



Freelisting as a suitable method to estimate the composition and harvest rates of hunted species in tropical forests

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ABSTRACT

The aim of this study was to test the use of measures obtained from freelisting as possible surrogates of the harvest rate of hunted species. For this purpose, we interviewed 100 rural and urban hunters in southwestern Amazonia to obtain the frequency of citations of each hunted species through freelisting and gather information on the number of individuals hunted per species in the last five hunting events through hunting recalls. We assessed the relationship between the percentage of records per species by each method through a generalized linear model, and then compared the predicted values obtained from this model with the values observed in our dataset using Pearson's correlation. During freelisting, forty-three taxa were listed in 608 citations as hunted by the informants. Freelisting provided data on around twice the number of species obtained from recalls. During the last five hunting trips, urban hunters reported the hunting of 164 individuals of 18 species, representing 54.5% of the freelisted species. Rural hunters caught 146 individuals of 21 species, 60.0% of the freelisted species. We found a strong logistic relationship between the harvest rates, i.e., percentage of individuals hunted per species from recalls, and the freelisting percentage citations of hunted species, with the estimated and observed values of harvest rates highly matching (Pearson's $R = 0.98$, $p < 0.0001$). The freelisting method allowed a good estimate of the composition and harvest rates of hunted species. The formula produced in this study can be used as a reference for further studies, enabling researchers to use freelisting effectively to assess the composition of hunted species and to address the difficulty of obtaining reliable data on species harvest rates in tropical forests, especially in short-term studies and contexts in which hunters distrust research.

Keywords: Wildlife; Hunting; Participatory Methods; Local Communities; Amazon. .

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SIGNIFICANCE STATEMENT

In this study, we compare the estimates of harvest rates of hunted species obtained from hunting recalls and the frequency of citations of species hunted through freelisting with 100 hunters in southwestern Amazonia. We show that freelisting provided data on twice the number of species obtained from recalls, and the frequency of citations of hunted species was strongly correlated with recalls' harvest rates, both in urban and rural areas. Freelisting may be efficiently used in assessments of the composition of hunted species, and to estimate both the harvest rates and total number of animals harvested in tropical areas, especially in short-term studies and contexts in which hunters distrust research.

INTRODUCTION

Hunting is an ancient activity performed by several human societies around the world (Alves *et al.* 2018). Despite ensuring food security for local populations and benefits to conservation (Isaac *et al.* 2015; Nunes *et al.* 2019a; Sarti *et al.* 2015; Da Silva *et al.* 2020), hunting is also a major driver of biodiversity loss (Benítez-López *et al.* 2017; Scabin and Peres 2021). Uncovering the harvest rates of hunted species is key to determine the impacts of hunting and develop feasible strategies to sustainably managing them.

In principle, to effectively estimate harvest rates, hunting activity should be monitored continuously through methods such as self-monitoring (Valsecchi *et al.* 2014), hunting calendars (Oliveira and Calouro 2019), or through recalls of hunting events (Nunes *et al.* 2019b). However, due to logistical hurdles, in particular the high costs of monitoring (Abrahams *et al.* 2018), the difficulties of accessing more isolated communities, and the distrust of hunters in research (Chaves *et al.* 2021; Oliveira *et al.* 2018), data acquisition on harvests through these methods is not always achievable (Garden *et al.* 2007; Rist *et al.* 2008).

As an alternative, researchers have been using the method of freelisting, in which hunters cite freely the species hunted or consumed in their household (El Bizri *et al.* 2020; Knoop *et al.* 2020; Tavares *et al.* 2020). These data are then used to calculate the representativeness of each taxon within the pool of species cited (Ramos *et al.* 2020; Santos *et al.* 2019). However, it is unclear whether freelisting provides a good measure of the composition of species hunted, and whether measures generated through freelisting, such as the frequency of citations per species, are suitable surrogates of the proportion with which each species is harvested. This is because citations may reflect cultural preferences for certain species rather than actual offtake, or species may be more or less cited because of specific traits, e.g., higher body mass.

Given the limitations related to surveying and

monitoring hunting activities, the aim of this study is to test whether the measures obtained through freelisting may be used as surrogates of the composition and harvest rates of hunted species (here considered as the frequency with which each species is hunted). We interviewed Amazonian rural and urban hunters to compare the number of species cited and the frequency of citations of each hunted species obtained through freelisting with the hunters' recall of the species harvested during their last hunting events.

