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Rural Wage-Earners' Attitudes Towards Diverse Wildlife Groups Differ Between Tropical Ecoregions: Implications for Forest and Savanna Conservation in the Brazilian Amazon

Fernanda Michalski[1,2,3], Ricardo Luiz Pires Boulhosa[3], Yuri Nascimento do Nascimento[1,2] and Darren Norris[1,2,4]

Abstract

Understanding people's attitudes towards wildlife species is key for developing and effectively implementing conservation initiatives. Although attitudes towards different wildlife classes have been examined separately within a variety of regions, there have been no comprehensive comparisons of attitudes towards wildlife between different tropical ecoregions over large spatial scales. Here, we examined attitudes of 106 rural wage-earners from two ecoregions in the eastern Brazilian Amazon. We used generalized Linear Models (GLMs) to examine the influence of socioeconomic variables and ecoregion type on attitudes towards wildlife species, grouped into three classes (liked, disliked, and damage income). Overall we obtained attitudes regarding 57 wildlife species that were organized into 11 faunal groups (amphibians, ants, bats, birds, fishes, medium-bodied mammals, large-bodied mammals, primates, snakes, tortoises and turtles, and other invertebrates). Ecoregions where wage-earners lived was the strongest predictor of the total number of liked and disliked wildlife species. The total number of species damaging income was explained by socioeconomic variables related to the number of people living in the property and level of education. Medium and large-bodied mammals were most frequently reported both as liked and causing damage, while snakes were most frequently reported as disliked in both ecoregions. Although socioeconomic variables were important predictors to wage-earners' attitudes towards wildlife species, the environment (ecoregion) was the strongest predictor affecting human-wildlife attitudes. Our findings contribute with information about the importance of considering differences in local attitudes across a representative spectrum of wildlife species to inform the identification of effective focal species in different tropical regions.

Keywords

attitudes, human dimensions, invertebrates, perceptions, management, vertebrates

Human perceptions and attitudes towards wildlife species are complex and dynamic (Colléony et al., 2017; Decker et al., 2001; Destefano & Deblinger, 2005; Jordan et al., 2020), with negative interactions between increasing human populations and wildlife becoming increasingly widespread (Dickman, 2010). These negative interactions can arise when the needs and behavior of wildlife impact and/or are perceived to impact negatively on the goals of humans (Madden, 2004). In fact, the rapid growth and expansion of human populations worldwide (United Nations et al., 2017) means that

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people and wildlife are more prone to increase their frequency of contact. As humans and wildlife compete for space and resources human-wildlife interactions are likely to continue to increase through the 21st century (Madden, 2004; Nyhus, 2016).

Understanding the social contexts and factors that influence human attitudes towards wildlife is important to enable wildlife managers, researchers and educational programs to attract support from the general public and stakeholders (Castilho et al., 2018; Colléony et al., 2017; Ebua et al., 2011; George et al., 2016), which can be key to mitigate negative human-wildlife interactions and promote biodiversity conservation (Dickman, 2010; König et al., 2020; Peterson et al., 2010; Störmer et al., 2019). For example, negative-interactions can arise due to crop damage (Abrahams et al., 2018; Linkie et al., 2007), livestock depredation (Gebresenbet et al., 2018; Michalski et al., 2006), competition for similar resources (Michalski et al., 2012; Shibia, 2010), and fear (Alves et al., 2012). Attitudes towards wildlife can differ with a number of variables including gender (Bencin et al., 2016; Martino, 2008), age (Fabian et al., 2020; Mankin et al., 1999), and level of education (Hariohay et al., 2018; Shibia, 2010; Vodouhê et al., 2010).

The success of wildlife conservation depends on the attitudes of the local population. Information about the attitudes of commensal species is a prerequisite to ensuring human-wildlife coexistence and designing optimal and effective management schemes (Gillingham & Lee, 1999; D. Parry & Campbell, 1992; Torres et al., 2018). Indeed, existing personal values can be leveraged to incentivize changes in people's attitudes. For example, in a similar manner to that which has been adopted to reduce water and energy consumption (Allcott & Rogers, 2014) charismatic species can generate positive attitudes (Colléony et al., 2017; Ducarme et al., 2013). Identifying species that determine different attitudes is therefore the cornerstone of developing effective conservation actions. Such species based approaches would appeal to people's affective intuitive and rational thinking simultaneously (Reddy et al., 2017). For example, crop damage and livestock depredation can cause negative attitudes towards wildlife in rural and/or subsistence agricultural societies as well as in domestic production of animals (Hartter et al., 2011; Liu et al., 2011; Torres et al., 2018). People can also feel threatened by wildlife, both in terms of crop loss and personal safety (Hill, 1997; Linkie et al., 2007; Liu et al., 2011; Webber & Hill, 2014).

Although human attitudes towards wildlife have been examined within a variety of regions (Destefano & Deblinger, 2005; Dickman, 2010; Ebua et al., 2011; Mankin et al., 1999; Shibia, 2010), there have been no comparisons of attitudes towards different faunal groups between different tropical ecoregions and habitats. Therefore, the purpose of this study was threefold: to (1) understand local people's attitudes towards widely differing wildlife species; (2) explore if people living in different ecoregions differ in their attitudes towards wildlife species, and (3) examine if socioeconomic variables could affect people's attitudes. We also contribute with suggestions to increase the success of conservation initiatives and management practices in the Amazon.

Methods

Study Area

This study was conducted across 10,000 km^2 in Amapá State, eastern Brazilian Amazon (Figure 1). Amapá has an extensive network of protected areas, including indigenous lands, strictly protected and sustainable-use reserves (International Union for Conservation of Nature [IUCN] & UN Environment Programme World Conservation Monitoring Centre [UNEP-WCMC], 2019). These protected areas account for over 105,000 km^2 (IUCN & UNEP-WCMC, 2019), which represents ca. 74% of the 142,000 km^2 total area of Amapá state (Instituto Brasileiro de Geografia e Estatistica [IBGE], 2019a). Amapá has by far the lowest deforestation rates compared with all other states of the Legal Brazilian Amazon. From 1988 to 2018, Amapá had an accumulated deforestation rate of 1559 km^2, which is 99% lower than the accumulated deforestation for the same period of its neighbour Pará State, the leader in deforestation rates among all Legal Brazilian Amazon states (Instituto Nacional de Pesquisas Espaciais, 2019).

