conservation, as higher educational attainment is generally associated with reduced conflict, and more positive perceptions and attitudes towards wildlife [48–50]. However, in Brazil, science and biology curricula often remain dissociated from the local socio-environmental reality, potentially contributing to conceptual misunderstandings and limited knowledge of the Caatinga's biodiversity [50,51]. Oliveira et al. [50,51] and Silva et al. [52] argue that school curricula should incorporate more content focused on local biodiversity, particularly threatened native species, rather than emphasizing exotic animals.

Although education has the potential to foster more positive attitudes towards wildlife, the formal education system must adopt a more contextualized, systemic, and interdisciplinary approach [50,51]. Marchini and Macdonald [49] suggest that basic education, combined with more communicative and inclusive interventions, can reduce negative perceptions of 'uncharismatic' species and serve as an effective tool in conservation strategies that account for local perceptions. Oliveira et al. [51] further argue that both formal education and access to media influence people's attitudes and behaviors towards wildlife. Moreover, informal learning processes and access to educational content via the media vary significantly between urban and rural contexts, shaping environmental awareness in distinct ways [50–52].

Many characteristics, concepts, perceptions, anatomical parts, and uses of species, as well as their relationships to other organisms, are used in local systems of classification and nomenclature across the three study areas. This demonstrates that understanding semantic categories provides insights into the knowledge a particular society has developed about the environment in which it is embedded, as well as its worldview from a cultural perspective [53,54]. It is worth noting that a deeper understanding of local classification systems can lead to the discovery of new species, the description of behaviors, the documentation of species in previously unrecorded regions, the identification of endangered species, and the development of alternative conservation strategies. It also enriches our understanding of human–bird relationships [30].

Our results show that the presence and/or vocalizations of birds are frequently associated with the cultural interpretation of natural (climatic/ecological) or supernatural (omens of human tragedy and/or misfortune) events. This finding is consistent with other studies conducted in Brazil [5,55] and worldwide [1,32,56–58]. The association between the vocalizations of the Laughing Falcon and climatic events has been documented in several studies [1,5,32,53–55], which highlight this species as a key indicator of climate change in many regions of the world. Araújo et al. [55] emphasize that climatic factors influence both the vocal behavior and the breeding season of this and many other species in the Caatinga. These authors explain that the search for meteorological cues in environmental signs forms part of the broader adaptive strategy of the 'sertanejos' (inhabitants of the semi-arid hinterlands) to cope with the adversities of the Caatinga. Elderly residents, in particular, rely on these signs to determine the appropriate timing for agricultural activities.

Owls such as the Barn Owl, Burrowing Owl, and Tropical Screech Owl, all belonging to the order Strigiformes, are among the principal phobogenic (fear-inducing) species whose vocalizations can cause significant behavioral responses in people across different cultures worldwide [1,6,7,32,57,58]. According to Wyndham and Park [58], owls are the birds most frequently cited as harbingers of events or messengers of the supernatural world. These authors suggest that owls possess a range of characteristics, including distinctive vocalizations, an unnaturally flexible neck, nocturnal habits, and heightened sensory

abilities, that are commonly associated with witchcraft and death in many regions. This aligns with our findings, which indicate that owls are often persecuted and killed due to their cultural association with bad omens.

The distinct patterns of bird vocalizations and presence, depending on their manifestations, are interpreted by humans, forming a zoosemiotic relationship based on a network of interspecific signals that acquire culturally situated meanings. This interaction enables co-adaptations between people and birds [53,54], as exemplified by the practice of anticipating rainfall following the vocalization of the Laughing Falcon, as reported by informants. Other studies [1,32,58] suggest that this phenomenological–sociocognitive experience is multifactorial, shaped by a combination of phenotypic, demographic, behavioral, and eco-cultural traits. As such, the recognition of birds as prophetic beings appears to be a widespread phenomenon across human cultures.

Regarding respondents' perceptions of the importance of these species, birds of prey that feed on carrion and prey on small rodents and insects are recognized as critical components of ecosystems. They contribute to the regulation of food chains and are considered important bioindicators of pollution, as well as changes in habitats, ecosystems, and landscapes. Consequently, they play a vital role in maintaining ecosystem services [12,14–16]. Species belonging to the family Cathartidae are particularly significant, as they are among the primary recyclers of energy and nutrients in ecosystems and contribute to the control of infectious–contagious diseases, especially in regions lacking adequate environmental sanitation [14].

The traditional use of species as pets and for food identified in our study is not in the semi-arid region of Brazil. In other parts of the world, such practices are widespread activities directly linked to falconry [10,11] and/or traditional uses [59–61]. In Brazil, particularly in the semi-arid region, Mendonça et al. [20] and Soares et al. [9] reported that, although these species are used as food, the primary motivation for killing them is their predation on domestic animals. Their consumption, therefore, is more a means of resource exploitation than the initial purpose (retaliation) of hunting, which aligns with the justifications provided by participants in our study.

Predation on pets and livestock is a major reason for the killing of birds of prey and other predators in Brazil [20,28,62,63], as well as globally [24,64–67]. Although retaliation against conflict species often occurs due to the predation of both small and large domestic animals, in many regions, this fact is also associated with rapid and unregulated human expansion into previously uninhabited areas. The drastic alterations in ecosystems caused by human encroachment have led many birds of prey to replace their natural prey with domestic animals, due to both their proximity to anthropic areas and the decline in natural prey populations [63,68,69]. We emphasize that the rapid expansion of human-induced impacts and increased human presence in previously uninhabited regions are likely to intensify interactions between humans and large birds of prey, thereby raising the likelihood of conflict.