MATERIAL AND METHODS

Study area

This study was conducted in the state of Rondônia, located in the southwestern region of Northern Brazil (Figure 1). Rondônia occupies a territorial area of 237,765 km², distributed across 52 municipalities (administrative divisions containing rural areas and a seat city). The estimated population of Rondônia is 1,777,225 inhabitants, with the urban population (1,149,180 inhabitants) being almost thrice as large as the rural population (413,229 inhabitants) (IBGE 2017). The main river that flows through the state is the Madeira River, and the predominant vegetation coverage of the state is the Open Ombrophilous Forest within the Amazon domain (IBGE 2010). The study area presents a Humid Equatorial Climate, characterized by an average annual rainfall between 2,000 and 2,300 mm, and average temperatures between 24 and 27°C throughout the year. The seasonality is marked by a short dry season, between June and August, in which the rainfall is lower than 100 mm and temperatures can reach 37°C (Mendonça and Danni-Oliveira 2007). There is a wet season that starts in September and lasts until May, January being considered the rainy month, with 300 mm of rainfall and an average temperature of 25°C (Franca 2015).

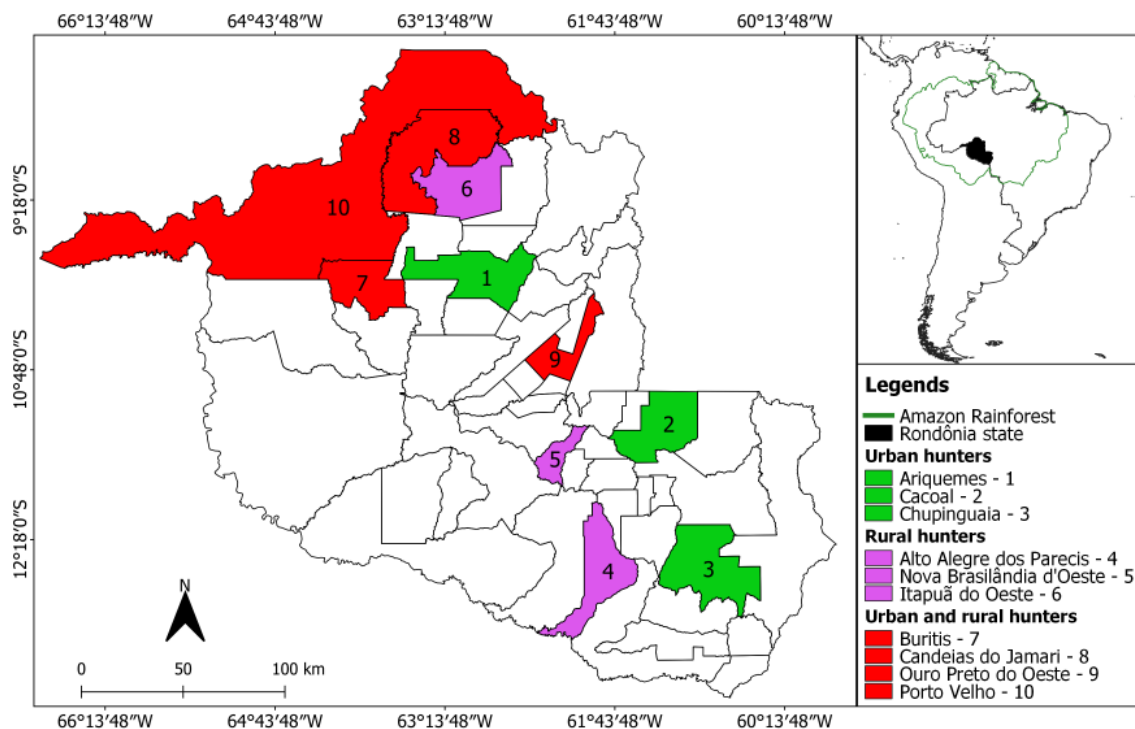


Figure 1. Municipalities of hunting interviews in the state of Rondônia, Southwestern Amazonia.