This new deforestation frontier in the Brazilian Amazon is facing several threats including mercury contamination from mining activities (Akagi et al., 1995; Fostier et al., 2000; Guimaraes et al., 1999; Hacon et al., 2020), construction of new hydroelectric dams (Fearnside, 1995; Norris et al., 2018), and increased agriculture production with consequent land cover change (IBGE, 2019a). The Brazilian savanna ecoregion in the south and east of the Amazon rainforest is in rapid decline due to agriculture expansion (Brannstrom et al., 2008), coupled with an increased demand for crop (cereal, beans and oil seeds) in eastern Amazonia, with Amapá state producing 56,542 tons per year by December 2017 (IBGE, 2019b). These crops are mainly produced in savanna habitat as almost all forest habitat in Amapá state is covered by some type of protected area (IUCN & UNEP-WCMC, 2019). Additionally, population growth in Amapá has been increasing rapidly, with a population of ca. 500,000 people in 2000 projected to double to over one million people by 2030 (IBGE,2019a). Thus, as per many regions across Amazonia, interactions between local people and wildlife species has been recorded in and around protected areas (Michalski et al., 2012), and the consumption of

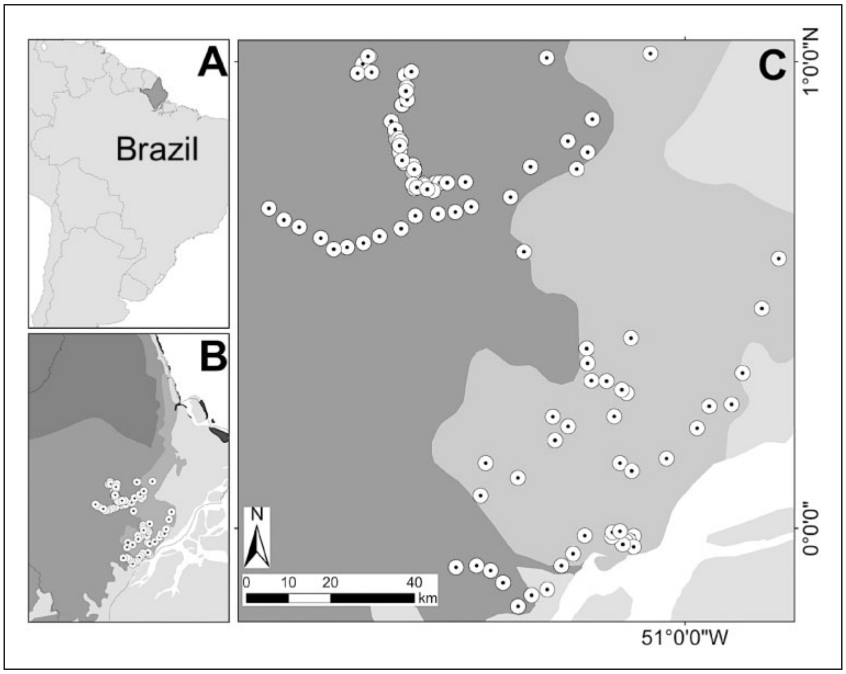

Figure 1. Study Area. (A) State of Amapá in Brazil. (B) Location of the study area within Amapá. (C) Location of the 106 interviews (circles) conducted with local wage-earners between March to December 2011, and May to August 2015. Dark and light grey represent Uatumã-Trombetas moist forests and Guianan savanna ecoregions, respectively.

protein from wildlife by local landowners has also been recorded in this region (Norris & Michalski, 2013).

Study Design

Locations of interviews across the 10,000 km^2 study area were initially selected using Google Earth (GE) to obtain approximate coordinates, location of villages and local communities supported by key landmarks such as rivers, roads, and other visual features that could be clearly distinguished by GE images. As a prerequisite, all candidate sampling sites that had been previously identified using GE images were associated with one local informant selected at random, usually a long-term resident or landowner, who was (1) willing to be interviewed, (2) was thoroughly familiar with the history of the area, (3) had knowledge of the local wild fauna, and (4) had been living in the property or close to it for at least one year. Ethical approval to conduct interviews with humans was obtained from the Ethics Committee in Research from the Federal University of Amapá (CAAE 42064815.5.0000.0003, Permit number 1.013.843).

Data Collection on People's Attitudes

From March to December 2011 and May to August 2015 we used pre-elaborated semi-structured questionnaires to interview local residents within the study area (Figure 1). Interviews conducted in the two ecoregions were distributed between the two sampling periods, and were carried out on a one to one basis with researchers asking questions and taking notes of the responses. We recorded socioeconomic characteristics of the respondents, such as gender, age, level of education, number of years living in the property, total number of people living in the property, and total monthly income (i.e., predictor variables). To understand attitudes towards wildlife species we focused on replies to three questions (i.e., response variables): (1) list five wild animal species they like, with species ranked according to the order in which they were mentioned (e.g., first mentioned species was the most liked); (2) list five wild animal species that they dislike, with species ranked according to the order in which they were mentioned (e.g., first mentioned was the most disliked); and (3) which five wild species damage their family income, with species ranked according to the order in which they were mentioned (e.g., first mentioned species was the most damaging income). Respondents were also questioned as to the reason why they liked, disliked or perceived the species as damaging their income. Our sampling focused on wage-earners, to understand attitudes towards wildlife causing damage to income, we therefore interviewed only the person responsible for the major income of the household, who was male in almost all cases (n = 101, 95.3% of all respondents, 96.9% and 92.7% forest and savanna ecoregions respectively). As differences in gender can cause bias related with attitudes (Allendorf &

Allendorf, 2013; Miller & Jones, 2006) we do not attempt to evaluate attitudes in relation to different genders in our study. As there was no difference in respondent gender between ecoregions no systematic bias was introduced.

We obtained the ecoregion type where each interview was conducted (Figure 1) by overlapping the interview coordinates on a map of the Earth's terrestrial ecoregions and biomes (Dinerstein et al., 2017) using ArcGIS 10.1 (Environmental Systems Research Institute, 2011).

