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Informal supply chains of wild meat from rural Amazonia and food security in an urban center

Fiorella Briceño Huerta[1] | **Michael P. Gilmore**[2] | **Mark Bowler**[3,4] | **Brian M. Griffiths**[5]

[1]Institute of Environment, Department of Earth and Environment, Florida International University, Miami, Florida, USA

[2]School of Integrative Studies, George Mason University, Fairfax, Virginia, USA

[3]School of Science, Technology and Engineering, University of Suffolk, Ipswich, UK

[4]Suffolk Sustainability Institute, Ipswich, UK

[5]The Earth Commons—Georgetown University's Institute for Environment & Sustainability, Washington, DC, USA

Correspondence
Brian M. Griffiths, The Earth Commons—Georgetown University's Institute for Environment & Sustainability, 3700 O St. NW, Washington, DC 20057, USA.
Email: brian.griffiths@georgetown.edu

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Abstract

Iquitos, the most populated city in the Peruvian Amazon, is a hub in the regional supply chain of wild meat and supplies urban consumers. Studies on wild meat consumption have focused primarily on markets, limiting the scope of species considered to those that are economically valuable and potential inferences from those data. We conducted interviews with 1548 households in Iquitos across all four districts to assess wild meat consumption rates for 7831 people in those households. We used species- and source-specific conversion factors to estimate biomass consumed from different species and sources in the supply chain. We estimated that 1786 t (95% CI 636.48–3317.62) of wild mammal meat were consumed in 2019 in Iquitos, which is about 4.25 kg (95% CI 1.54–8.02) per person per year. Markets supplied 57.22% of all wild mammal meat, but 14.67% was purchased from other sources and 27.85% was not purchased. Paca (*Cuniculus paca*) and collared peccary (*Dicotyles tajacu*) were the most heavily consumed species, mostly from markets. The majority of meat from other species, such as the woolly monkey (*Lagothrix lagotricha*) and capybara (*Hydrochoerus hydrochaeris*), was traded outside markets. Our results indicated that wild mammal consumption rates may be much higher in Iquitos than previously reported, likely because social connections accounted for about half of the supply chain; consumers are receiving wild meat as gifts or were hunting themselves. The breadth of mammal meat consumption demonstrates the contributions of hunting to the food security and economic stability of consumers in Iquitos and the potential for sustainable supply chains of some mammals.

KEYWORDS
Amazon, bushmeat, food security, game meat, hunting, sustainability

INTRODUCTION

Tropical forests are ecologically complex ecosystems and epicenters of global biodiversity, hosting most of the world's terrestrial species (Laurance, 1999; Peres, 2011; Wright, 2010). Tropical forests meet diverse environmental, social, and productive functions, such as climate stability, hydrological cycles, timber and nontimber forest products, animal habitat, and food for urban and rural populations (Laurance, 1999; Mittermeier et al., 1998; Robinson, 2004; Wright, 2010). However, tropical forests and their wildlife are threatened by a wide range of anthropogenic disturbances, such as land-use change, timber extraction, unsustainable hunting, human migration, and climate change (Laurance & Williamson, 2001; Wright, 2010).

Overhunting is one of the most important drivers of large vertebrate population declines and has caused biodiversity loss and changes in the structure and composition of forests (Luz et al., 2015; Peres & Lake, 2003). Hunting likely results in the local depletion or extirpation of game species (Laurance, 1999; Peres, 2000; Peres & Lake, 2003; Redford, 1992; Robinson & Redford, 1994; de Araujo Lima Constantino, 2016), and depletion has already occurred throughout the Amazon (Bogoni et al., 2020). Hunting wildlife for consumption is an

important resource for forest dwelling people. Game species depletion may result in changes in ecological processes of forest ecosystems and can also lead to a decline in food security of local people (Robinson & Redford, 1991).

Hunting, whether for subsistence or commercial purposes, has a long history in the Amazon, which makes up over 50% of the world's remaining tropical rainforest (Laurance & Williamson, 2001; Laurance et al., 2000). Millions of Indigenous and non-Indigenous people inhabit the Amazon and consume wild meat for subsistence or to supplement their diet. Most of the species that are consumed are mammals. Most previous research focused on wild meat consumption at the local or subsistence level (e.g., Alvard et al., 1997; Griffiths & Gilmore, 2022; Mayor et al., 2017; Redford, 1992; Smith, 2008).