Data collection

We conducted semistructured interviews between October 2018 and February 2020 with 49 urban hunters and 51 rural hunters living in 10 municipalities within Rondônia state (Figure 1). Hunters were all above 18 years of age and permanent residents of the Rondônia state. Participants were selected through the snowball sampling method (Goodman 1961), forming a network of urban and rural informants. We started with previously known hunters living in the city of Porto Velho who openly provided information regarding wild meat consumption and/or hunting activity. These initial informants led us to additional interviewees, strengthening bonds of trust with the new participant. Because of the proximity and constant displacement of people between rural and urban areas in the studied site, the classification of hunters into urban or rural inhabitant was based on self-declaration. We took into account: whether the hunter considered themselves a resident of a rural or an urban area; the place of permanent residence: whether their permanent house was settled in a rural or urban environment; and the length of stay in the location: whether the hunter spent around 90% of their weekly time in rural or urban areas. Interviews were conducted individually. We divided the interview in three stages: (1) we defined with the interviewee whether they should be considered an urban

or rural hunter, (2) we asked the interviewee to freely list the species hunted by them in the area in the last year, and (3) we asked the interviewee to recall the species and number of specimens hunted in their last five hunting events. The freelisting method followed Albuquerque *et al.* (2010), in which the species hunted by the participant were noted down at the same order as presented by the informant.

The study was approved by the Research Ethics Committee (CEP) of Centro Universitário Aparício Carvalho (protocol 2 661 332), complying with the norms of Resolution 466/12 of the National Health Council. We used Abreu *et al.* (2021) for taxonomic classification of mammals, Pacheco *et al.* (2021) for birds and Costa *et al.* (2021) for reptiles.

Data analysis

We summed the number of citations per species per location (rural/urban) in the freelisting and calculated the representativeness of each species in terms of percentage of citations among all species cited. We did the same procedure for the number of individuals reported as hunted in the recall, calculating the harvest rates as the percentage of the number of individuals hunted of each species within the overall number of harvested individuals. We estimated the representativeness, in percentage, of the number of species reported during recalls in relation to those cited through

freelisting.

After that, we assessed whether the percentage of citations generated from freelisting and the harvest rates from hunting recalls were related to each other. To do so, we used a generalized linear model (GLM) with the Zero-adjust Gamma family of distribution with the identity link function (Stasinopoulos and Rigby 2008), using harvest rates from recalls as a response variable and both freelisting percentage citations and location (rural/urban) as predictor variables. We used different combinations of the predictor variables, from the simplest model (no predictor variables) to the more complex model (all predictor variables), including a model with interaction between freelisting percentage citations and location, and a model fitting a logistic curve. We decided that a logistic curve would be appropriate to be tested because the variables are based on percentage of citations, and therefore an asymptote is expected. The best-fitted model was selected based on AIC values (the fit with lowest AIC was selected). At the end, we also compared the predicted values obtained through this model with observed values in our dataset through Pearson's correlation. We used Microsoft Excel for data tabulation and management, and R version 3.6.3 (R Core Team 2021) for statistical analyses, using the R-packages *gamlss* (Stasinopoulos and Rigby 2008) for the GLM and *stats* (R Core Team 2021) for the Pearson's correlation.

RESULTS

In total, 43 taxa were freelisted in 608 citations as hunted by participants, 33 by urban hunters and 35 by rural hunters. During freelisting, urban and rural participants cited 5.9 (\pm 3.5 SD) and 5.9 (\pm 3.3 SD) species on average, respectively. All species recorded from hunting recalls were cited through freelisting. During recalls, 25 species were reported as hunted by the interviewees. Urban and rural participants cited 3.4 (\pm 1.5 SD) and 2.7 (\pm 1.4 SD) species on average during recalls, respectively. In their last five hunting trips, urban hunters reported the capture of 164 individuals of 18 species, representing 54.5% of the freelisted species. Rural hunters caught 146 individuals of 21 species, 60.0% of the freelisted species (Table 1).

Considering urban hunters only, the nine-banded armadillo, collared peccary, white-lipped peccary, and red brocket deer comprised 52.7% of all citations of species during freelisting, while paca, collared peccary and white-lipped peccary comprised 61.6% of the number of individuals reported as hunted in the last five hunting trips. Considering rural hunters only, the paca, nine-banded armadillo, collared peccary, white-lipped peccary, and agouti comprised 52.7% of all ci-

tations during freelisting, while paca, nine-banded armadillo, and collared peccary comprised 54.1% of the number of individuals reported as hunted in the last five hunting trips.

We found a strong logistic relationship between freelisting percentage citations and harvest rates from hunting recalls (GAMLSS Estimate = 0.96, $t = 6.6$, $p < 0.00001$) (Figure 2A) with no effect of location, according to the following formula: Harvest rate = $47.7 / (1 + 78.5 * e^{-0.315 * \text{Freelisting percentage citations}})$. There was also a strong match between the observed values of harvest rate from our dataset and the predicted values from our model (Pearson's $R = 0.96$, $p < 0.0001$) (Figure 2B).