Data Analyses

All analyses were performed in R (R Development Core Team, 2019). We performed descriptive analysis examining households and interviewees characteristics comparing their age, number of years living in the property, and the number of people living in the property between forest and savanna ecoregions using Kruskal-Wallis test. For the categorical variables [level of education (with four levels: non-literate, elementary, secondary school, or graduated) and the total monthly income reported for the family (with four levels: <1.0, 1.0–2.0, 2.1–3.0, and >3.0 Brazilian minimum wages) we tested the null hypothesis that proportions of responses were equal between ecoregions using the "prop.test" R function. The common names reported by wage-earners were summarized into 11 faunal groups (amphibians, ants, bats, birds, fishes, medium-bodied mammals, large-bodied mammals, primates, snakes, tortoises and turtles, and other invertebrates). These groupings were established based on documented preferences and attitudes (Alves et al., 2012; Batt, 2009; Dohm et al., 2011; Massad et al., 2013; Peres & Palacios, 2007) and to include species that are likely to require similar conservation management actions. When respondents unambiguously identified the species or congeners they liked, disliked or that damaged their income we obtained the proportion of interviews reporting the same species/congeners. We used Kruskal-Wallis test to determine significant differences between wage-earners interviewed from the two different ecoregions and total number of wildlife species reported as liked, disliked and that cause damage to their income. For all tests, a p value lower or equal to 0.05 was considered statistically significant.

To test for differences in the total number of wildlife species reported as liked, disliked and that cause damage and socioeconomic and ecoregion variables we used generalized Linear Models (GLMs, error distribution family = poisson). To assess the total number of wildlife species liked, disliked and that cause damage to income we examined the effects of (i) socioeconomic variables (e.g., age, time since living in the property, number of people living in the property, level of education, and total monthly income), and (ii) ecoregion where the interview was conducted. We controlled for high levels of inter-dependence between socioeconomic variables by performing a Spearman correlation matrix. This preliminary analysis showed that there were no strong correlations (Spearman $r < 0.70$) between the socioeconomic variables, with pair-wise correlation values ranging between 0.08 and 0.35, we therefore retained all variables in subsequent analyses. The influence of these predictors on the response variables was tested with separate GLMs to understand how these predictors could affect interviewee's responses. We adopted a stepwise selection (R function *step*) applying the program defaults to reach the most parsimonious, "best" model. We compared variable slope estimates in both the full and the "best" models selected, which enables us to avoid well known caveats of stepwise approaches, such as inflated Type I error rates (Mundry & Nunn, 2009).

A PERMANOVA (Permutational Multivariate Analysis of Variance) (McArdle & Anderson, 2001) was used to test the hypothesis that species composition differed based on the attitudes (liked, disliked, and damaging income), ecoregion (forest vs savanna) and socioeconomic factors (number of years living in the property, education level and monthly income) and their interaction. The similarities in species composition of respondents attitudes was visualized using Non-Metric Multidimensional Scaling (NMDS). Both NMDS and PERMANOVA analysis were performed in the vegan package (Oksanen et al., 2019) using the function metaMDS and anosim2, with dissimilarities calculated from Jaccard (Jaccard, 1901) distance matrix. An indicator species analysis (Cáceres & Legendre, 2009) was then used to identify the species most strongly associated with different attitudes (like, dislike, and damage income).

To understand motives for the differences in the species mentioned we focused on the first (most important) species reported for each question in each interview. When respondents unambiguously identified the species or congeners they liked, disliked or that damaged their income. Thus we obtained the proportion of interviews reporting the same species/congeners, coupled with the reason for such a positive or negative attitude only including interviews that were unambiguous in their answers.

Results

We conducted 106 interviews with local wage-earners in Amapá State (Figure 1). From this total, 65 interviews were conducted in Uatumã-Trombetas moist forest ecoregion (tropical & subtropical moist broadleaf forests biome) and 41 interviews were conducted in Guianan

Table 1. Socioeconomic Profile and Overall Attitudes on Wildlife Species of Wage-Earners in Different Ecoregions/Biomes Interviewed in Amapá State, Eastern Brazilian Amazon.

Variables of wage-earners interviewed	Uatumã-Trombetas moist forests/tropical and subtropical moist broadleaf forests	Guianan savanna/tropical and subtropical grasslands, savannas and shrublands
Total number of interviews	65	41
Age (mean ± SD, range)	53.5 ± 12.5 (26–81)	53.0 ± 13.9 (27–79)
Number of years living in the property (mean ± SD, range)	**18.9 ± 14.6 (1.5–58)**	**26.6 ± 17.4 (1.5–65)**
Level of education		
Non literate	17 (26.2%)	6 (14.6%)
Elementary school	36 (55.4%)	18 (43.9%)
Secondary education	9 (13.8%)	12 (29.3%)
Graduated	3 (4.6%)	5 (12.2%)
Monthly income (in relation to the Brazilian minimum wage)[a]		
<1.0	**18 (27.7%)**	**4 (9.8%)**
1.0–2.0	35 (53.8%)	16 (39.0%)
2.1–3.0	5 (7.7%)	9 (22.0%)
>3.0	**7 (10.8%)**	**12 (29.3%)**
Number of people living in the household (mean ± SD, range)	4.1 ± 2.3 (1–9)	4.6 ± 2.7 (1–12)
Total number of species liked (mean± SD, range)	**3.08 ± 1.45 (0–5)**	**4.17 ± 1.12 (1–5)**
Total number of species disliked (mean± SD, range)	**2.11 ± 1.20 (0–5)**	**2.78 ± 1.72 (0–5)**
Total number of species causing damage (mean± SD, range)	2.29 ± 1.33 (0–5)	2.61 ± 1.83 (0–5)

Values in bold denote significant differences between variables in forest and savanna ecoregions ($P < 0.05$).
[a]Minimum wage in Brazil as defined by decree 9.661/2019 was R$998.00 (US$256.48 based on exchange rate of 1 USD = 3.89118 BRL from 25/03/2019).

savanna ecoregion (tropical & subtropical grasslands, savannas & shrublands biome). The Euclidean nearest neighbour distance between all interviews was on average 57.7 km (±SD = 36.3 km, n = 11,130 pairwise comparisons).