Wild meat is also an important resource in large urban centers, such as Iquitos in the Peruvian Amazon (Alves & van Vliet, 2018; El Bizri, Morcatty, Valsecchi, et al., 2020; Ingram et al., 2021). Even though most of its sale is illegal, wild meat is openly sold in markets (Mayor et al., 2022). Though Iquitos has been widely studied in relation to wild mammal meat consumption, previous studies included only markets in their sampling (Bardales García et al., 2004; Bendayán, 1991; Bodmer & Lozano, 2001; Bodmer & Pezo, 1999; Bodmer et al., 2004; Mayor et al., 2019, 2022; Moya, 2011) and ignored other potential sources of wild meat (Appendix S1).

Wild meat consumed in Amazonian urban centers is accessed through various sources. In Brazil, wild meat is purchased in city markets and docks, from hawkers, and through riverboats (El Bizri, Morcatty, Valsecchi, et al., 2020; El Bizri, Morcatty, Ferreira, et al., 2020). Hunters from rural areas sell wild meat directly to their relatives in the city, to people who preordered wild meat, directly to consumers in local fairs, and to intermediaries (El Bizri, Morcatty, Ferreira, et al., 2020). Lemos et al. (2025) and Chaves, Valle, Tavares, Morcatty, et al. (2021) describe some noncommercial channels of wild meat trade and an "urbanization gradient," in which wild meat consumption and trade increase in newly established or peri-urban areas. Thus, our objective was to quantify the magnitude of the consumption of wild mammal meat in Iquitos by focusing on the consumer rather than on market sales and by including newly established peri-urban areas. We sampled across the entire city of Iquitos, including small suburban towns connected by the Iquitos–Nauta Road. Our objectives were to measure how much mammal meat was consumed by households in Iquitos based on information provided by consumers; identify which mammal species are most frequently consumed and document whether they were obtained through purchase, gift, subsistence hunting, or other means; estimate household expenditure on wild mammal meat and assess its contribution to urban food budgets and local economies; and determine how much consumption is overlooked if analyses are restricted to markets, thereby highlighting the importance of household-level data for understanding total wild meat use.

METHODS

Study site

We focused on the Amazonian city of Iquitos in the Department of Loreto in the northeastern Peruvian Amazon (Figure 1a). Loreto is the largest department in Peru and is 28.7% of the country by area. Iquitos, the capital and commercial center of Loreto, is geographically isolated. It is accessible only by boat or plane and is located at the confluence of the Nanay, Itaya, and Amazon rivers (INEI, 2018). There is a marked rainy season that typically lasts from December to June; dry season runs from July to November.

Iquitos is in the Province of Maynas (one of the eight provinces of Loreto). Maynas has 11 districts: Alto Nanay, Fernando Lores, Indiana, Iquitos, Las Amazonas, Mazán, Napo, Punchana, Torres Causana, Belen, and San Juan Bautista. The city of Iquitos includes areas of the Iquitos, Punchana, Belen, and San Juan Bautista districts and different urban and suburban towns (*centros poblados*) within those four districts. Medium- and small-sized urban and suburban towns connected to the city via the Iquitos–Nauta Road were considered part of the city and were included in this study. Towns that are only present in the San Juan Bautista district were included in this study because we wanted to have recently established and smaller settlements in our sample to account for wild meat consumption in other settlements where people do not have access to the main markets in the center of Iquitos and to consider people who had recently migrated from rural areas and people with fewer resources living farther away from the center of the city.

Based on the national census, Loreto's population in 2017 was 883,510 (68.7% urban and suburban residents) (INEI, 2018), and Iquitos had a population of 413,556. In Loreto, the urban population is increasing 0.8% per year, and the rural population is declining 1.9% per year (INEI, 2018). Food in Iquitos is expensive relative to the rest of the country because a significant amount needs to be imported from other regions by boat or air transport (Castro et al., 1976). People living in Iquitos have access to beef, pork, fish, poultry, and wild meat.

