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Patterns of wildlife hunting and trade by local communities in eastern Amazonian floodplains

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ABSTRACT

Local people living in the Amazon rainforest rely heavily on wild meat as a source of protein and income. While the patterns and drivers of wildlife hunting and trade by local communities are well-known for upland forests, such aspects have been poorly explored in Amazonian floodplains. This study aims to describe wild meat hunting and trade patterns and assess the hunting dynamics of local communities in Amazonian floodplain areas. For this purpose, we interviewed 121 hunters in 36 communities living in white-water flooded forests in the lower Amazon River, Brazil. Thirty taxa were cited as hunted by interviewees, who used a repertoire of 13 hunting techniques. Aquatic and semi-aquatic taxa were the most prevalent, especially *Hydrochoerus hydrochaeris*, *Cairina moschata*, and *Podocnemis unifilis*. Eight taxa were cited as traded; wild meat was sold at 2.57 ± 2.22 USD/kg, while eggs of birds and turtles were sold at 0.37 ± 0.27 USD/unit. We found an inverted-U relationship between the body mass and the number of citations per taxa, with species weighing between 10-40 kg presenting the highest number of citations. The hunting patterns found here are different from those frequently found in the literature for upland environments. Understanding these hunting and trade patterns will help develop tailored wildlife conservation and management strategies for Amazonian floodplains.

Keywords: Wild meat; Subsistence; Várzea; Wildlife use.

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SIGNIFICANCE STATEMENT

This study is one of the few presenting information on hunting and trade of wildlife in floodplain ecosystems of the Amazon. Due to constraints on species occurrence, with low populations of terrestrial species, aquatic (i.e., chelonians and birds) and semi-aquatic (i.e., capybaras) taxa were the most used and traded species, contrasting with results usually found for upland environments. Hunters used 13 different techniques to catch hunted species, and the species' body mass was an important driver shaping wildlife use in these areas. Understanding these hunting and trade patterns will help develop tailored wildlife conservation and management strategies for Amazonian floodplains.

INTRODUCTION

The consumption and trade of wild meat are considered the primary reasons for hunting worldwide (Ingram et al. 2021). Wild meat hunting and consumption are particularly prevalent in developing countries in the tropics, which possess high richness of wildlife (Nielsen et al. 2018). Wild meat constitutes one of the main animal protein and income sources for rural people in several parts of Africa, Southeast Asia, and Latin America (e.g., Shanee 2012; Souto et al. 2019; Zanvo et al. 2021). In Latin American countries, wild meat hunting persists in different sociocultural contexts, especially in subsistence-based societies living in tropical forests (Souza-Mazurek et al. 2000). Hunting of animals is widespread from north to south of this region, in areas that vary widely in terms of urbanization and biodiversity levels (e.g., Parry et al. 2009; van Vliet et al. 2015). For instance, most rural people living in the Amazon rainforest rely heavily on wild meat as a nutritional, economic and cultural component of their livelihoods (e.g., Barros et al. 2012; Morsello et al. 2015).

More recently, however, a shift towards cash economies, increased access to remote areas, widespread use of guns, and technological improvements in communication, transportation and equipment have altered traditional hunting behavior in Amazonia and increased the sale of wild meat to meet urban demands (e.g., Bowler et al. 2020). Morsello et al. (2015) reported that at least one third of households in urban centers of the Brazilian and Colombian Amazon regularly consume wild meat, while El Bizri et al. (2020a) estimated that around 10 thousand tons of wild meat are consumed annually by urban residents in the Central Amazon.

Despite the social, cultural and economic (i.e., wild meat being the main or an additional source of income for several families) importance of hunting, there is increasing evidence that unsustainable hunting and trade of wild meat are among the main causes of wildlife population declines worldwide. In the Amazon, Parry and Peres (2015) estimated a large-scale level of depletion of hunted species populations along rivers and near densely populated villages and cities, possibly due to the higher involvement of hunters in the wild meat trade. Peres and Palacios (2007) found that 73% of the 30 game species analyzed in the Brazilian Amazon showed declines in their population numbers, reaching reductions of up to 74.8% in hunted sites compared to less intensively hunted sites. Fauna depletion caused by hunting not only affects hunted species populations but also has negative cascading effects on the structure of tropical forests due to the reduction of ecological services (e.g., seed dispersal) provided by hunted species (Peres et al. 2016). This fact highlights the need for a better understanding of hunting patterns and drivers in Amazonia to guide better decision-making on the management and sustainability of wild meat use, especially in poorly studied areas and environments of the biome.

Amazonian floodplains are wetlands that oscillate between terrestrial and aquatic phases with the seasonal rise of river water levels and consequent flooding of the area. Along the banks of the Amazon River, forests are periodically flooded with white water rich in nutrients, an environment that is therefore determined as white-water flooded forest (or várzea). White-water flooded forests constitute 6% of the whole Amazon biome (Ribeiro 2007). Although most of the white-water flooded forest consists of narrow stretches connected to upland, unflooded forests, some large extents of the Amazon composed uniquely of white-water flooded forests also exist (e.g., Western Amazon – Bodmer et al. 1999; Central Amazon – Lopes et al. 2012; Eastern Amazon – McGrath et al. 1993). These areas are suitable for aquatic and arboreal organisms, but the occurrence of terrestrial wildlife is limited. While the patterns and drivers of hunting by rural communities of upland forests are better known, hunting in Amazonian white-water flooded forests has been poorly explored (but see Valsecchi 2005; Lopes et al. 2012; Barboza et al. 2014; Kirkland et al 2018; Bodmer et al. 2018).

Seasonal conditions, cultural aspects of local communities, species traits and urban demand are commonly identified drivers of the frequency and intensity of hunting and trade of wild meat in the Amazon (Baia Júnior et al. 2010; Morcatty and Valsecchi 2015). In upland forest communities, local people usually employ different hunting techniques in differ-

ent periods of the year and hunt more during the high river level due to the lower availability of fish in this period (Endo et al. 2016). In addition, culturally distinct human societies (e.g., different indigenous ethnolinguistic groups and immigrants) usually have a preference for and hunt different taxa (Constantino et al. 2021). In terms of species traits, hunters usually take into account the body mass and availability of species in the environment to decide which species to catch (Bodmer 1995); these same traits also shape the occurrence and rates of trade of species in wild meat markets (El Bizri et al. 2020a,b). However, the limitation in terrestrial species availability in Amazonian white-water flooded forests and the constraints posed by the critical seasonal conditions of this environment (Bodmer et al. 2018) make local communities culturally different from upland communities, which may reflect in their hunting patterns, in particular in the bulk of species consumed, techniques used and rates of wild meat trade.

In this study, we describe wild meat hunting and trade patterns and assess the hunting dynamics of local communities living in floodplain areas in the Eastern Amazon, Brazil. More specifically, we report on the most hunted species during different seasons of the year, the species under trade and the prices applied. We also tested the hypothesis that species selected by hunters would be related to the body mass of the species.

MATERIAL AND METHODS

Study area

This study was conducted in five municipalities on the lower Amazon River floodplain ecosystem: Alenquer, Curuá, Óbidos, Prainha and Santarém, in the state of Pará, Brazil. All studied communities are non-indigenous riverine communities settled in white-water flooded forests, locally referred to as várzea, comprehending around 11,000 residents and 1542 households. Some communities located in white-water flooded forests occasionally use upland forests. The river water level fluctuates seasonally by around 5.7 m; thus, this environment is completely inundated during some months of the year (Dec-May). The settlements in our study area consist of smallholder communities. Although fishing is the main economic activity, they commonly use a combination of livelihood strategies involving fishing, hunting, farming of small animals, meliponiculture, and craftwork (McGrath et al. 2008). Local communities have organized themselves to protect local fisheries from outsider commercial fishers, in which some communities created diverse co-management practices related to economic activities, natural habitats, and key resources (Castello et al. 2013).