Interviewee's and Households' Characteristics

Overall respondents lived at the property for an average of 21.9 years (±SD = 16.2, range = 1.5–65), and were aged between 26 and 81 years (average ± SD = 53.3 ± 13.0). Their level of education ranged from non-literate (n = 23, 21.7%) to graduated (n = 8, 7.5%), with half of the interviewees (n = 54, 50.9%) reporting having only elementary school level. Total monthly household income was between one and two Brazilian minimum wages for almost half of the respondents (n = 51, 48.1%), and the number of people living in the property ranged from 1 to 12 people (average ± SD = 4.3 ± 2.5) (Table 1).

Most of the socioeconomic characteristics of the interviewees were similar between the two ecoregions (Table 1). However, there was a statistically insignificant tendency of an increased number of non-literate and fewer graduated interviewees from the Uatumã-Trombetas moist forests ecoregion (Table 1). Some significant differences in the total monthly household income were found between the two ecoregions, with families in the Uatumã-Trombetas moist forests ecoregion showing a higher number of households with less than one Brazilian minimum wage per month and fewer households receiving more than three minimum wages per month compared to the Guianan savanna ecoregion (Table 1).

Attitudes Towards Wildlife

Overall respondents unambiguously identified 57 species/congeners (Table 2) that were liked (n = 31 species), disliked (n = 36 species) or damaged income (n = 31 species). Interviewees were consistent with their responses while citing liked and disliked species, never contradicting themselves while answering our questions. For example, although it is possible for a species such as wild pigs (*Pecari tajacu* and *Tayassu pecari*) to be both liked for food and disliked due to the same species causing crop damage, none of the respondents indicated the same species as both liked and disliked. Kruskal-Wallis tests demonstrated a significant difference in the total number of liked species between the two ecoregions, with people from the Guianan savanna reporting more species liked compared with Uatumã-Trombetas moist forest (Kruskal-Wallis $\chi^2 = 15.44$, df = 1, $p < 0.001$). Differences in total number of disliked wildlife species between the two ecoregions were marginally significant (Kruskal-Wallis $\chi^2 = 3.83$, df = 1, $p = 0.050$), but there was no significant difference in the number of species reported to damage income between the two ecoregions (Kruskal-Wallis $\chi^2 = 0.52$, df = 1, $p = 0.473$).

Table 2. List of 57 Species or Congeners Perceived by Local Wage-Earners as Liked, Disliked, or Damaging Income in Forest and Guianan Savanna Ecoregions.

Faunal group	Species or congeners	Common names
Ants	*Atta* sp.	Leaf-cutter ant
Birds	*Amazona* spp.	Amazon parrot
	Ara spp.	Macaw
	Ardea spp.	Great egret
	Cairina moschata	Muscovy duck
	Crax alector	Black curassow
	Harpia harpyja	Harpy eagle
	Ortalis sp.	Chachalaca
	Penelope sp.	Guan
	Psophia crepitans	Trumpeter
	Ramphastos spp.	Toucan
	Sporophila sp.	Finch
	Turdus sp.	Blackbird
Fishes	*Electrophorus* sp.	Electric eel
Large-bodied mammals	*Bubalus* sp.	Water buffalo
	Hydrochoerus hydrochaeris	Capybara
	Mazama spp.	Deer
	Myrmecophaga tridactyla	Giant anteater
	Panthera onca	Jaguar
	Pecari tajacu	Collared peccary
	Pteronura brasiliensis	Giant otter
	Puma concolor	Cougar
	Tapirus terrestris	Tapir
	Tayassu pecari	White-lipped peccary
Medium-bodied mammals	*Coendou* sp.	Coendou
	Cuniculus paca	Lowland paca
	Dasyprocta sp.	Agouti
	Dasypus spp.	Armadillo
	Didelphis marsupialis	Common opossum
	Eira barbara	Tayra
	Leopardus pardalis	Ocelot
	Leopardus wiedii	Margay
	Lontra longicaudis	Neotropical otter
	Nasua nasua	Coati
	Procyon cancrivorus	Raccoon
	Puma yagouaroundi	Jaguarundi
	Tamandua tetradactyla	Collared anteater
Other invertebrates	*Achatina fulica*	Giant African Snail
	Aedes sp.	Mosquito
	Bactrocera carambolae	Carambola fruit fly
	Scolopendra sp.	Centipede
	Theraphosa spp.	Tarantula
	Tityus spp.	Scorpion
Primates	*Alouatta* spp.	Howler monkey
	Aotus sp.	Night monkey
	Ateles paniscus	Spider monkey
	Saguinus midas	Golden-handed tamarin
	Sapajus apella	Capuchin
Reptiles	*Coleodactylus* sp.	Gecko
	Hemidactylus sp.	House gecko
Snakes	*Boa* sp.	Boa
	Bothrops spp.	Fer-de-lance
	Crotalus sp.	Rattlesnake
	Eunectes murinus	Anaconda
	Lachesis muta	Bushmaster
Tortoises and turtles	*Chelonoidis* spp.	Tortoise
	Podocnemis unifilis	Yellow-spotted river turtle

Table 3. GLM Model Results (Slope Coefficients With Associated ± SE in Parentheses) of Predictors of the Total Number of Wildlife Species Reported as Liked, Disliked and That Cause Damage to Their Income From 106 Interviews With Wage-Earners in Amapá state, Eastern Brazilian Amazon.