Sampling protocol

We conducted our surveys from June to October in 2019. All sampling protocols were approved by the George Mason University Institutional Review Board (IRBNet number: 1436180–1). Free, prior, and informed consent was obtained from all participants before they were interviewed. To properly account for the diversity of consumers eating wild meat in the city of Iquitos, we divided the city into 1-km grid squares (Figure 1b). Additional grid squares were added based on satellite images to include more recently established suburban towns in the San Juan Bautista district. We sampled grid squares (64 km^2); these covered the city of Iquitos in its entirety. Five to 30 interviews were conducted with heads of households in each grid square,

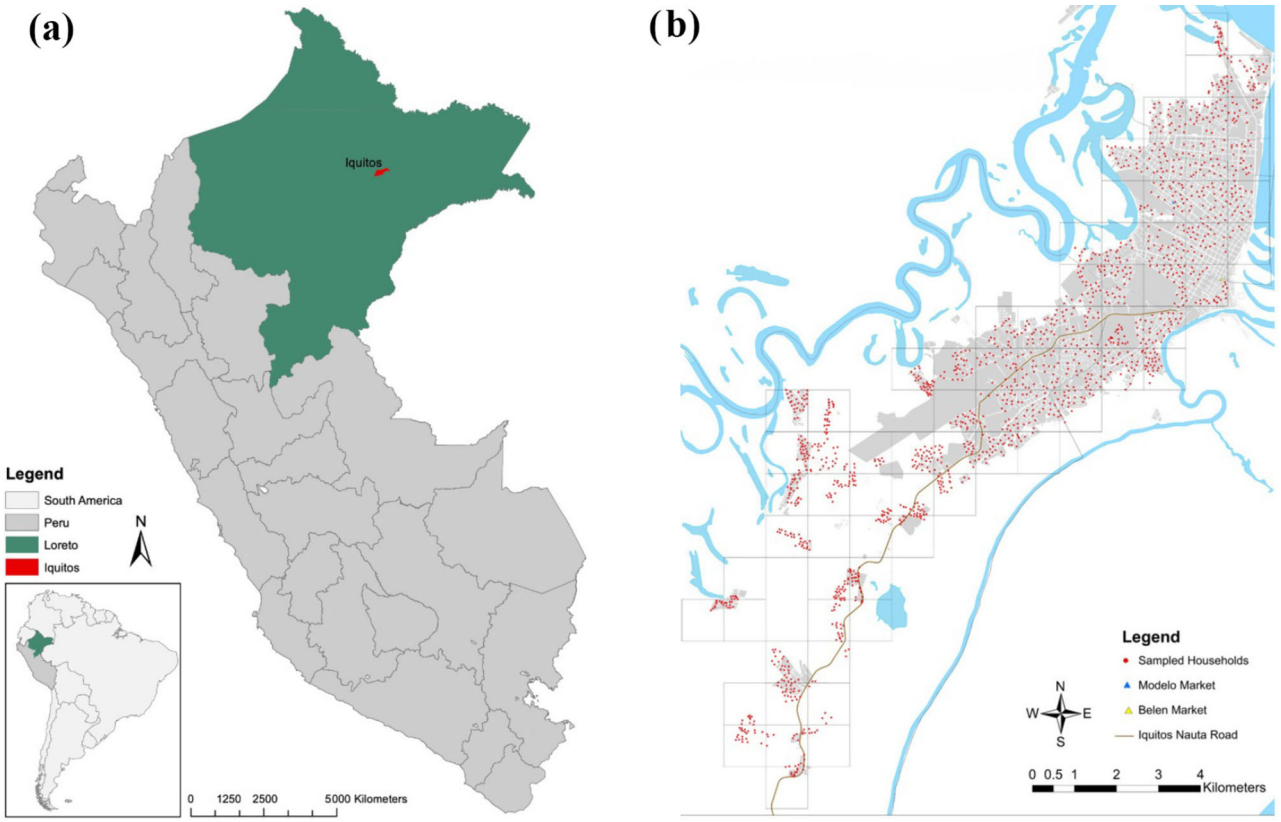

FIGURE 1 Study area in (a) Iquitos, Peru, the capital of the Department of Loreto, and (b) the grid-based sampling protocol encompassing the city. Map adapted from Briceño Huerta et al. (2025).

depending on the population of the grid square, to avoid oversampling less populated squares in a stratified random sampling approach weighted by population. We estimated the total number of people per new settlement identified using satellite images (not included in the 2017 national census) by multiplying the total number of counted houses by the mean population number per house in the suburban area of Iquitos reported in the 2017 national census.