Data collection

We collected information on the patterns and drivers of hunting in 36 communities living in the study area. All participants were hunters who lived in local rural communities settled in white-water flooded forests. We selected two distinct groups of communities according to their access to natural resources from different habitats (hereafter "habitat type"): communities surrounded by flooded forest ($n = 30$; "core communities"), or at the edge between flooded and upland, non-flooded forest ($n = 6$; "edge communities"), able to hunt terrestrial species (Figure 1).

The inclusion of participants in our study was initially based on opportunistic sampling, whereby the first contacted hunters were already known to the authors. We then adopted a snowball sampling in which each hunter named successive ones in their respective community or adjacent areas to participate in the research. The sampling was not exhaustive of all hunters in the communities because data collection was conducted in short sampling expeditions, being limited by time and funding resources. In addition, several of the mentioned hunters were not available in the community by the time of data collection (i.e., they were working on agriculture, traveling to the city, or taking part in fishing or hunting excursions, etc.). We interviewed only one hunter per household. A total of 121 hunters participated in our survey, 3.36 ± 2.62 interviews per community on average, representing 7.8% of the total number of households in the studied communities. Despite that, we recognize the limitation of the sample size of our dataset and the long time since data collection, and as such, we limited our analyses to descriptive statistics and hypothesis tests in which pooling the data from different communities was feasible.

The questionnaire adopted here was part of a larger effort in the surveyed area to understand the dynamics of wildlife use by local communities and aid them in land regularization (i.e., creation of agroextractivist settlements). The interviews were conducted between 2008 and 2011. We asked interviewees to list freely the common names of the species they usually hunt in the dry and wet season, and the respective hunting techniques used to catch them. We also asked about whether the species were traded for commercial purposes, the prices applied and the selling unit (i.e., entire specimen or kg). People were free to answer questions they felt comfortable with, so some respondents preferred to not answer some questions in the questionnaire, specifically questions referring to trade of wild meat. Only 41 hunters from our sample answered questions on this topic.

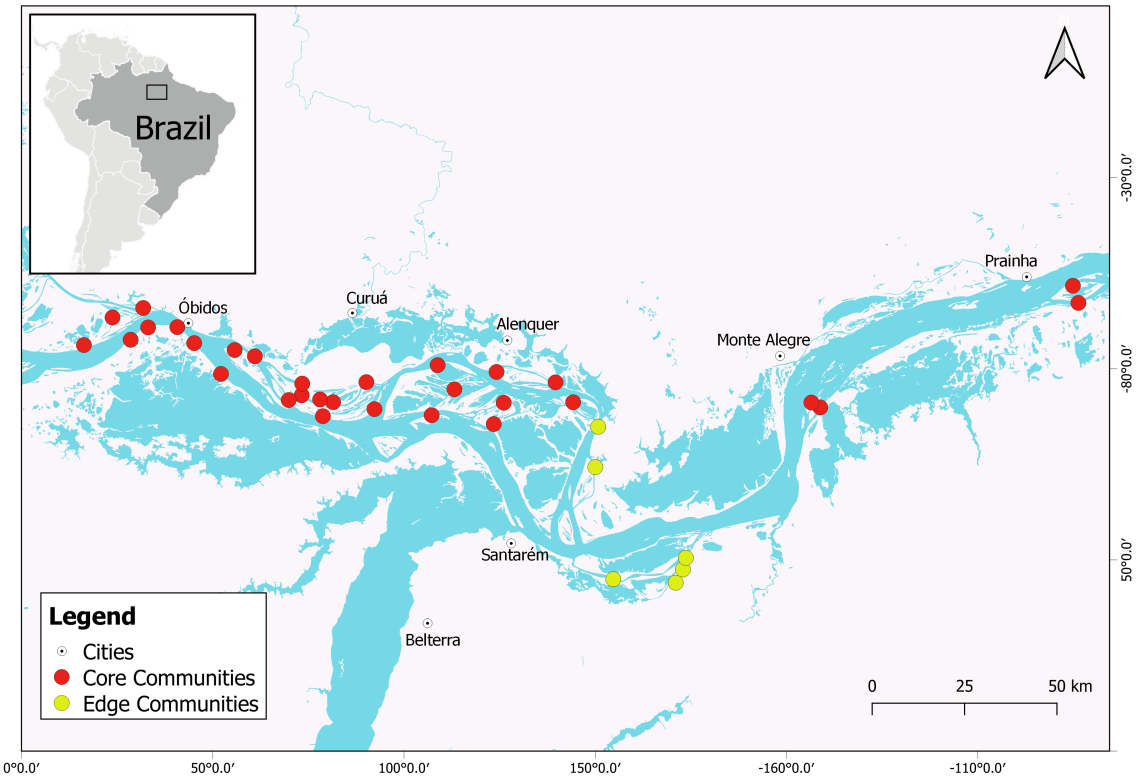

Figure 1. Communities surveyed in this study, located in the lower Amazon River. Areas surrounded by white-water flooded forest (core) and areas at the edge of the white-water flooded forest with the upland, non-flooded forest (edge).

Before each interview, we made participants comfortable by informing them about our study aims. Participants were informed that they could refrain from responding to any question they felt uncomfortable with and leave the study at any time. We also assured them that all interview notes were anonymous. We obtained verbal consent from all participants to use the interviews in the research.

Data analysis

We categorized each cited taxon for which we could identify the species according to their threatened status on the IUCN (2021). The adult body mass of the mentioned taxa was obtained from García et al. (2004), Robinson and Redford (1986), and El Bizri et al. (2020a). We used descriptive statistics to report on the number and percentage of citations per taxon, season, and habitat type. We compared the mean number of citations of hunted taxa per interviewee between habitat types using a Student's t-test. We also qualitatively described and classified into categories the techniques used to hunt each taxa, following an adaptation of hunting technique descriptions by Barboza et al. (2014) and Mesquita and Isaac-Nahum (2015). In addition, we report on the mean price (in USD/Kg) applied for each taxon cited as traded. For taxa that were sold as entire specimens (e.g., chelonians), we divided the price by the body mass of the taxon. The selling price of each taxon was converted using the exchange rate on July 1, 2008 to convert Brazilian reals (R$) into US dollars (R$1.61 = 1.00 USD), taking into account the General Price Index for Brazil estimated by the Getúlio Vargas Foundation.

We tested the hypothesis that the selection of species by hunters would be related to the species' body mass. For that purpose, we conducted a generalized linear model (R-package gamlss) with the Log-Normal family of distribution to test the effect of the body mass of the taxa on their number of citations. In this analysis, some species were pooled at a higher taxonomic level because it was not possible to unequivocally identify them at the species level in all responses. We included all armadillos within the Order Cingulata, alligators within the Family Alligatoridae, brocket deer within the genus Mazama, and all beach-nesting turtles within the genus Podocnemis. For pooled taxa, we used the average body mass

of the identified species. We included habitat type as a fixed factor in the model to control for differences in the number of interviews among communities from different habitats, and tested for a possible interaction between body mass and seasonality. We fitted both linear and second-order polynomial curves to the data. The best model between these two was defined based on their Akaike information criterion (AIC), and the one with lower AIC was selected. All analyses were performed in Rstudio Version 1.3.1093 (RStudio Team 2020) at a probability threshold level of $p < 0.05$.