	Liked		Disliked		Cause damage	
Model components	Complete	Best[a]	Complete	Best[a]	Complete	Best[a]
Age	−0.00 (0.00)		0.00 (0.00)		0.01 (0.01)	
Number of years living in the property	0.00 (0.00)		−0.00 (0.00)		0.00 (0.00)	0.01 (0.00)$^{+}$
Number of people living in the property	0.01 (0.02)		0.03 (0.26)	0.04 (0.02)	0.05 (0.03)$^{+}$	0.05 (0.02)*
Level of Education (compared with non literate)						
Elementary school	0.08 (0.15)		0.11 (0.18)		0.02 (0.17)	−0.00 (0.16)
Secondary education	0.10 (0.19)		−0.08 (0.24)		−0.22 (0.24)	−0.28 (0.21)
Graduated	0.19 (0.24)		0.40 (0.29)		0.61 (0.27)*	0.46 (0.22)*
Total monthly income (compared with <1 Brazilian minimum wage)						
1.0–2.0	0.12 (0.16)		0.32 (0.20)		0.19 (0.19)	
2.1–3.0	0.15 (0.21)		0.39 (0.26)		0.30 (0.25)	
>3.0	0.19 (0.21)		0.14 (0.26)		−0.07 (0.26)	
Ecoregion (compared with Guianan savanna)	−0.22 (0.12)$^{+}$	−0.30 (0.10)**	−0.24 (0.14)$^{+}$	−0.26 (0.13)*	−0.06 (0.14)	
Model Deviance Explained	15.80	10.80	12.90	6.20	15.30	12.00
Model AIC	405.34	391.25	382.44	373.61	391.52	385.79

[a]The most parsimonious model obtained from backwards selection based on comparison of AIC values.
Significance levels: $^{+}$<0.10, *<0.05, **<0.01.

The Generalized Linear Models (GLMs) indicated that the explanatory power of the complete and best models were low for all attitudes on wildlife species (Table 3), with a maximum deviance explained of 15.8% (for the complete model of liked species) and a minimum of 6.2% (for the best model of disliked species). When considering the most parsimonious ("best") models, ecoregion was the only variable retained for explaining variation in the number of wildlife species reported as liked and disliked. Although number of people living in the property was also retained in the model of disliked species it was not significant. Socioeconomic variables were retained for explaining the number of species reported as damaging income (Table 3). The significant socioeconomic variables retained for the best model were number of people living in the property and level of education (graduated), with both variables positively related to the number of species reported as causing damage.

Medium and large-bodied mammals were the most liked faunal groups in both savanna and forest ecoregions (Figure 2). Although snakes were the most commonly reported disliked group in the two ecoregions, the second most disliked group in the Uatumã-Trombetas moist forest was large-bodied mammals, while in Guianan savanna the second most disliked faunal group was medium-bodied mammals (Figure 2). However, the largest difference between the attitudes

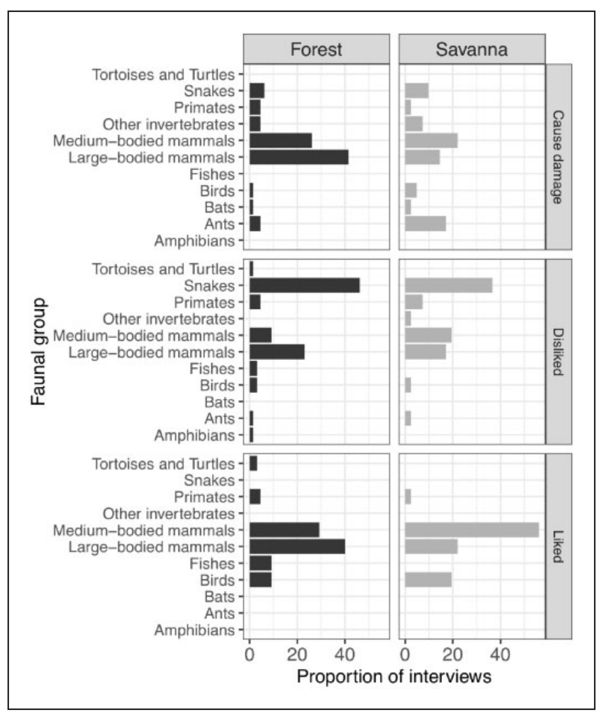

Figure 2. Proportion of Interviews That Reported Attitudes of "Like", "Dislike" and "Cause Damage" to 11 Faunal Groups in 106 Interviews Conducted With Local Wage-Earners in the Eastern Brazilian Amazon. Dark and light grey bars represent Uatumã-Trombetas moist forests (forest) and Guianan savanna (savanna) ecoregions, respectively.

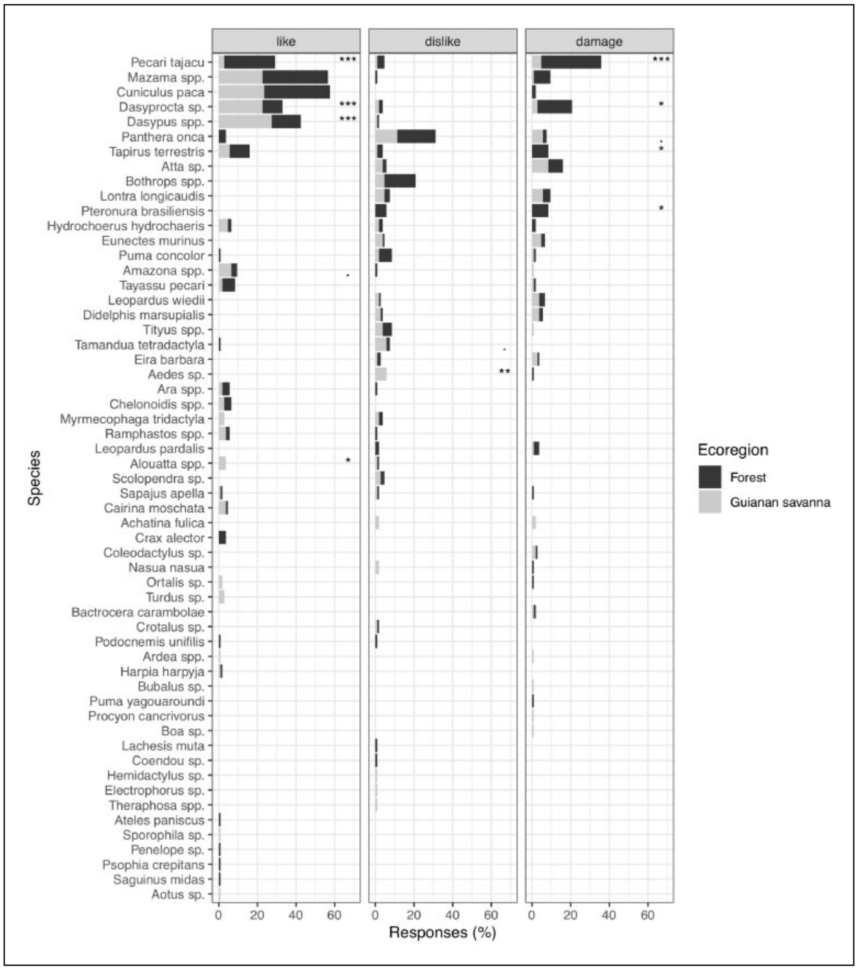

Figure 3. Attitudes of Species/Congeners. Percentage of respondents citing liked, disliked and damaging species/congeners across forest (black) and savannah (grey) ecoregions. Symbols indicate significant differences in proportion of responses between ecoregions (Significance levels: $^{+}$<0.10, *<0.05, **<0.01, ***<0.001).