Sampled houses were randomly selected by navigating outward from the center of the grid square, locating the nearest road to the center of the square, and soliciting the first interview with the closest available household (Briceño Huerta et al., 2025). Semistructured interviews (Bernard, 2011) were conducted with heads of households and lasted typically 20–40 min. To increase independence between sampled households, given that it is common for there to be family relationships between neighbors in Iquitos, a radius of at least three houses was created between interviewed households. Interviews were mostly done on weekdays, from 08:00 to 18:00; some interviews were performed over the weekends from 09:00 to 13:00.

Heads of households were asked specific questions about the consumption of wild mammal meat in their households for the past 7 days (Appendix S2). Seven-day recall may be vulnerable to memory and desirability bias (Chaves, Valle, Tavares, von Mühlen, et al., 2021), but our extensive pilot studies in June 2019 indicated heads of households could recall what they had eaten in the past week. For each record of wild meat consumption, data on the species name, quantity, price paid, source of purchase, frequency of consumption, and meat processing method before purchase (fresh, fresh salted, smoked) were obtained. We then asked a set of questions for each of several mammal species that were selected based on previously published studies on wild meat consumption in the region (Bendayán, 1991; Bodmer & Lozano, 2001; Bodmer & Pezo, 1999; Mayor et al., 2019). To account for novel or rarely eaten species, respondents were to identify other species consumed. No restaurant personnel were interviewed for this study. When the head of household reported selling food informally from home, only the amounts of wild meat relevant to their household consumption were considered.

Data analyses

Data on the amount of wild mammal meat eaten per household in the last 7 days were summarized by species, source, and district. This was used to estimate the mass of wild mammal meat eaten by each person per year in the sampled population and the entire Iquitos population for 2019. To account for oversampling, all city-wide estimations were calculated first per district then summed. We assumed there was a seasonal influence on wild meat consumption, where consumption rises during the

rainy season, an effect described in the Iquitos literature on wild meat consumption (Bodmer & Pezo, 1999; Bodmer et al., 2004). Using the mean biomass of wild meat sold per month during the rainy season (higher demand) and dry season (lower demand) reported by Bodmer et al. (2004), we calculated that 16.2% more wild meat was sold each month during the rainy season. Because this study was conducted in the dry season, half of the wild meat predicted to be consumed was multiplied by a factor of 1.162 to account for increased consumption of wild meat over the rainy season.

Wild meat not identified at the species level was excluded from analyses. Species recorded fewer than three times were also excluded from the analyses because there were insufficient data to extrapolate estimates of species-specific wild meat consumption for the city. An exception was made for the species identified only as "wild meat," which, according to respondents, was either collared peccary or lowland paca meat but without the species specified. We assumed that the amount of wild meat was distributed according to the proportion of both species in this study by mass.

In Iquitos, wild meat was obtained from (numbered and lettered lists are not allowed) purchases in formal markets, purchases made outside markets, hunting or receipt as a gift, and other unknown sources (Table 1). Indirect costs of hunting an animal, such as the cost of the cartridge and fuel used to reach the hunting grounds and of shipping wild meat, were not considered. We used the mean prices for meat purchased in markets and outside markets to estimate the total yearly expenditure by the sample population and the entire city of Iquitos on wild mammal meat.

The most common measurement of wild mammal meat reported was in kilograms. Other measurements reported included "piece of meat," by posterior or anterior limb of the animal's body, and "plates of food." Using information provided by participants during data collection, a weight in kilograms was estimated and assigned to each of these categories (Appendix S3). There were three different sources of wild meat obtained on food plates: street food vendors, restaurants, and other households. Because food plates purchased at restaurants were on average three times larger than food plates obtained from street vendors, each was assigned a different average mass, based on reported portion sizes. In case a whole individual animal was reported as consumed, the mass assigned to that category was based on the eviscerated mass of the species reported by Bardales García et al. (2004).

Species were typically purchased in three different forms: fresh, fresh salted, and smoked. Conversion factors were used to transform the number of kilograms of fresh-salted and smoked meat to kilograms of fresh meat and consequently to number of individuals (Bardales García et al., 2004). All the final estimations of the amounts of wild meat eaten by the population of Iquitos are represented hereafter in kilograms or tons of fresh meat.