DISCUSSION

Detailed and long-term studies on hunting usually depend on high community engagement, and a great presence of researchers in the study area (Oliveira *et al.* 2018). Therefore, having access to a network of informants along with applying less invasive methods may be beneficial to the success of hunting surveys, especially in urban environments, where gaining trust from hunters tend to be more challenging (van Vliet *et al.* 2015). Our results show that freelisting may be a cheaper, faster, and likely less invasive, yet reliable, methodological approach to make hunters more comfortable with research. This method proved to be efficient in both urban and rural contexts, which favours scalability for large-scale studies, and may be used as a gateway to the first contact of researchers with hunters.

Freelisting offers a good measure of the harvest rates, in terms of representativeness of each hunted species within the pool of species hunted. In addition, freelisting resulted in twice the number of species reported in hunting recalls. The lists included species that may be less frequently caught by hunters and therefore more difficult to be recorded in recalls or even through long-term methods, such as community-based monitoring. In addition, several species may be seasonally hunted and therefore were not cited in our recalls, since this method was applied only in one season. Therefore, freelisting may be suitable to have a first glance of the most impacted taxa and can be used complementarily to hunting recalls or other hunting survey methods to provide a better assessment of the composition of hunted species. To avoid bias, freelisting interviews should always be conducted individually, without the presence of third parties who can influence the response of the participant (Quinlan 2005). It is also important to bear in mind that, although not tested here, the order of citation of the species during freelisting may sometimes be as important as the number of citations, since in some situa-

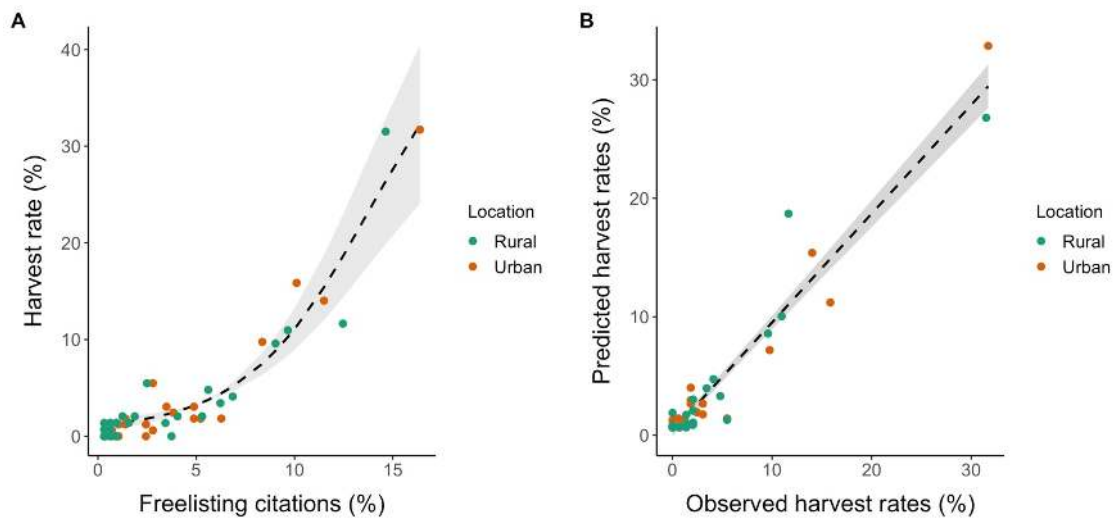


Figure 2. Relationship between A) the freelisting percentage citations and harvest rate (percentage of individuals hunted) through hunting recalls with urban and rural hunters from Rondônia, Southwestern Amazonia; and B) the observed and predicted harvest rates from the formula generated in this study.

tions hunters may tend to mention first the species with higher cultural or dietary importance (Albuquerque *et al.* 2010).

We consider that the formula produced in this study could be used as a reference for subsequent studies on wildlife hunting. This formula can be especially useful when the number of species harvested is similar or higher than the number we obtained here. If researchers ask hunters for an estimate of the number of specimens they catch over a year, this formula could also be used to extrapolate the total yearly extraction per species without requiring an extensive and long-term monitoring.