of wage-earners in the two ecoregions was related to faunal groups considered to cause damage (Figure 2). Interviews from Uatumã-Trombetas moist forest reported medium- and large-bodied mammals as the two most commonly damaging faunal groups, and interviews from the Guianan savanna reporting medium-bodied mammals and ants as the faunal groups causing most damage to their income (Figure 2).

Overall, from the total of 57 species/congeners mentioned there were generally more positive responses ("like") regarding five species (*Pecari tajacu*, *Mazama* spp., *Cuniculus paca*, *Dasyprocta* sp., and *Dasypus* spp.) (Figure 3). With paca (*C. paca*) and deer (*Mazama* spp.) liked by the majority of respondents (57.5% and 56.6, respectively). Yet, the majority of species (54.3%; 31/57) were rarely mentioned i.e. cited less than 1% of responses (Figure 3). After excluding those species with less than 1% of responses, the majority of the remaining 26 species (84.6%; 22/26) tended to be mentioned in both ecoregions (forest and Guianan savanna), but with the proportion of responses sometimes differing between ecoregions (Figure 3). For example *Dasyprocta* sp. and *Dasypus* spp. were liked more by respondents in the savannah ecoregion, whereas *Dasyprocta* sp. was more likely to be perceived as damaging income in the forest ecoregion. In contrast there was less consistency in disliked species and species perceived as damaging income, with relatively low number of responses per species (<30% per species) (Figure 3).

The PERMANOVA results revealed significant differences in species composition between respondents (Table 4). There were significant differences in species between attitudes, region and interactions (Table 4). Of the socio-economic factors, only number of years since living in the property was associated with differences in species reported. Additionally, a significant interaction was found between number of years living in the property and education level (Table 4). The species reported also varied depending on attitude with region and number of years living in the property (Table 4).

Table 4. PERMANOVA Results.

Factor	Df	SS	R^2	F	*P*
Attitude (like, dislike, damage)	2	11.67	0.10	14.87	0.001
Ecoregion (savanna, forest)	1	2.13	0.02	5.43	0.001
Number of years living in the property	1	0.60	0.01	1.52	0.049
Attitude × Ecoregion	2	2.46	0.02	3.14	0.001
Attitude × years living at property	2	1.0	0.01	1.27	0.076
Years at property × Level of Education	3	1.58	0.01	1.34	0.035

Results based on Jaccard dissimilarity of the composition of liked, disliked and damaging wildlife species reported by 106 wage-earners in Amapá State, Eastern Brazilian Amazon. Only the most significant ($P < 0.1$) variables and interactions are reported. Df: Degrees of freedom; SS: sum of squares; R^2: partial R-squared value; *P*: *P* value (probability of F statistic obtained from 999 permutations).

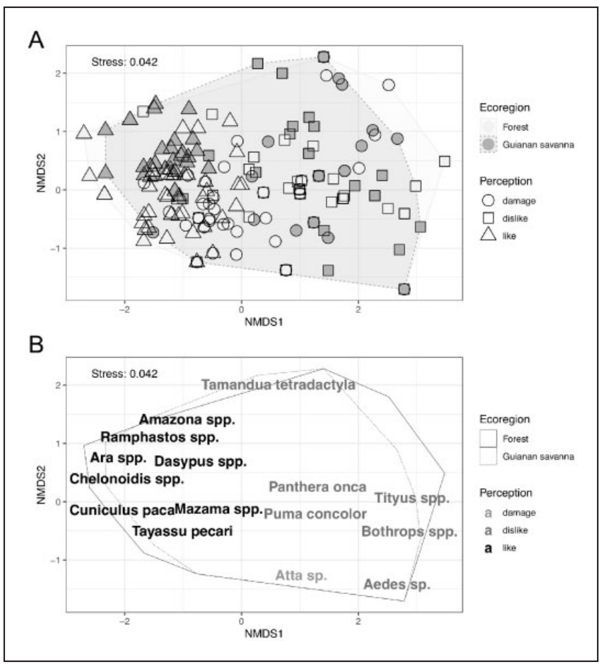

Figure 4. Ordinations. Two-dimensional non-metric multi-dimensional scaling (NMDS) ordination of (A) interviews and attitudes and (B) indicator species most strongly associated with attitudes. Lines represent convex hull encompassing all responses from different ecoregions.

Ordinations showed a clear pattern in the composition (dissimilarities) of species/congeners associated with different attitudes (Stress value = 0.042, Figure 4). For example, species reported as liked were clearly different from the ones reported as disliked or damaging to income (Figure 4A). Eight species were most strongly indicative from the 31 species cited as liked (Figure 4B). These eight included mammals (*Cuniculus paca*, *Dasypus* spp., *Mazama* spp. and *Tayassu pecari*), birds (*Amazonas* spp., *Ara* spp. and *Ramphastos* spp.) and a tortoise (*Chelonoidis* spp.). A total of 6 species were most strongly indicative of the 36 disliked species, including mammals (*Panthera onca*, *Puma concolor* and *Tamandua tetradactyla*), other invertebrates (*Aedes* sp., *Tityus* spp.) and snakes (*Bothrops* spp.) (Figure 4B). In contrast only leafcutter ants (*Atta* sp.) were strongly indicative of the 31 species cited as damaging income (Figure 4B).