We calculated 95% confidence intervals (CIs) around all projections by conducting 10,000 bootstrap iterations of random sampling of the interview data. Bootstrapped samples were drawn following the distribution of sampling in each district to ensure that bootstraps did not oversample any one district and skew projections. Thus, random sampling mimicked our spatial sampling approach. All analyses were performed in R 4.4.0 (R Core Team, 2024).

RESULTS

Overall, four core large urban centers (*centros poblados*) were sampled: Iquitos, Belen, Punchana, and San Juan Bautista. Five medium-sized suburban towns were sampled: Santa Clara, Santo Tomas, Quistococha, Zungaro Cocha, and Los Delfines. Ten small-sized suburban towns were sampled: Rumococha, Laguna Azul, La Union, La Paz, 25 de Enero, 12 de Diciembre, Union Progreso, Peña Negra, and two with unidentified names (not included in the national census). A total of 1548 households were interviewed. Data on wild meat consumption were obtained for 7831 people, including 4663 adults and 3168 children (Appendix S5). Overall, 23.06% of households reported consuming wild meat within the last 7 days of the interview. Most households (76.87%) reported that they eat wild meat but had not eaten any over the last 7 days. Consumption was concentrated in the San Juan Bautista district; 56.37% of the sampled households consumed wild meat in the last week.

The sample population consumed 640 kg of wild mammal meat in the 7 days before the interview, made up of an estimated 83 individual animals from nine species that were reported at least three times (Table 2). Only possums (reported two times, 2.8 kg total) and an ambiguous small primate (one reported, 700 g consumed) were reported but omitted from extrapolation. Based on these numbers, we estimated that the entire population of the city of Iquitos consumes about 1786.31 t (95% CI 636.48–3317.62) of wild meat annually and spends about USD4.138 (95% CI 2.08–6.36) million annually on wild meat (Table 2). The average consumer in Iquitos ate about 4.25 kg (95% CI 1.54–8.02) of wild meat per year in 2019.

The predominant source of wild meat was markets, which supplied 55.76% of all wild meat and seven of the nine species (Appendix S4), but significant portions of the total wild meat came from other sources (purchased outside markets, 14.00%; not purchased, 29.96% of all wild meat by mass) (Table 2). The Belen market alone accounted for an estimated 617.55 t (95% CI 373.43–854.82) of wild meat, including 374.78 t (95% CI 263.80–449.20) of paca and 198.30 t (95% CI 109.63–289.79) of collared peccary meat. The Modelo market accounted for 211.91 t (95% CI 102.47–327.57) of wild meat (Appendix S4). Belen and Modelo markets alone accounted for annual expenditures in excess of USD2.635 (95% CI 1.576–3.574) million annually on wild game meat.

Paca (a species of least concern and stable populations [Emmons, 2016]) was the most heavily consumed wild mammal (estimated 51.55% of all mammal meat by mass). Estimated annual consumption was 920.90 t (95% CI 425.83–1520.48), which constituted about 153.48 thousand individual paca (Table 2; Figures 2 & 3). Consumers were estimated to spend about USD2.33 (95% CI 1.354–3.225) million annually on paca

TABLE 1 Estimated consumption of and expenditure on wild meat in the city of Iquitos, Peru, in 2019 based on projections from survey data broken down by wild meat source.