RESULTS

Hunted taxa and hunting techniques used

A total of 105 participants (86.8%) provided information on hunted taxa and the techniques used to capture them. Thirty taxa were mentioned as hunted by these respondents in a total of 358 citations. Mammals ($n = 147$) were the most cited group, followed by reptiles ($n = 106$) and birds ($n = 105$). However, the four most-cited species are representatives of all three groups, with *Hydrochoerus hydrochaeris* (21.79%), *Cairina moschata* (13.13%), *Podocnemis unifilis* (13.13%) and *Dendrocygna autumnalis* (7.0%) as the top four hunted species and together comprising 55% of all citations. The number of citations of hunted taxa per interviewee was significantly higher in the edge communities (4.64 ± 1.93 citations/interviewee) than in core communities (2.15 ± 1.23) ($t = 7.6$, $p < 0.001$). Of the 24 identified species, six (25%) are currently threatened with extinction (Table 1).

Regardless of the environment or season, in core communities, considering the dry season, the main hunted taxa were *P. unifilis* (22.07%), *C. moschata* (20.69%) and *H. hydrochaeris* (16.55%); in the wet season, it was *H. hydrochaeris* (41.89%). In edge communities, in the dry season the main taxa hunted were *Cuniculus paca* (13.75%) and *H. hydrochaeris* (13.75%); in the wet season it was *H. hydrochaeris* (20.34%), *Dasyprocta leporina* (15.25%) and the Order Cingulata (15.25%) (Table 1).

A total of 13 hunting techniques were mentioned by interviewees. In general, "shotgun" was the most widespread hunting technique used by respondents (66%), followed by "manual capture" (33%) and "harpoon" (30%). *Podocnemis unifilis* was a target species for 80% of the different recorded hunting techniques. On the other hand, 60% of the taxa were associated to a unique specific technique, especially the "shotgun" (80%); these taxa were *Amazonetta brasiliensis*, *Anhinga anhinga*, *Ardea cocoi*, *C. moschata*, *Crax alector*, *Mazama* spp., *Mycteria americana*, *Phalacrocorax brasilianus*, *Penelope* sp., *Tayassu pecari*, and *Aburria cujubi* (Table 2). Some specimens caught from hunting activities mentioned in our study are shown in Figure 2.

Trade in wild meat and eggs

A total of 41 interviewees provided information on the trade of wild meat ($n = 108$ citations), and at least one interviewee in each community reported trading wild meat. Eggs of wild species were also traded ($n = 33$ citations). Eight taxa were cited as traded. Reptiles represented 71% ($n = 77$) of the species cited as traded in terms of meat and 88% ($n = 29$) in terms of eggs.

Prices were substantially different between meat and eggs. Wild meat was sold on average at 2.57 ± 2.22 USD/Kg. *Podocnemis unifilis* was the taxon most cited as sold ($n = 33$). The most expensive taxon was *Podocnemis sextuberculata*, sold for 6.47 ± 2.70 USD/Kg. In general, eggs (birds and turtles) were sold at 0.37 ± 0.27 USD/unit. *Podocnemis sextuberculata* eggs presented the highest value among turtle species, sold for 0.52 ± 0.14 USD/unit (Table 3). The eggs from *P. expansa* and *D. autumnalis* were the cheapest, less than half the price of other taxa. According to the informants, the trade of wild meat and eggs usually occurs between communities, which are bought usually by retired and salaried people (education and health professionals); and to a lesser intensity in nearby urban centers.

Body mass shaping hunting patterns

The hypothesis that the number of citations per species would be determined to their body mass was confirmed. The best model involved a polynomial curve fitted to the data (ΔAIC linear model = 11.43). We found a strong inverted-U relationship between the body mass and the number of citations per taxa, with the highest number of citations detected for taxa weighing around 10 to 40 kg. This relationship was independent of the season, i.e., no interaction between season and body mass was detected (Figure 3; Table 4).

Figure 2. Photographs showing specimens caught during hunting activities in the lower Amazon River: a) wood stork *Mycteria americana* hunted for Christmas dinner, b) bones of a spectacled caiman *Caiman crocodilus* that was killed during a hunting activity, c) collected eggs of yellow-spotted river turtle *Podocnemis unifilis*, and d) individuals of yellow-spotted river turtle *Podocnemis unifilis* captured using large adapted funnel-shaped net. Photographs: R. Barboza.

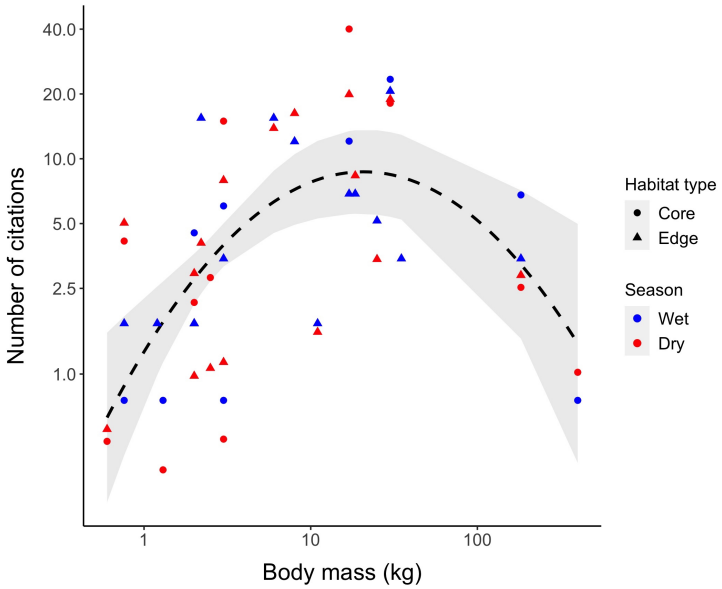

Figure 3. Relationship between body mass and number of citations of the taxa reported as consumed in the lower Amazon River. The shaded area is the 95% confidence interval. The points are normalized residuals, which are plotted on log-transformed (ln) y-axis and x-axis.

Table 1. Details of the hunted taxa cited by 105 interviewed (358 citations) of 31 local communities in the foodplains areas of the Lower Amazon River, with values for body mass, the popular name of the species, conservation status and percentage of citations as consumed. Number of respondents: Core = 25, Edge = 80. The names are ordered in alphabetical order:

Taxa	Common name	IUCN	Body mass (kg)	Core communities		Total	Edge communities		Total	Total of citations (%)
				Dry	Wet		Dry	Wet		
Aves				60 (41.38)	17 (22.97)	77 (35.16)	22 (27.50)	6 (10.17)	28 (20.14)	105 (29.33)
Aburria cujubi	Red-throated Piping-guan	LC	1.2					1 (1.69)	1	1 (0.28)
Amazonetta brasiliensis	Brazilian Teal	LC	0.6	2 (1.38)		2	1 (1.25)		1	3 (0.84)
Anhinga anhinga	Anhinga	LC	3	1 (0.69)	1 (1.35)	2				2 (0.56)
Ardea cocoi	Cocoi Heron	LC	2	5 (3.45)	6 (8.11)	11	3 (3.75)	1 (1.69)	4	15 (4.19)
Cairina moschata	Muscovy Duck	LC	3	30 (20.69)	8 (10.81)	38	7 (8.75)	2 (3.39)	9	47 (13.13)
Crax alector	Black Curassow	VU	3				1 (1.25)		1	1 (0.28)
Dendrocygna autumnalis	Black-bellied Whistling-duck	LC	0.76	15 (10.34)	1 (1.35)	16	8 (10.00)	1 (1.69)	9	25 (6.98)
Mycteria americana	Wood stork	LC	2.5	6 (4.14)		6	1 (1.25)		1	7 (1.96)
Phalacrocorax brasilianus	Neotropical Cormorant	LC	1.3	1 (0.69)	1 (1.35)	2				2 (0.56)
Penelope spp.			2				1 (1.25)	1 (1.69)	2	2 (0.56)
Mammalia				26 (17.93)	32 (43.24)	58 (26.48)	43 (53.75)	46 (77.97)	89 (64.03)	147 (41.06)
Cabassous spp.	Southern Naked-Tailed Armadillo	LC	4.8				1 (1.25)		1	1 (0.28)
Cingulata			6				8 (10.00)	9 (15.25)	17	17 (4.75)
Cuniculus paca	Agouti	LC	8				11 (13.75)	7 (11.86)	18	18 (5.03)
Dasyprocta leporina	Red-rumped Agouti	LC	2.2				4 (5.00)	9 (15.25)	13	13 (3.63)
Euphractus sexcinctus	Yellow Armadillo	LC	4.4				1 (1.25)		1	1 (0.28)
Hydrochoerus hydrochaeris	Capybara	LC	30	24 (16.55)	31 (41.89)	55	11 (13.75)	12 (20.34)	23	78 (21.79)
Mazama americana	Red Brocket	DD	20				2 (2.50)		2	2 (0.56)
Mazama nemorivaga	Amazonian Brown Brocket	LC	17				2 (2.50)	1 (1.69)	3	3 (0.84)
Mazama spp.			18.5				1 (1.25)	3 (5.08)	4	4 (1.12)
Pecari tajacu	Collared Peccary	LC	25				2 (2.50)	3 (5.08)	5	5 (1.40)
Tayassu pecari	White-lipped Peccary	VU	35					2 (3.39)	2	2 (0.56)
Trichechus inunguis	Amazonian Manatee	VU	400	2 (1.38)	1 (1.35)	3				3 (0.84)
Reptilia				59 (40.69)	25 (33.78)	84 (38.36)	15 (18.75)	7 (11.86)	22 (15.83)	106 (26.91)

Alligatoridae			182.5	3 (2.07)	4 (5.41)	7	2 (2.50)	2 (3.39)	4	11 (3.07)
Caiman crocodilus	Spectacled Caiman	LC	65		4 (5.41)	4				4 (1.12)
Melanosuchus niger	Black Caiman	LC	300	1 (0.69)	1 (1.35)	2				2 (0.56)
Testudines			17	2 (1.38)	1 (1.35)	3	6 (7.50)	2 (3.39)	8	
Peltocephalus dumerilianus	Big-headed Amazon River Turtle	VU	11				1 (1.25)	1 (1.69)	2	2 (0.56)
Podocnemis expansa	South American River Turtle	LC/CD	40	8 (5.52)	2 (2.70)	10	1 (1.25)		1	11 (3.07)
Podocnemis sextuberculata	Six-tubercled Amazon River Turtle	VU	3	13 (8.97)	3 (4.05)	16	1 (1.25)	1 (1.69)	2	18 (5.03)
Podocnemis unifilis	Yellow-spotted River Turtle	VU	8	32 (22.07)	10 (13.51)	42	4 (5.00)	1 (1.69)	5	47 (13.13)
Total: 30		-	-	145 (66.21)	74 (33.79)	219 (61.17)	80 (57.55)	59 (42.45)	139 (38.83)	358

Table 2. Hunting techniques used by interviewees, including their level of selectivity, season in which they are used, and species cited by the participants.

Category	Hunting technique (local names)	Description and season	Selectivity	Seasonality	Animals
Net	Gillnet ("malhadeira")	Traditional gill net of different sizes.	medium	wet, dry	Chelonians; *Dendrocygna autumnalis*
	Trawl net ("arrasto")	Seine trawl or beach trawl	high	wet, dry	Chelonians
	Funnel-shaped net ("puçá")	Artisanal funnel-shaped net adapted to be pulled with wooden structure by small regional boats	very high	wet	Chelonians
	Small net ("redinha")	A piece of net tied up under the branch where turtles usually bask. When the animal jumps, it falls directly into the net	very high	wet	Chelonians
	Cast net ("tarrafa")	Cone-shaped nets with small lead weights are arranged around the outer edge to increase their weight. The net is also cast over the animal, forming a large circle in the air	high	wet, dry	Chelonians; *D. autumnalis*
Hook	Hook and line ("caniço", "anzol")	Line and hook, sometimes with home-made fishing poles	high	wet, dry	Caimans; Chelonians; *Mycteria americana*; *Ardea cocoi*
Trap	Snare ("mundé", "demundé" or "laço")	It can be used in two ways, with a heavy trunk on a pole or using a noose to capture the animal's leg	very high	wet, dry	*Hydrochoerus hydrochaeris*
Fire gun	Shotgun ("espingarda")		low	wet, dry	Birds; mammals
Other	Arrow ("flecha")	Wooden bow and arrow	medium	wet, dry	*H. hydrochaeris*; chelonians
	Harpoon ("arpão")	Wooden lance with a pointed tip to which a cord is attached allowing the tip to separate from the shaft upon hitting the target	medium	wet, dry	*H. hydrochaeris*; caimans; *Trichechus inunguis*; chelonians

Manual capture	Capture of the animal or eggs by hand	medium	wet, dry	Eggs of ducks and chelonians; *D. autumnalis*; chelonians; armadillo
"Sororoca" or "soca-soca"	Long wooden stick used in the active search for chelonians buried in the sediment during the dry season	very high	dry	Chelonians
Hunting with dog ("cachorro")	Active search with the help of dogs.	medium	wet, dry	*H. hydrochaeris; Pecari tajacu; Dasyprocta leporina; D. autumnalis; Cuniculus paca; Euphractus sexcinctus*

Table 3. Details of species cited as sold and prices practiced. The taxa names are ordered alphabetically. SD = standard deviation.

Taxa	N of citations as sold (%)	Price (USD ± SD)	Unit
Aves			
Muscovy Duck (*Cairina moschata*)	1 (0.71)	4.67 ± 0.00	kg
Black-bellied Whistling-duck (*Dendrocygna autumnalis*)	2 (1.42)	4.99 ± 4.85	kg
Eggs Black-bellied Whistling-duck (*Dendrocygna autumnalis*)	4 (2.84)	0.21 ± 0.14	unit
Mammalia			
Capybara (*Hydrochoerus hydrochaeris*)	28 (19.86)	1.78 ± 0.36	kg
Reptilia			
Alligatoridae	1 (0.71)	0.62 ± 0.00	kg
Spectacled Caiman (*Caiman crocodilus*)	1 (0.71)	0.93 ± 0.00	kg
Testudines			
South American River Turtle (*Podocnemis expansa*)	23 (16.31)	1.56 ± 0.77	kg
Six-tubercled Amazon River Turtle (*Podocnemis sextuberculata*)	19 (13.48)	6.47 ± 2.70	kg
Yellow-spotted River Turtle (*Podocnemis unifilis*)	33 (23.40)	1.93 ± 0.72	kg
Eggs South American River Turtle (*Podocnemis expansa*)	1 (0.71)	0.19 ± 0.00	unit
Eggs Yellow-spotted River Turtle (*Podocnemis unifilis*)	26 (18.44)	0.41 ± 0.40	unit
Eggs Six-tubercled Amazon River Turtle (*Podocnemis sextuberculata*)	2 (1.42)	0.52 ± 0.14	unit
Total:12	141	2.02 ± 2.05	

Table 4. Details of the generalized linear model for the effects of body mass (in natural log scale) of the taxa on their frequency of citations as hunted by hunters living in the Lower Amazon River, Brazil. Habitat type of the community (whether within the core or edge of the white-water flooded forest) was included as a predictor variable to control for the distinct number of participants in each community. Significance codes (p): 0 '***' 0.001 '**' 0.01 '*' 0.05.