First Cited Species and Motives

A total of 17 species/congeners were first cited as liked. People interviewed in the forest cited more species as liked compared with the savanna ecoregion (12 and 9 species/congeners, respectively, Figure 5A). There were also differences in the groups cited as liked between ecoregions. For example, more large-bodied mammal species were reported as liked in the forest, whereas the majority of the species perceived as liked in the savanna were medium-bodied mammal species (Figure 5A). The reasons for respondents perceiving species as "liked" were consistent among answers for the different species (Figure 5A). The most frequently first cited species (e.g. *Cuniculus paca*, *Dasyprocta* sp., *Dasypus* spp., *Mazama* spp., and *Pecari tayassu*) were all liked because they were used for food. Indeed the majority of species (58.9%, 10/17) were liked because of their use as food, yet seven species (3 birds, 2 mid- and 2 large-bodied mammals) were liked because of their beauty (Figure 5A).

A total of 17 species/congeners were also cited as disliked. Overall, people in the forest disliked more species compared with people in the savanna (13 and 9 species, respectively) (Figure 5B). Species were disliked as they were not used for food (7 species), dangerous (5 species) or damaged subsistence (6 species). Reasons for disliking species were the same between forest and savannah ecoregions except for howler monkeys (*Alouatta* spp.), which were disliked as they damaged subsistence or were not used as food in forest and savannah areas respectively (Figure 5B).

Fewer species/congeners (n = 15) were cited as damaging income (Figure 5C). Species first cited as damaging income were linked directly with predation on domestic animals (7 species) or causing damage to plantations/crops (8 species, Figure 5C). Three species were most frequently cited as damaging income, all due to damage caused to plantations/crops: mid- (*Dasyprocta*

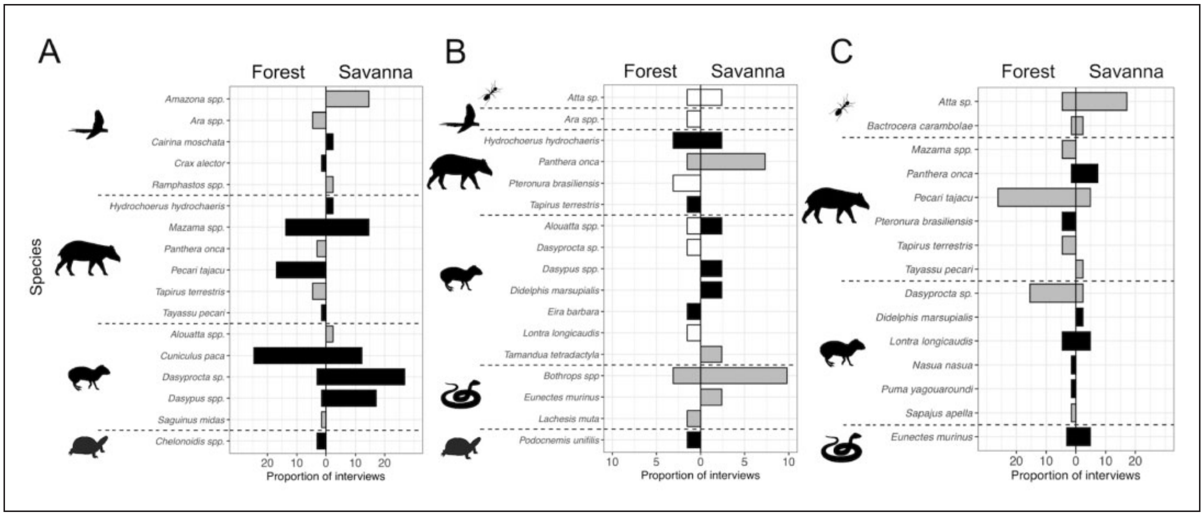

Figure 5. Wage-Earners' attitudes towards wildlife. Proportion of interviews that reported attitudes of (A) like, (B) dislike, and (C) damage income to first cited species or congeners in faunal groups (invertebrates, birds, large-bodied mammals, medium-bodied mammals, turtles and tortoises, and snakes) for 106 interviews conducted with local wage-earners in Uatumã-Trombetas moist forests (forest) and Guianan savanna (savanna) ecoregions. Bars shaded based on the motivation for the attitude. Colours represent: (A) black and grey bars indicate species used for food or considered beautiful, respectively, (B) black, grey, and white bars represent species not used for food, dangerous, or that cause damage to subsistence, respectively, and (C) black and grey bars represent species perceived as predators of domestic animals/livestock, or causing damage to plantation/crops, respectively.

sp.) and large-bodied (*Pecari tajacu*) mammals and leaf-cutter ants (*Atta* sp., Figure 5C).

Discussion

Linking local people with conservation actions is fundamental for effective biodiversity conservation as the creation and maintenance of protected areas on its own does not necessarily prevent hunting and other illegal activities inside their boundaries (Kauano et al., 2017). Our analysis of wage-earners' attitudes in the eastern Brazilian Amazon showed that in addition to socioeconomic variables the environment (ecoregion) was strongly associated with human attitudes of wildlife species. Differences in species/congeners cited in both ecoregions were unlikely to be due to preexisting differences in species occurrence in the two biomes as all species cited were broadly distributed across the Amazon (IUCN, 2019). We first turn to wage-earners' attitudes about wildlife species at two levels (faunal groups and species/congeners) in the two ecoregions, and then explore which socioeconomics and other variables affected people's attitude.