CONCLUSION

Our assessment offers evidence that freelisting can be used effectively to overcome the challenge of obtaining reliable data on hunted species composition and harvest rates, especially in short-term studies and contexts in which hunters distrust research. Freelisting is also useful for research conducted within one season only, as we did here, since in these cases hunting recalls may not yield the overall number of species potentially hunted by locals over the year. Recalls or other hunting survey methods should therefore be used in conjunction with freelisting to complement and offer a better overview of the composition of species harvested by hunters. The measures produced by freelisting were related to the harvest rates obtained from hunting recalls in southwestern Amazonia, and freelisting provided twice as large the number of species obtained through recalls. The formula we

generated can be used as a reference for further studies. The freelisting method is a less invasive approach that can facilitate and complement studies involving hunting of wildlife. Future studies should be directed towards validating our formula, and also comparing the measures obtained through freelisting with long-term hunter offtake methods, *i.e.* community-based monitoring.

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DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

CONTRIBUTION STATEMENT

Conceived of the presented idea: MAO, HREB, TQM.

Carried out the experiment: MAO.

Carried out the data analysis: HREB, TQM.

Wrote the first draft of the manuscript: MAO, HREB, TQM.

Review and final write of the manuscript: MAO, HREB, TQM, MRM, CRCD.

Supervision: MRM, CRCD.

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Table 1. Freelisting citations and number of specimens hunted from recalls reported by urban and rural hunters in Rondônia, Southwestern Amazonia.

Taxon	Local name	Popular name	Freelisting citations (%)			Hunting recalls (%)		
			Urban	Rural	Total	Urban	Rural	Total
Mammalia								
<i>Nasua nasua</i>	Quati	Coati	0	3 (0.9)	3 (0.5)	0	0	0
<i>Puma concolor</i>	Onça-parda	Puma	2 (0.7)	5 (1.6)	7 (1.2)	0	2 (1.4)	2 (0.6)
<i>Panthera onca</i>	Onça-pintada	Jaguar	1 (0.3)	6 (1.9)	7 (1.2)	0	3 (2.1)	3 (1.0)
<i>Mazama americana</i>	Veado-mateiro	Red brocket	18 (6.3)	17 (5.3)	35 (5.8)	3 (1.8)	3 (2.1)	6 (1.9)
<i>Mazama nemorivaga</i>	Veado-roxo	Amazonian brown brocket	8 (2.8)	12 (3.7)	20 (3.3)	1 (0.6)	0	1 (0.3)
<i>Ozotoceros bezoarticus</i>	Veado-galheiro	Pampas deer	1 (0.3)	0	1 (0.2)	0	0	0
<i>Dicotyles tajacu</i>	Catitu	Collared peccary	33 (11.5)	29 (9.0)	62 (10.2)	23(14.0)	14 (9.6)	37 (11.9)
<i>Tayassu pecari</i>	Queixada	White-lipped peccary	24 (8.4)	31 (9.7)	55 (9.0)	16 (9.8)	16 (11.0)	32 (10.3)
<i>Dasypus novemcinctus</i>	Tatu-galinha	Nine-banded armadillo	29 (10.1)	40 (12.5)	69 (11.3)	26 (15.9)	17 (11.6)	43 (13.9)
<i>Dasypus beniensis</i>	Tatu-15kg	Greater long-nosed armadillo	15 (5.2)	4 (1.2)	19 (3.1)	3 (1.8)	3 (2.1)	6 (1.9)
<i>Euphractus sexcinctus</i>	Tatu-peba	Yellow armadillo	3 (1.0)	2 (0.6)	5 (0.8)	2 (1.2)	1 (0.7)	3 (1.0)
<i>Cabassous unicinctus</i>	Tatu-rabo-mole	Southern naked-tailed armadillo	2 (0.7)	3 (0.9)	5 (0.8)	0	0	0
<i>Priodontes maximus</i>	Tatu-canastra	Giant armadillo	4 (1.4)	3 (0.9)	7 (1.2)	2 (1.2)	0	2 (0.6)
<i>Didelphis marsupialis</i>	Mucura	Common opossum	0	2 (0.6)	2 (0.3)	0	2 (1.4)	2 (0.6)
<i>Tapirus terrestris</i>	Anta	Tapir	14 (4.9)	20 (6.2)	34 (5.6)	3 (1.8)	5 (3.4)	8 (2.6)
<i>Alouatta puruensis</i>	Guariba	Purús red howler monkey	1 (0.3)	2 (0.6)	3 (0.5)	0	0	0
<i>Ateles chamek</i>	Macaco-aranha	Black-faced Black spider monkey	1 (0.3)	3 (0.9)	4 (0.7)	0	0	0
<i>Saguinus weddelli</i>	Soin	Weddell's saddle-back tamarin	1 (0.3)	0	1 (0.2)	0	0	0
<i>Saimiri ustus</i>	Macaco-de-cheiro	Golden-backed squirrel monkey	1 (0.3)	0	1 (0.2)	0	0	0
<i>Sapajus apella</i>	Macaco-prego	Black-capped capuchin	1 (0.3)	1 (0.3)	2 (0.3)	0	2 (1.4)	2 (0.6)
<i>Hydrochoerus hydrochaeris</i>	Capivara	Capibara	10 (3.5)	18 (5.6)	28 (4.6)	5 (3.0)	7 (4.8)	12 (3.9)
<i>Cuniculus paca</i>	Paca	Paca	47 (16.4)	47 (14.6)	94 (15.5)	52 (31.7)	46 (31.5)	98 (31.6)
<i>Dasyprocta</i> spp.	Cutia	Agouti	11 (3.8)	22 (6.9)	33 (5.4)	4 (2.4)	6 (4.1)	10 (3.2)
<i>Coendou longicaudatus</i>	Coendu	Long-Tailed Porcupine	0	2 (0.6)	2 (0.3)	0	0	0
<i>Hadrosceiurus spadiceus</i>	Quatipuru	Southern Amazon red squirrel	0	1 (0.3)	1 (0.2)	0	1 (0.7)	1 (0.3)
Aves								
<i>Tinamus solitarius</i>	Macuco	Solitary Tinamou	7 (2.4)	3 (0.9)	10 (1.6)	2 (1.2)	0	2 (0.6)
<i>Tinamus guttatus</i>	Nambu-galinha	White-throated Tinamou	0	1 (0.3)	1 (0.2)	0	1 (0.7)	1 (0.3)
<i>Dendrocygna</i> spp.	Marreca	Whistling-Duck	2 (0.7)	0	2 (0.3)	1 (0.6)	0	1 (0.3)
<i>Cairina moschata</i>	Pato-do-mato	Muscovy Duck	4 (1.4)	3 (0.9)	7 (1.2)	3 (1.8)	2 (1.4)	5 (1.6)
<i>Penelope jacquacu</i>	Jacu	Spix's Guan	11 (3.8)	13 (4.0)	24 (3.9)	4 (2.4)	3 (2.1)	7 (2.3)
<i>Ortalis guttata</i>	Aracua-pintado	Speckled Chachalaca	0	1 (0.3)	1 (0.2)	0	0	0
<i>Pauxi tuberosa</i>	Mutum	Razor-billed Curassow	14 (4.9)	11 (3.4)	25 (4.1)	5 (3.0)	2 (1.4)	7 (2.3)