Predictor variable	Estimate	Std. Error	t-value
Intercept	-0.30381	0.54833	-0.554
Ln Body mass (coefficient 1)	1.5176	0.40141	3.781***
Ln Body mass (coefficient 2)	-0.20949	0.06049	-3.463***
Season (Dry)	1.1764	0.69465	1.694
Habitat type (Edge)	-0.8229	0.27733	-2.967**
Ln Body mass * Season (Dry) (coefficient 1)	-0.56546	0.51893	-1.09
Ln Body mass * Season (Dry) (coefficient 2)	0.06782	0.07896	0.859

DISCUSSION

This study stands out for being one of the few presenting information on hunting in floodplain ecosystems in the Amazon. Fishing is usually considered the main source of protein and income for many Amazonian communities, especially those living in white-water flooded forests, an environment that presents high productivity of fish (Mc Grath et al. 2008; Morcatty & Valsecchi 2015; Endo et al. 2016). However, hunting activity is also relevant for populations living in the Amazonian floodplains. A large number of hunted taxa ($n = 30$) were cited as used by respondents both for subsistence and/or income, demonstrating that eating and trading wild meat are important to support the livelihoods of resident populations.

Due to the characteristics of this environment, with extreme seasonal variation in river level, the availability of species was a decisive factor in the choice of animals used by hunters. The assemblages of hunted species found in this study are different from those traditionally found in the literature for upland environments, where terrestrial animals are usually the main exploited animals (Fonseca and Pezzuti 2013, Mesquita and Barreto 2015; Guimarães et al. 2019). The high prevalence of aquatic, semi-aquatic and arboreal animals – such as capybaras, river turtles, and birds – as the main species hunted is in line with the wild vertebrate assemblage in this area, since terrestrial animals are virtually non-existent in Amazon flooded forests (Haugaasen and Peres 2005; van Vliet et al. 2015).

These results corroborate with those of Lopes et al. (2012), who found that river turtles (*P. unifilis*, *P. sextuberculata*, *P. expansa*), *H. hydrochaeris* and *C. moschata* were among the most commonly hunted species in the Mamirauá Sustainable Development Reserve, a large protected area composed exclusively of white-water flooded forest in central Amazonia. We also found that communities living on the edge of the white-water flooded forest, near upland forest areas, included some terrestrial species in their diet, such as agoutis, pacas and armadillos. This demonstrates the need for targeted conservation and management actions for hunted species according to the access to different environments and species in the Amazon.

Hydrochoerus hydrochaeris was the most widely cited species in both habitat types, regardless of the season, and was also among the top traded species. Other studies have shown that *H. hydrochaeris* is one of the most important hunted mammals in Eastern Brazilian Amazon (Fonseca and Pezutti 2013; Baia Júnior et al. 2010; Mesquita et al. 2018). The year-round prevalence of citations for this rodent by hunters reflects the high potential for exploiting this animal as a source of meat, regardless of seasonality. As registered by Hoffman and Cawthorn (2012), the net cash return per hectare of *H. hydrochaeris* is almost three times greater than for cattle. Furthermore, despite *H. hydrochaeris* being a minor wild meat source for Amerindians (Peres and Nascimento 2006; Zapata-Ríos et al. 2009) and non-urban residents of Eastern Amazon (Mesquita and Barreto 2015), for several urban areas in the Amazon region, *H. hydrochaeris* meat is considered tasty (van Vliet et al. 2017) and this can be considered an important explanation for the preference of this species in the communities studied, given that it is amongst the most

locally traded wild meats. In illegal wild meat markets in Pará, for example, *H. hydrochaeris* accounted for more than 60% of all meat sold (Baia Júnior et al. 2010). In addition, the species is among the most seized in urban markets of Brazil (de Azevedo Chagas et al. 2015) and one of the preferred species by Brazilian sport hunters (El Bizri et al. 2015).

In our study area, we detected two species of river turtles from the *Podocnemis* genus (*P. unifilis* and *P. sextuberculata*) among the most consumed and sold taxa, with hunters selling both their meat and eggs. El Bizri et al. (2020a) found that turtle species, in particular *P. unifilis* and *P. expansa*, were among the top five species in terms of wild meat consumed in urban centers in Central Amazonia. In addition, in a recent wide-scale study, wild meat from approximately 1.7 million turtles and tortoises was estimated to be consumed annually in urban centers in Central Amazonia (Chaves et al. 2020). River turtles are targeted across different life stages (from eggs to adult stage). In some areas, it has been shown that the consumption of eggs is more frequent than meat (Rebêlo and Pezzuti 2000), and in several regions of the Amazon, freshwater turtles and their eggs are considered a delicacy (Vogt 2008; Schneider et al. 2011). In our study area, eggs are sold by the dozen or the hundred, especially the eggs of *P. unifilis* which, being more profitable and therefore presented a higher number of citations.

Drivers of hunting

Our results have shown that the body mass of the taxa influences their number of citations as hunted. Although not tested here, we expect that the number of citations would reflect the frequency with which hunters hunt each species (see Oliveira et al. 2022). Under this assumption, it is possible to state that the pattern we found meets the optimal foraging theory. This theory states that hunters would harvest prey based on a balance of cost/benefit according to profitability, availability and risks (Hawkes et al. 1982; Jerozolimski and Peres 2003). Accordingly, we found an increase in the number of citations with body mass up to a maximum and optimum point of around 30–40 kg (e.g., capybara). This suggests that hunters may be actively choosing to hunt large-sized taxa because these usually yield more meat per individual captured. However, after that point, we detected a steep decrease in the number of citations for larger taxa (i.e., caimans and manatee), likely due to constraints posed by species availability or risks. Although those two taxa are possibly the most profitable ones in terms of meat, they may be less dense, or even more dangerous to hunt in the case of caimans, and consequently more difficult to catch. According to informal dialogues with hunters, the commerce of caiman meat in the region is inexpressive when compared to the Central Amazon (Da Silveira and Thorbjarnarson 1999), probably due to the lower local abundance of this taxon in the region. Therefore, this makes them less prevalent in the bulk of taxa consumed by hunters. This result corroborates that of Mayor et al. (2022), who found a similar inverted-U relationship between species body mass and wild meat biomass traded in Amazonian markets.

The predominance of shotguns as the main hunting technique in all communities reinforces the role observed in recent decades of the widespread incorporation of modern technological resources in hunting practices by urban and rural residents, traditional or non-traditional peoples, throughout the Neotropical region (Swamy and Pinedo-Vasquez 2014; Barboza et al. 2016). Together with other equipment (e.g., flashlights, motorized land or water vehicles), shotguns can be used in day and night journeys, increasing the scope and frequency of hunting (Redford and Robinson 1987). This explains the non-selective character of this technique, which is used for virtually all birds and several mammal species. The popularity of firearms is ultimately in line with other socio-economic transformations in the Amazon, with an increasing access to urban goods (e.g., due to income growth, highway expansion, among other factors) (Godoy et al. 2010). These transformations exert a strong influence on the consumption of wildlife, as well as facilitate the acquisition of equipment such as motor vehicles, firearms and ammunition (Godoy et al. 2010).

On the other hand, the maintenance of the use of certain hunting techniques may be a consequence of the specificity of some target species to certain habitats and, to a certain extent, the perception of the effectiveness of these techniques (e.g., Tavares et al. 2020). Our findings are consistent with studies on hunting patterns among traditional or urban people in the tropics, which showed that, in addition to the aforementioned factors, some traditional strategies, including traps or silent felling tools, are employed to avoid detection of enforcement agents (where law enforcement is present) or to prevent the escape of target species (Barboza et al. 2016; Rogan et al. 2017; Loke et al. 2020).