Source		Definition	Estimated annual consumption (t) (95% CI)[a]	Estimated annual expenditure (thousand USD) (95% CI)[a,b]
Market		Wild meat acquired in an established market	996.09 (542.88–1460.18)	3275.2 (1831.89–4634.88)
	Belen Market	Wild meat acquired in Belen Market	617.55 (373.43–854.82)	1903.77 (1220.58–2474.9)
	Modelo Market	Wild meat acquired in Modelo Market	211.91 (102.47–327.57)	731.88 (355.8–1098.98)
	Other Markets	Wild meat acquired in other markets	166.63 (66.98–277.79)	639.55 (255.51–1061)
Purchased outside markets		Wild meat that was purchased outside of a market	250.01 (59.64–483.8)	762.32 (244.77–1424.31)
	Neighbor	Raw wild meat purchased from a neighbor	72.7 (21.01–132.44)	223.01 (68.11–408.03)
	Restaurant	Cooked wild meat eaten in restaurants or in food stands (set menu) in the street	68.23 (33.52–103.05)	310.64 (155.82–459.24)
	Street vendor	Raw wild meat sold in the streets by mobile vendors	20.23 (4.45–40.71)	89.15 (18.18–186.88)
	Bodega	Raw wild meat obtained from small stores (bodega) spread throughout the city	12.08 (0.66–27.73)	53.35 (2.66–121.28)
	Travel	Raw wild meat obtained while the interviewee was traveling	76.77 (0–179.87)	86.17 (0–248.88)
Not purchased		Wild meat obtained outside of a market that was not paid for	535.12 (33.96–1358.6)	84.15 (0–249.37)
	Hunting	Sourced from hunting	121.45 (0.74–315.11)	24.83 (0–72.07)
	Parcel of wild meat	Raw wild meat sent as a gift from rural areas in Loreto	333.18 (28.27–837.36)	59.32 (0–177.3)
	Travel gift	Raw wild meat obtained as a gift from someone who traveled outside the city	69.67 (2.96–182.22)	0 (0–0)
	Food plate	Cooked wild meat eaten on a food plate as an invited guest in somebody's house	10.82 (1.99–23.91)	0 (0–0)
Unidentified		Source of wild meat was not identified by consumer	5.09 (0–15.04)	16.95 (0–50.16)

[a]Confidence intervals based on 10,000 bootstrapped iterations of random sampling.
[b]Based on mean 2019 exchange rate of 3.362.

meat in Iquitos, mostly purchased from markets (59% of all paca meat, total annual expenditure of USD1.86 million). Paca was also purchased from nonmarket sources and not purchased (12% and 28% of all paca meat, respectively). The mean price of paca meat recorded was USD4.22 per kg.

Collared peccary (least concern, stable [Gongora et al., 2011]) was the second most consumed wild mammal (31.16% of all mammal meat, by mass). Estimated annual consumption was 556.66 t (95% CI 210.65–974.34) of approximately 40.33 thousand individual peccaries (Table 2; Figures 2 & 3). We estimated that consumers spent about USD1.54 (95% CI 0.72–2.42) million annually on collared peccary meat in Iquitos, most of which was purchased from markets (66% of all collared peccary meat, total annual expenditure of USD1.19 million). Like paca, collared peccary was also purchased from nonmarket sources and not purchased (20% and 14% of all collared peccary meat, respectively). The mean price of collared peccary meat recorded was USD4.17 per kg.

Woolly monkeys (*Lagothrix lagotricha*) (vulnerable, decreasing [Stevenson et al., 2021]), which were recorded five times during interviews, were the third most heavily consumed species (5.23% of all mammal meat, by mass). Estimated annual consumption was 93.54 t (95% CI 0.00–257.29) (Table 2; Figure 2). None of the woolly monkeys recorded were purchased; therefore, projections of annual expenditure on woolly monkey meat were USD0. Most woolly monkey meat was obtained by wild meat parcels and travel gifts (42.47% and 33.11%, respectively, likely sent from a rural area or gifted from a rural area).

Brocket deer (*Mazama* sp.) (data deficient, unknown population trend [Duarte & Vogliotti, 2016]) and armadillos (*Dasypus novemcinctus*) (least concern, populations stable [Loughry et al., 2014]) were each recorded more than 10 times in interviews

TABLE 2 Raw wild meat consumption data from interviews and resulting projections for annual consumption in Iquitos, Peru.