Social vulnerability is another factor that plays a role in conflicts with wild animals. For example, communities that are dependent on a single livelihood strategy or face financial hardship often exhibit heightened hostility towards animals perceived as dangerous or harmful, as the loss of resources (e.g., livestock or crops) is compounded by the lack of alternative subsistence options or income [24,66,68,70]. This mirrors the reality observed in the study areas, which are located in the Caatinga—an ecosystem characterized mainly by semi-aridity and long periods of drought (up to 11 months)—where agriculture and domestic livestock rearing are unviable due to severe resource limitations.

The data obtained in our study supports the statement that the perception of birds of prey by the inhabitants is ambiguous. Perceptions and attitudes can be positive and/or neg-

ative depending on the species, which is also confirmed by other studies [42,64,71,72]. Our results show that species are considered important because they 'clean' the environment and feed on insects, rodents, and snakes (animals considered pests in the communities studied). However, they are associated with misfortune or omens and are killed when they attack domestic animals.

Although most conflicts are related to the predation of domestic animals, various social factors, such as educational background, religion, beliefs, cultural taboos, fear, and others, contribute to the complexity and severity of such conflicts [24,48,65,66,68,73]. Perceptions related to dominance, harm, fear, and aversion towards certain animals can lead to negative attitudes, including the killing of the animals involved [6,23,25,58,64,71,73].

A wide diversity of species contributes to the maintenance of numerous ecosystem services, such as pest control, nutrient cycling, and indicators of environmental quality display, and are also involved in various folk practices and belief systems [74,75]. Thus, understanding how local communities perceive both the ecosystem and cultural services provided by birds can enhance the management of human–bird interactions by identifying and addressing both the benefits and drawbacks of such interactions, while also improving efforts to mitigate negative perceptions and promote conservation [74,75]. Many bird species hold important roles in virtually all human cultures and societies. Therefore, societal perceptions and attitudes towards wildlife can be strongly shaped by cultural factors. In this regard, although mitigation measures, such as subsidies or compensation for damage caused by wildlife, may reduce hostility towards conflict-prone species, cultural beliefs or inherent biases are typically more difficult to overcome and often cause stronger negative reactions than the actual damage incurred [57,68,69,76].

Beliefs are an important cultural mechanism that can be useful for conservation, as they impose constraints on community members' behaviors and practices that may either protect or harm natural elements [64,71,77,78]. Therefore, it is evident that targeted research is required to understand how and why certain species are perceived, and how their habits and behaviors influence the beliefs and actions of the human population, in order to develop more effective conservation measures. It is worth noting that, in Brazil, there is no legal provision for conflict mitigation involving any predator species, and the hunting and killing of wildlife are prohibited throughout the country under Law N° 5.197/197 [79], with the exception of wild boar control (Normative instruction IBAMA N° 3/2013 [80]). As stated in the first article of this law "Animals of any species, at any stage of their development and that live naturally outside of captivity, constituting wild fauna, as well as their nests, shelters and natural breeding grounds are property of the State, and their use persecution, destruction, hunting or capture are prohibited" [79].

Thus, the development of awareness campaigns and more innovative, complex, and interdisciplinary approaches, which address the multiple ecological and socio-cultural factors underlying socio-environmental conflicts, is critical for effective conflict mitigation. It is, therefore, imperative to involve traditional communities in decision-making processes to foster broader awareness and promote coexistence between people and birds of prey and/or other predators and conflict-associated species.

5. Conclusions

Considering this is the first study to address traditional populations' perceptions about birds of prey and their relationships in semi-arid regions of Brazil, it presents several limitations that should be acknowledged. First, the findings are primarily based on self-reported data from local residents, which may be subject to memory bias, cultural interpretations, and inaccuracies in species identification. Therefore, it is to be expected that the number of species, perceptions, and attitudes recorded here represents only a

fraction of the socio-ecological dimensions that influence human–raptor relationships. Second, the limited spatial scope—restricted to three rural communities—constrains the generalizability of the results to other regions with different socioecological dynamics. In addition, external variables such as media exposure, religious influences, and modernization were not controlled, despite their potential impact on local perceptions. Our findings also reflect a temporal snapshot and do not account for intergenerational variations in knowledge and attitudes. Cultural associations with certain species, such as omens or superstitions, may lead to distorted perceptions that challenge conservation efforts grounded in ecological evidence.

In this context, many other raptor species and socio-cultural factors could also be involved in conflicts with human populations in other regions of Brazil. Additionally, a significant percentage of respondents reported killing these birds due to perceived threats to domestic animals, which reflects a broader issue of socio-economic vulnerability in rural communities that should be addressed in future research about human–bird of prey relationships. Thus, studies such as the one presented here should be complemented by other approaches that assess the tangible impacts of damage caused by birds of prey and the socio-cultural factors that drive or intensify conflict. This would support the development of measures aimed at mitigating negative perceptions and attitudes towards these animals, thereby promoting coexistence and ensuring their conservation. Future research incorporating longitudinal designs and broader sociocultural analyses would enhance the understanding and the applicability of the findings.

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Appendix A. Semi-Structures Form Questionnaire Used in the Face-to-Face Interviews

Ethno-ornithological form

Name:
Community:
Age:
Residence time in commnunity:
Job:
Education level:

General questions

1—Do you know any birds that feed on other animals?
2—How many these birds there is in the region? Which do you know?
3—Do you know what a bird of prey is?
4—Have these birds any importance? If yes, which?
5—Which the animals that these birds prey on?
6—Is there any these birds that harbinger any signal? Which bird? Which signals?
7—What do you do if you encounter with these birds? Why?

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