Although the Amazon biome is one of the most studied biomes in Brazil in terms of hunting (Fernandes-Ferreira and Alves 2017), floodplain regions are usually neglected in terms of hunting research. Therefore, further studies in other floodplain ecosystems across the Amazon are needed to increase the understanding of the particularities of hunting profiles occurring in these areas. Considering that our study area was located in two distinct environments,

one more inland in the floodplain and the other more on the edge, it would be possible that the selection of species could respond to their availability in the environment.

Implications for conservation

Although six of the hunted species were threatened with extinction, four of them (white-lipped peccary, manatee, big-headed Amazon river turtle and black curassow) were cited only eight times in total, which shows that wild meat consumption in our study area targets mostly species of lower conservation concern. Nonetheless, there are several aspects which deserve consideration. A key point is that species listed as non-endangered in governmental or international databases can be locally endangered or near to extirpation (Ocampo-Peñuela et al. 2016). Size of human settlements, rates of use of wild meat as sources of protein and status of wildlife populations in source areas are aspects that need constant evaluation.

Beyond their importance as food for local people, a large set of game species in Amazon flooded areas perform important ecosystem services, such as seed dispersal. This is particularly true for river turtles (Laso 2009; Falcon et al. 2020). The harvest of eggs and adults of turtles without well-established management rules can result in critical population reductions with the consequent loss of services that guarantee forest regeneration, as well as affect the livelihood and food security of local human populations. Community-based management initiatives for the protection of chelonian nesting beaches have already showed to positively affect the recovery of river turtle populations in several areas of the Amazon (Miorando et al. 2013), and we advocate that these should be a priority to be implemented in our study area.

Understanding the consumption and trade patterns of wild meat, as well as the hunting dynamics of local communities, can be an important step to tackling socio-ecological problems and improving the conservation of target species. Communities with better socio-political organization can be seen as potentially more concerned with maintaining biodiversity because they often have mechanisms of community agreements to regulate the exploitation of natural resources (Wali et al. 2017; Constantino 2019). Studies have reported more sustainable management of floodplain species, such as capybara and turtles, in communities with a higher level of sociopolitical organization in the Amazon (see Barboza 2012 and Pezzuti et al. 2018). Good examples of community-based management include giant arapaima fish (*Arapaima gigas*) in the Amazon, which enabled sustainable commercial exploitation of the species along with the recovery of its populations (Freitas et al. 2019) and the collective fishing agreements adopted by some communities in the Eastern Amazon region (McGrath et al. 2008; Barboza 2012; Miorando et al. 2013). Similar initiatives could be employed for hunted species in our study area, aiming at the conservation of hunted species and taking into account the nutritional and financial needs of local people.

Wildlife trade takes place informally in all communities and is neglected by legislative and environmental protection bodies. Trade of wild meat is prohibited by law in Brazil (Law No. 5.197/1967), while consumption of wildlife for subsistence, although tolerated, is only vaguely defined in the current legal framework. As highlighted by Antunes et al. (2019) there is a need to revise and redefine subsistence hunting in legal frameworks, taking into account the reality of communities of the modern Amazon. It is important to highlight, however, that our data were collected 10 years ago and was based on a relatively small sample size, which limits our analytical inference. Hunting, trade and socio-ecological systems are dynamic, and may be influenced by a myriad of factors, such as changes in economy, legislation and environment. This is particularly true for flooded environments. For instance, Bodmer et al. (2018) showed that climate change has been causing great impacts on the abundance of hunted wildlife in floodplains of the Peruvian Amazon. In addition, the conservation status of some species has changed since the period of our data collection, such as for the white-lipped peccary (*Tayassu pecari*), which shifted from Least Concern to Vulnerable. Therefore, we recommend caution while interpreting our findings, and we claim that evaluation of the current conditions of hunting in our study area and periodic assessments should be undertaken to measure if and how these studies match or differ from our results.

CONCLUSION

In this study, we concluded that in floodplains of the lower Amazon River, different taxa are used by hunters, and the rates of use per taxon vary according to the body mass of the species. Regardless of the environment and season, the capybara *Hydrochoerus hydrochaeris* was the most cited species and one of the most traded one. Hunters are probably selectively hunting this species due to its constant availability over the year and the high return rates in terms of meat per captured individual. Reptiles represented 75% of the cited traded animals, with both their meat and eggs being sold. As trade in wild animals is prohibited in Brazil and these species are threatened with extinction, strategies to better manage hunted species in these study areas are

needed. This demonstrates the importance of developing tailored sustainable use of resources through co-management initiatives, aiming at the conservation of game species and the continuity of this important activity for local populations of Amazonian floodplains.

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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 the presented idea: ABS, PERP, HRB, RSLB.
Carried out the interviews: RSLB.
Carried out the data analysis: PERP, HRB.
Wrote the first draft of the manuscript: ABS, PERP, HRB, WMSS, RSLB.
Review and final writing of the manuscript: ABS, PERP, HRB, WMSS, RSLB.
Supervision: HRB, WMSS.
All authors read and approved the final manuscript.

REFERENCES

Antunes AP, Rebêlo GH, Pezzuti JC, de Mattos Vieira MA, Constantino PD, Campos-Silva JV, Fonseca R, Durigan CC, Ramos RM, do Amaral JV, Pimenta NC, Ranzi, TJD, Lima, NAS, Shepard Jr, GH (2019) **A conspiracy of silence: Subsistence hunting rights in the Brazilian Amazon**. *Land Use Policy* 84:1-11.

Baia Júnior PC, Guimarães DAA, Le Pendu Y (2010) **Non-legalized commerce in game meat in the Brazilian amazon: a case study**. *Revista de Biología Tropical* 58:1079–1088.

Barboza RRD, Lopes SF, Souto WMS, Fernandes-Ferreira H, Alves RRN (2016) **The role of game mammals as bushmeat In the Caatinga, northeast Brazil**. *Ecology and Society* 21:2.

Barboza RSL (2012)**Etnoecologia, pesca e manejo comunitário de quelônios aquáticos na várzea do Baixo rio Amazonas**. PhD Thesis. Universidade Federal do Pará, Belém, Pará.

Barboza RSL, Barboza MSL, Pezzuti JCB (2014)**"Estava pescando de malhadeira, vi na praia uns cascos brilhando, era luar, abeirei a terra e fui pegar": práticas de pesca de quelônios na várzea Amazônica (Santarém-PA)**. *Amazônica-Revista de Antropologia* 5:622–653.

Barros F, Varela S, Pereira H, Vicente L (2012) **Medicinal use of fauna by a traditional community in the Brazilian Amazonia**. *Journal of Ethnobiology and Ethnomedicine* 8:37.

Bodmer RE (1995) **Managing Amazonian Wildlife: Biological Correlates of Game Choice by Detribalized Hunters**. *Ecological Applications* 5:872–877.

Bodmer R, Mayor P, Antunez M, Chota K, Fang T, Puertas P, Pittet M, Kirkland M, Walkey M, Rios C, Perez-Peña C, Henderson P, Bodmer W, Bicerra A, Zegarra J, Docherty E. (2018) **Major shifts in Amazon wildlife populations from recent intensification of floods and drought**. *Conservation Biology* 32:333-344.

Bodmer RE, Puertas PE, Garcia JE, Dias DR, Reyes C (1999) **Game animals, palms, and people of the flooded forests: Management considerations for the Pacaya-Samiria national reserve, Peru**. *Advances in Economic Botany* 13:217-231.