Species	Sample (1548 households)				Projections for Iquitos			Proportion of species' meat sourced		
	No. reported	Amount eaten (kg) in 1 week	Amount eaten (ind.) in 1 week	Mean price (USD/kg)[b]	Estimated annual consumption (mt) (95% CI)[a]	Estimated annual consumption (thousand ind.) (95% CI)[a]	Estimated annual expenditure (thousand USD) (95% CI)[a,b]	Markets	Purchased outside markets	Not purchased
Paca (*Cuniculus paca*)	220	322.12	53.69	4.22	920.9 (425.83–1520.48)	153.48 (70.97–253.41)	2331.38 (1354.33–3225.07)	0.59	0.12	0.28
Collared Peccary (*Dicotyles tajacu*)	124	175.6	12.72	4.17	556.55 (210.65–974.34)	40.33 (15.26–70.60)	1535.85 (722.33–2420.97)	0.66	0.20	0.14
Woolly Monkey (*Lagothrix lagotricha*)	5	47.07	5.88	0.00	93.54 (0.00–257.29)	11.69 (0.00–32.16)	0 (0.00–0.00)	0.00	0.00	1.00
Brocket Deer (*Mazama* sp.)	15	39.21	2.80	3.36	80.12 (0.00–199.39)	5.72 (0.00–14.24)	105.64 (0.00–272.66)	0.39	0.15	0.46
Nine-banded Armadillo (*Dasypus novemcinctus*)	11	24.22	6.06	2.47	61.33 (0.00–159)	15.33 (0.00–39.75)	70.6 (0.00–172.14)	0.63	0.07	0.30
Lowland Tapir (*Tapirus terrestris*)	6	8.2	0.09	3.47	25.42 (0.00–71.61)	0.28 (0.00–.80)	23.89 (0.00–69.2)	0.18	0.12	0.70
White-lipped Peccary (*Tayassu pecari*)	5	8.46	0.42	2.92	18.02 (0.00–48.98)	0.90 (0.00–2.45)	41.04 (0.00–110.84)	0.65	0.00	0.35
Capybara (*Hydrochoerus hydrochaeris*)	3	13.36	0.74	3.40	22.36 (0.00–63.07)	1.24 (0.00–3.50)	3.75 (0.00–10.83)	0.00	0.09	0.91
Black Agouti (*Dasyprocta fuliginosa*)	3	1.76	0.45	6.00	8.07 (0.00–23.46)	2.07 (0.00–6.02)	26.47 (0.00–77.01)	0.55	0.18	0.28

[a]Confidence intervals based on 10,000 bootstrapped iterations of random sampling.
[b]Based on mean 2019 exchange rate of 3.362.