<i>Sarcoramphus papa</i>	Urubu-rei	King Vulture	0	1 (0.3)	1 (0.2)	0	0	0
<i>Psophia viridis</i>	Jacamim-das-costas-verdes	Green-winged Trumpeter	1 (0.3)	0	1 (0.2)	0	0	0
<i>Ara</i> spp.	Arara-vermelha	Macaw	0	1 (0.3)	1 (0.2)	0	0	0
<i>Patagioenas</i> spp.	Pomba	Pigeon	3 (1.0)	0	3 (0.5)	0	0	0
<i>Leptotila</i> spp.	Juriti	Dove	1 (0.3)	0	1 (0.2)	0	0	0
<i>Crotophaga major</i>	Anu-coroca	Greater Ani	0	1 (0.3)	1 (0.2)	0	0	0
<i>Ramphastos</i> spp.	Tucano	Toucan	0	1 (0.3)	1 (0.2)	0	0	0
Reptilia								
<i>Boa constrictor</i>	Jiboia	Common boa	1 (0.3)	0	1 (0.2)	0	0	0
<i>Eunectes murinus</i>	Sucuri	Green anaconda	1 (0.3)	1 (0.3)	2 (0.3)	0	0	0
<i>Melanosuchus niger</i>	Jacaré-açu	Black caiman	7 (2.4)	8 (2.5)	15 (2.5)	0	8 (5.5)	8 (2.6)
<i>Caiman crocodilus</i>	Jacaretinga	Common caiman	8 (2.89)	3 (0.9)	11 (1.8)	9 (5.5)	2 (1.4)	11 (3.5)
<i>Total</i>			287	321	608	164	146	310