Bowler M, Beirne C, Tobler MW, Anderson M, DiPaola A, Fa JE, Gilmore MP, Lemos LP, Mayor P, Meier A, Menie GM, Meza D, Moreno-Gutierrez D, Poulsen JR, Jesus AS, Valsecchi J, El Bizri HR (2020)

LED flashlight technology facilitates wild meat extraction across the tropics. *Frontiers in Ecology and the Environment* 18:489–495.

Castello L, McGrath DG, Arantes CC, Almeida OT (2013) **Accounting for heterogeneity in small-scale fisheries management: The Amazon case**. *Marine Policy* 38:557–565.

Chaves LS, Alves RRN, Albuquerque UP (2020) **Hunters' preferences and perceptions as hunting predictors in a semiarid ecosystem**. *Science of the Total Environment* 726:138494.

Constantino PDAL (2019) **Subsistence hunting with mixed-breed dogs reduces hunting pressure on sensitive Amazonian game species in protected areas**. *Environmental Conservation* 46:92-98.

Constantino PDAL, Valente-Neto F, Nunes AV, Campos-Silva JV (2021) **Culture still matters: conservation implications of hunting by ethnolinguistic groups in Southwestern Amazonia after centuries of contact**. *Biodiversity and Conservation* 30:445–460.

da Silveira R, Thorbjarnarson JB (1999) **Conservation implications of commercial hunting of black and spectacled caiman in the Mamirauá Sustainable Development Reserve, Brazil**. *Biological Conservation* 88:103–109.

de Azevedo Chagas AT, da Costa MA, Martins APV, Resende LC, Kalapothakis E (2015) **Illegal hunting and fishing in Brazil: a study based on data provided by environmental military police**. *Natureza & conservação* 13:183-189.

El Bizri H, Morcatty T, Lima J, Valsecchi J (2015) **The thrill of the chase: uncovering illegal sport hunting in Brazil through YouTubeTM posts**. *Ecology and Society*, 20:1-30.

El Bizri HR, Morcatty TQ, Valsecchi J, Mayor P, Ribeiro JES, Vasconcelos Neto CFA, Oliveira JS, Furtado KM, Ferreira UC, Miranda CFS, Silva CH, Lopes VL, Lopes GP, Florindo CCF, Chagas RC, Nijman V, Fa JE (2020a) **Urban wild meat consumption and trade in central Amazonia**. *Conservation Biology* 34:438–448.

El Bizri HR, Morcatty TQ, Ferreira JC, Mayor P, Neto CFV, Valsecchi J, Nijman V, Fa JE (2020b) **Social and biological correlates of wild meat consumption and trade by rural communities in the Jutaí River basin, central Amazonia**. *Journal of Ethnobiology* 40:183–201.

Endo W, Peres CA, Haugaasen T (2016) **Flood pulse dynamics affects exploitation of both aquatic and terrestrial prey by Amazonian floodplain settlements**. *Biological Conservation* 201:129–136.

Falcón W, Moll D, Hansen DM (2020) **Frugivory and seed dispersal by chelonians: a review and synthesis**. *Biological Reviews* 1:142-166.

Fernandes-Ferreira H, Alves RRN (2017) **The researches on the hunting in Brazil: a brief overview**. *Ethnobiology and Conservation* 6. doi: 10.15451/ec2017-07-6.6-1-7

Fonseca RA, Pezzuti JC (2013) **Dietary breadth of the animal protein consumed by riverine communities in the Tapajós National Forest, Brazil.** *Revista de Biología Tropical* 61:263–272.

Freitas CT, Lopes PFM, Campos-Silva JV, Noble MM, Dyball R, Peres CA (2019) **Co-Management of Culturally Important Species: A Tool to Promote Biodiversity Conservation and Human Well-Being**. *People and Nature* 2:61–81.

García JB, Acosta NB, Olivares LV (2004) **Técnicas de Preservación y Factor de Conversión de Fauna Silvestre en la Región Loreto, Perú**. In: Bodmer R (ed) Memorias del VI congresso internacional sobre el manejo de fauna silvestre en la Amazonía y Latinoamérica. Universidad Nacional de la Amazonía Peruana; Durrell Institute of Conservation and Ecology; and Wildlife Conservation Society, Iquitos, Peru, pp. 427–433.

Godoy R, Undurraga EA, Wilkie D, Reyes-García V, Huanca T, Leonard WR, McDade T, Tanner S, Vadez V, TAPS Bolivia Study Team (2010) **The effect of wealth and real income on wildlife consumption among native Amazonians in Bolivia: estimates of annual trends with longitudinal household data (2002–2006)**. *Animal Conservation* 3:265-274.

Guimarães CDO, Palha MDC, Tourinho MM (2019) **Estratégias e dinâmica de caça na ilha de Colares, Pará, Amazônia Oriental**. *Biota Amazonia* 9: 5-10.

Haugaasen T, Peres C (2005) **Mammal assemblage structure in Amazonian flooded and unflooded forests**. *Journal of Tropical Ecology* 21:133-145.

Hawkes K, Hill K, O'Connell JF (1982) **Why hunters gather: optimal foraging and the Ache of eastern Paraguay**. *American Ethnologist* 9:379–398.

Hoffman LC, Cawthorn DM (2012) **What is the role and contribution of meat from wildlife in providing high quality protein for consumption?** *Animal Frontiers* 2:40–53.

Ingram DJ, et al. (2021) **Wild meat is still on the menu: progress in wild meat research, policy, and practice from 2002 to 2020**. *Annual Review of Environment and Resources*, 46:221-254.

IUCN (2021) **The IUCN Red List of Threatened Species**. [https://www.iucnredlist.org] Accessed June 10, 2021.

Jerozolimski A, Peres CA (2003) **Bringing home the biggest bacon: A cross-site analysis of the structure of hunter-kill profiles in Neotropical forests**. *Biological Conservation* 111:415–425.

Kirkland M, Eisenberg C, Bicerra A, Bodmer RE, Mayor P, Axmacher JC (2018) **Sustainable wildlife extraction and the impacts of socio-economic change among the Kukama-Kukamilla people of the Pacaya-Samiria National Reserve, Peru**. *Orix* 54:260-269.

Laso F (2009) **Challenges to the conservation of river turtles (spp. *Podocnemis*) in the Peruvian Amazon**. *Consilience* 2:1-28.

Loke VPW, Lim T, Campos-Arceiz A (2020) **Hunting practices of the Jahai indigenous community in northern peninsular Malaysia**. *Global Ecology and Conservation* 21:e00815.

Lopes GP, Valsecchi J, Vieira TM, do Amaral PV, da Costa EWM (2012) **Hunting and hunters in lowland communities in the region of the middle Solimões, Amazonas, Brazil**. *Scientific Magazine UAKARI* 8:7–18.

Mayor P, El Bizri HR, Morcatty TQ, Moya K, Bendayán N, Solis S, Vasconcelos Neto CFA, Kirkland M, Arevalo O, Fang TG, Pérez-Peña PE, Bodmer RE (2022) **Wild meat trade over the last 45 years in the Peruvian Amazon.** *Conservation Biology* 36(2):e13801.

McGrath DG, Castro F, Futemma C, Amaral BD, Calabria J (1993) **Fisheries and the evolution of resource management on the lower Amazon floodplain**. *Human ecology* 21:167-195.

McGrath D, Cardoso A, Almeida OT, Pezzuti J (2008) **Constructing a policy and institutional framework for an ecosystem-based approach to managing the Lower Amazon floodplain**. *Environment, Development and Sustainability* 10:677–695.

Mesquita EMC, Isaac-Nahum VJ (2015) **Traditional knowledge and artisanal fishing technology on the Xingu River in Pará, Brazil**. *Brazilian Journal of Biology* 75:138-157.