Ecoregions, Faunal Groups and Wage-Earners' Attitudes Toward Wildlife Species

Differences among environments have determined human history and socioeconomic development (Gallup et al., 1999). Our results show that differences in environment can also influence differences in human attitudes. We found that the number of wildlife species liked differed between the two ecoregions studied, with Guianan savanna residents reporting more species compared with Uatumã-Trombetas moist forest ecoregion. As subsistence hunting of terrestrial and arboreal vertebrates is a widespread practice in tropical regions (Peres, 1990; Redford & Robinson, 1987; Robinson & Redford, 1991) it is not surprising that respondents from both ecoregions cited a variety of wildlife species as liked. In fact, the most liked faunal groups (medium and large-bodied mammals) and species/congeners include hunters preferred species across the Amazon (Michalski & Peres, 2007; L. Parry et al., 2009; Peres, 2001; Peres & Palacios, 2007; Read et al., 2010). The larger number of medium-bodied species cited as liked in the Guianan savanna could be associated with a closer proximity to species due to the more open savanna habitat, that allows easier movement, especially with horses and bicycles (Read et al., 2010) allowing residents to cover larger areas, encountering more game species, but with smaller body-size, compared with the most difficult movement in forested areas. Our results of large-bodied mammals (especially *Mazama* spp. and *Pecary tajacu*) being more frequently cited as liked, for being used as food, in the forest agrees with previous studies, where this faunal group is preferred in comparison to smaller-bodied species (Michalski & Peres, 2007; Peres, 2001; Peres & Palacios, 2007). Thus, careful consideration should be taken when people's attitude related with "liked" species are revealed as it could be directly linked with preferred species used for subsistence. Similar to our results, smaller bodied species such as armadillos (*Dasypus* spp.) were also documented as frequently used for subsistence hunting in savanna regions in the Amazon (Read et al., 2010). Additionally, the more open habitat in savanna that facilitates movement of hunters (Read et al., 2010) may also favour heavier hunting pressure, which is already known to reduce biomass of large-bodied taxa and promote the dominance of smaller bodied species (Peres, 2000; Suarez & Zapata-Ríos, 2019). Although we do not have data on species abundance for both ecoregions, it is possible that a larger number of protected areas in the forest compared with the savanna in our study region (IUCN & UNEP-WCMC, 2019) may affect species richness and biomass present in both regions studied.

Snakes were reported as the most disliked group in both ecoregions. Human attitudes towards reptiles in Brazil are usually negative (Alves et al., 2012) therefore this strong dislike in both ecoregions is to be expected. In fact, snakes are perceived as potentially dangerous (López-del-Toro et al., 2009), generating as much fear in humans as guns (Fox et al., 2007). This was consistent with respondents citing poisonous snake species (*Bothrops* spp. and *Lachesis muta*) as disliked species as they were perceived as dangerous in both ecoregions. The second most disliked faunal groups, medium-bodied and large-bodied mammals, were similar to the ones reported as liked in the savanna and forest ecoregions, respectively. As small and medium-bodied mammals are more common in savanna habitats than in forest areas (Read et al., 2010) it is expected that these faunal groups will also produce different attitudes that can be associated with crop damage and competition for food resources. For example, species of large mammals commonly recorded in forest areas, such as collared peccaries (*Tayassu tajacu*) can also be perceived as disliked by respondents as they are frequently associated with crop raiding (Abrahams et al., 2018; Pérez & Pacheco, 2006). Also, species that compete for food resources such as the piscivorous giant otters (*Pteronura brasiliensis*) were cited as disliked species by landowners in previous studies conducted in forested areas in the same study region (Michalski et al., 2012). Similarly, as large-bodied mammals included large felid species (e.g. jaguar) it is expected that respondents could also dislike this group because of fear, thus our results at group levels should be interpreted carefully.

Finally, medium and large-bodied mammals were most frequently reported as causing damage to the income of the savanna and forest wage-earners, respectively. This finding is largely associated with the expected most common species that can be found in each different habitat (Read et al., 2010). However, ants were the second group most cited as damaging income in the savanna ecoregion, which could be largely explained by the agricultural economic activity in this habitat type (IBGE,2019a). This is supported by the fact that some respondents unambiguously cited the leaf-cutter ant (*Atta* sp.) associated with negative attitudes related to the species causing damage to their income. Indeed, leaf-cutter ants are capable of negatively affecting agricultural productivity, destroying recently planted manioc maize fields in the Brazilian Amazon (Smith, 1978) and are generally considered as important pest species in Neotropical America (Della Lucia et al., 2014).

Socioeconomic Variables and Ecoregion Effects on Wage-Earners Attitudes

Our results indicate that ecoregion type was the most important determinant for the number of wildlife species liked and disliked reported by respondents. However, socioeconomic variables such as number of people living in the property and education level were also significant positive determinants on the number of species reported as causing damage to the income of respondents. An increased number of people living in a property will generate an increased demand on food resources and generate more acute perception of losses that can cause negative attitudes. As wildlife can cause crop damage (Abrahams et al., 2018; Pérez & Pacheco, 2006) as well as prey on livestock (Boulhosa & Azevedo, 2014; Carvalho et al., 2015; Michalski et al., 2006) and compete for protein resources (Michalski et al., 2012) it is possible that larger families perceive more species as causing damage compared with smaller families that will need smaller food supply.

Education level is a well-established social factor that can affect people's attitude towards wildlife (Fort et al., 2018; Hariohay et al., 2018; Shibia, 2010; Vodouhê et al., 2010). However, contrary to what we expected, respondents with higher education level (graduated) were the group reporting significantly more species as causing damage to their income. Our results should be looked carefully as our sample size was not equally distributed and the majority of our respondents had relatively low levels of education. However, it is interesting to highlight that, based on our results, higher levels of education do not necessarily equate with more positive attitudes towards wildlife species.

Implications for Conservation

People's attitudes towards wildlife species considered in this study were strongly related with the type of ecoregion where respondents lived. The two most important predictors of damage causing species were number of people living in the property and education level, which were both positively related with a higher number of species reported. Our results clearly demonstrate that region specific conservation strategies must be developed to adequately address the different attitudes of people living in different ecoregions. Region specific attitudes need to be fully addressed by conservationists if they plan to achieve successful actions (e.g., effective communication between researchers and landowners/residents, outreach actions with landowners/residents and environmental education) to maintain biodiversity. Additionally, socioeconomic variables such as number of people living in the family showed to be important predictors of attitudes towards wildlife and must be considered while planning future conservation actions for the tropical regions. While choosing flagship species for conservation purposes in the Amazon, it is important to focus in species perceived as liked. As several species perceived as liked were related with the use for food it is crucial to understand the motives of people perceiving different species, which should be interpreted carefully. For example, some disliked species were cited because they were not used for food. Thus, selecting flagship species can be challenging when actions span ecoregions, as a liked species cannot be perceived as causing damage to income or being dangerous as well. Our results highlight some potential candidates from birds, such as parrots (*Amazona* spp.) and toucans (*Ramphastos* spp.) to be used as flagship species across the Amazon.

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Supplemental material

Supplemental material for this article is available online.

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