Mesquita GP, Barreto LN (2015) **Evaluation of Mammals Hunting in Indigenous and Rural Localities in Eastern Brazilian Amazon**. *Ethnobiology and Conservation* 4. doi: 10.15451/ec2015-1-4.2-1-14

Mesquita GP, Rodríguez-Teijeiro JD, Barreto LN (2018) **Patterns of mammal subsistence hunting in eastern Amazon, Brazil**. *Wildlife Society Bulletin* 2:272-283.

Miorando PS, Rebêlo GH, Pignati MT, Brito Pezzuti JC (2013) **Effects of community-based management on Amazon river turtles: a case study of *Podocnemis sextuberculata* in the lower Amazon floodplain, Pará, Brazil**. *Chelonian Conservation and Biology* 12:143-150.

Morcatty TQ, Valsecchi, J (2015) **Social, biological, and environmental drivers of the hunting and trade of the endangered yellow-footed tortoise in the Amazon**. *Ecology and Society* 3:3.

Morsello C, Yagüe B, Beltreschi L, van Vliet N, Adams C, Schor T, Quiceno-Mesa MP, Cruz D (2015) **Cultural attitudes are stronger predictors of bushmeat consumption and preference than economic factors among urban Amazonians from Brazil and Colombia**. *Ecology and Society* 20:1–20.

Nielsen MR, Meilby H, Smith-Hall C, Pouliot M, Treue T (2018) **The importance of wild meat in the global south**. *Ecological Economics* 146:696-705.

Ocampo-Peñuela N, Jenkins CN, Vijay V, Li BV, Pimm SL (2016) **Incorporating explicit geospatial data shows more species at risk of extinction than the current Red List**. *Science Advances* 1:e1601367.

Oliveira MA, El Bizri HR, Morcatty TQ, Messias MR, Doria CRC (2022) **Freelisting as a suitable method to estimate the composition and harvest rates of hunted species in tropical forests**. *Ethnobiology and Conservation* 11. doi: 10.15451/ec2022-03-11.08-1-9

Parry L, Barlow JOS, Peres CA (2009) **Hunting for Sustainability in Tropical Secondary Forests**. *Conservation Biology* 23:1270-1280.

Parry L, Peres CA (2015) **Evaluating the use of local ecological knowledge to monitor hunted tropical-forest wildlife over large spatial scales**. *Ecology and Society* 20:15.

Peres C, Nascimento H (2006) **Impact of game hunting by the Kayapó of south-eastern Amazonia: implications for wildlife conservation in tropical forest indigenous reserves**. *Biodiversity and Conservation* 15:2627-2653.

Peres CA, Emilio T, Schietti J, Desmoulière SJ, Levi T (2016) **Dispersal limitation induces long-term biomass collapse in overhunted Amazonian forests**. *Proceedings of the National Academy of Sciences* 113:892-897.

Peres CA, Palacios E (2007) **Basin-Wide Effects of Game Harvest on Vertebrate Population Densities in Amazonian Forests: Implications for Animal-Mediated Seed Dispersal.** *Biotropica* 39:304–315.

Pezzuti JCB, Castro F, McGrath DG, Miorando PS, Barboza RSL, Romagnoli FC (2018) **Commoning in dynamic environments: community-based management of turtle nesting sites on the lower Amazon floodplain**. *Ecology and Society* 23:36.

Rebêlo G, Pezzuti J (2000) **Percepções sobre o consumo de quelônios na Amazônia: sustentabilidade e alternativas ao manejo atual**. *Ambiente & Sociedade* 85-104.

Redford KH, Robinson JG (1987) **The Game of Choice: Patterns of Indian and Colonist Hunting in the Neotropics**. *American Anthropologist*, v. 89, n. 3, p. 650–667. Disponível em: [http://www.jstor.org/stable/678057.

Ribeiro NV (2007) **Atlas da Várzea: Amazônia Brasil**. Ibama, Manaus, 132p.

Robinson JG, Redford KH (1986) **Body Size, Diet, and Population Density of Neotropical Forest Mammals**. *The American Naturalist* 128:665-680.

Rogan MS, Lindsey PA, Tambling CJ, Golabek KA, Chase MJ, Collins K, McNutt JW (2017) **Illegal bushmeat hunters compete with predators and threaten wild herbivore populations in a global tourism hotspot**. *Biological Conservation* 210:233-242.

RStudio Team (2020) **RStudio: Integrated Development for R**. PBC, Boston, MA [http://www.rstudio.com] Accessed 08 june 2021.

Schneider L, Ferrara CR, Vogt RC, Burger J (2011) **History of Turtle Exploitation and Management Techniques to Conserve Turtles in the Rio Negro Basin of the Brazilian Amazon**. *Chelonian Conservation and Biology* 10:149-157.

Shanee N (2012) **Trends in local wildlife hunting, trade and control in the Tropical Andes Biodiversity Hotspot, northeastern Peru**. *Endangered Species Research* 19:177-186.

Souto WMS, Lima RN, Sousa BFCF (2019) **Illegal bushmeat hunting and trade dynamics in a major road-hub region of the Brazilian Mid North**. *Indian Journal of Traditional Knowledge* 18:402-411.

Souza-Mazurek RR, Pedrinho T, Feliciano X, Hilário W, Gerôncio S, Marcelo E (2000) **Subsistence hunting among the Waimiri Atroari Indians in central Amazonia, Brazil**. *Biodiversity and Conservation* 9:579-596.

Swamy V, Pinedo-Vasquez M (2014) **Bushmeat harvest in tropical forests: Knowledge base, gaps and research priorities**. Bogor, Indonesia: CIFOR, 2014. 26p.

Tavares AS, Mayor P, Loureiro LF, Gilmore MP, Perez-Peña P, Bowler M, Lemos LP, Svensson MS, Nekaris KA, Nijman V, Valsecchi J, Morcatty TQ (2020) **Widespread use of traditional techniques by local people for hunting the yellow-footed tortoise (Chelonoidis denticulatus) across the Amazon**. *Journal of Ethnobiology* 40:268-80.

Valsecchi J (2005) **Diversidade de mamíferos e uso da fauna nas Reservas de Desenvolvimento Sustentável Mamirauá e Amanã**. Universidade Federal do Pará; Museu Paraense Emílio Goeldi.

van Vliet N, Cruz D, Quiceno-Mesa MP, Jonhson L, Aquino L, Moreno J, Ribeiro R, Fa J (2015) **Ride, shoot, and call: wildlife use among contemporary urban hunters in Três Fronteiras, Brazilian Amazon**. *Ecology and Society* 20:8.

van Vliet N, Quiceno M, Moreno J, Cruz D, Fa JE, Nasi R (2017) **Is urban bushmeat trade in Colombia really insignificant?** *Oryx* 51:305–314.

Vogt RC (2008) **Tartarugas da Amazônia**. Instituto Nacional de Pesquisas da Amazônia. Manaus, Amazonas. 104pp.

Wali A, Alvira D, Tallman P, Ravikumar A, Macedo M (2017) **A new approach to conservation: using community empowerment for sustainable well-being**. *Ecology and Society* 4:6.

Zanvo S, Djagoun SCAM, Azihou FA, Djossa B, Sinsin B, Gaubert P (2021) **Ethnozoological and commercial drivers of the pangolin trade in Benin**. *Journal of Ethnobiology and Ethnomedicine* 17:18.

Zapata-Ríos G, Urgilés C, Suárez E (2009) **Mammal hunting by the Shuar of the Ecuadorian Amazon: is it sustainable?** *Oryx* 43:375–385.

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