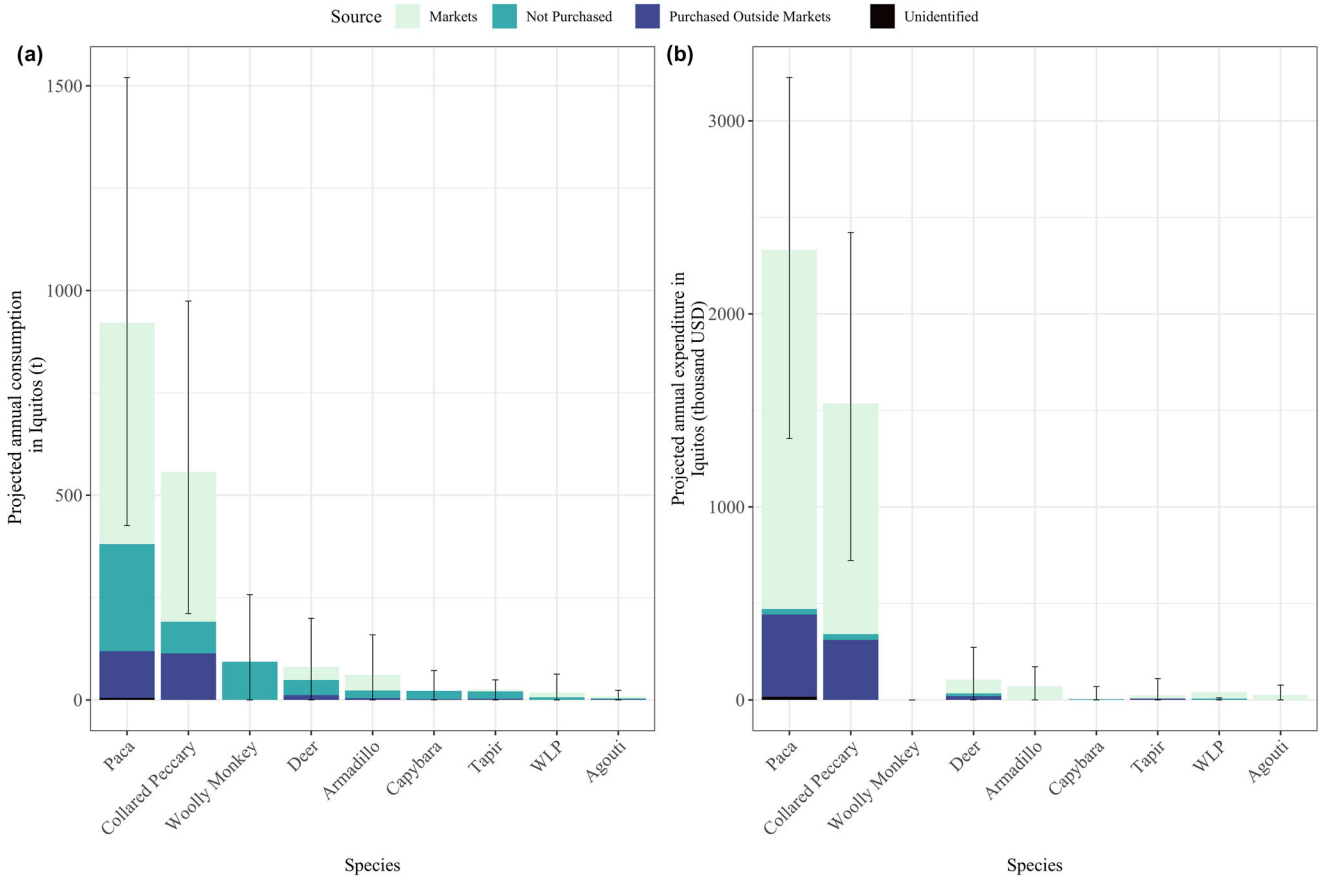

FIGURE 2 Estimated annual (a) consumption of individual species and (b) expenditure on individual species by source of wild meat for the city of Iquitos, Peru, in 2019 (error bars, 95% confidence intervals based on 10,000 bootstrapped iterations of random sampling; WLP, white-lipped peccary).

(15 and 11, respectively). We estimated that 801.12 t (95% CI 0.00–199.39) of brocket deer and 61.33 t (95% CI 0.00–159.00) of armadillo were consumed annually in Iquitos, accounting for approximately 5720 individual deer and 15,330 individual armadillos (Table 2; Figures 2 & 3). Total annual expenditure for these species for the city of Iquitos was estimated at USD105,640 for deer and USD70,600 for armadillos. The majority of deer were not purchased (46% of all deer meat by mass) (Figure 3), though 39% of deer was purchased from markets. The majority of armadillo was sourced from markets (63% of all armadillo meat by mass). The mean price of deer meat recorded was USD3.36 per kg, and the mean price for armadillo was USD2.47 per kg.

Tapir (*Tapirus terrestris*) (vulnerable, populations decreasing [Varela et al., 2019]), white-lipped peccary (*Tayassu pecari*) (vulnerable, populations decreasing [Beck et al., 2025]), capybara (*Hydrochoerus hydrochaeris*) (least concern, populations stable [Reid, 2016]), and agouti (*Dasyprocta fuliginosa*) (least concern, populations stable [Catzeflis et al., 2016]) were all reported at least three times by consumers but had the lowest predicted annual consumption of the mammal species (Table 2; Figure 2). We estimated that 25.42 t (95% CI 0.00–71.61) of tapir (about 280 individuals), 18.02 t (95% CI 0.00–48.98) of white-lipped peccary (about 900 individuals), 22.36 t (95% CI 0.00–63.07) of capybara (about 1240 individuals), and 8.07 t (95% CI 0.00–23.46) of agouti (about 2070 individuals) are consumed annually in Iquitos (Figure 2). We estimated that Iquitos residents spent an average of USD23,890 annually for tapir meat, along with USD41,040 for white-lipped peccary, USD3750 for capybara, and USD26,470 for agouti. Each of these mammals came from diverse sources, with the majority of white-lipped peccaries and agoutis coming from markets. Tapir and capybaras were typically not purchased.

DISCUSSION

Interviews have long been used to assess wild meat consumption in households across an urban gradient in the Amazon and have consistently targeted heads of households and relied on direct questioning to obtain data on the frequency of consumption, quantities eaten, sources used, and species identification (Chaves et al., 2019; El Bizri, Morcatty, Valsecchi, et al., 2020; Carignano Torres et al., 2021; Carignano Torres, Morsello, & Parry, 2022; Carignano Torres, Morsello, Orellana, et al., 2022; Chaves, Valle, Tavares, von Mühlen, et al., 2021). Previous estimates of per capita consumption have been based on the recall of total number of days per week per month or per year where

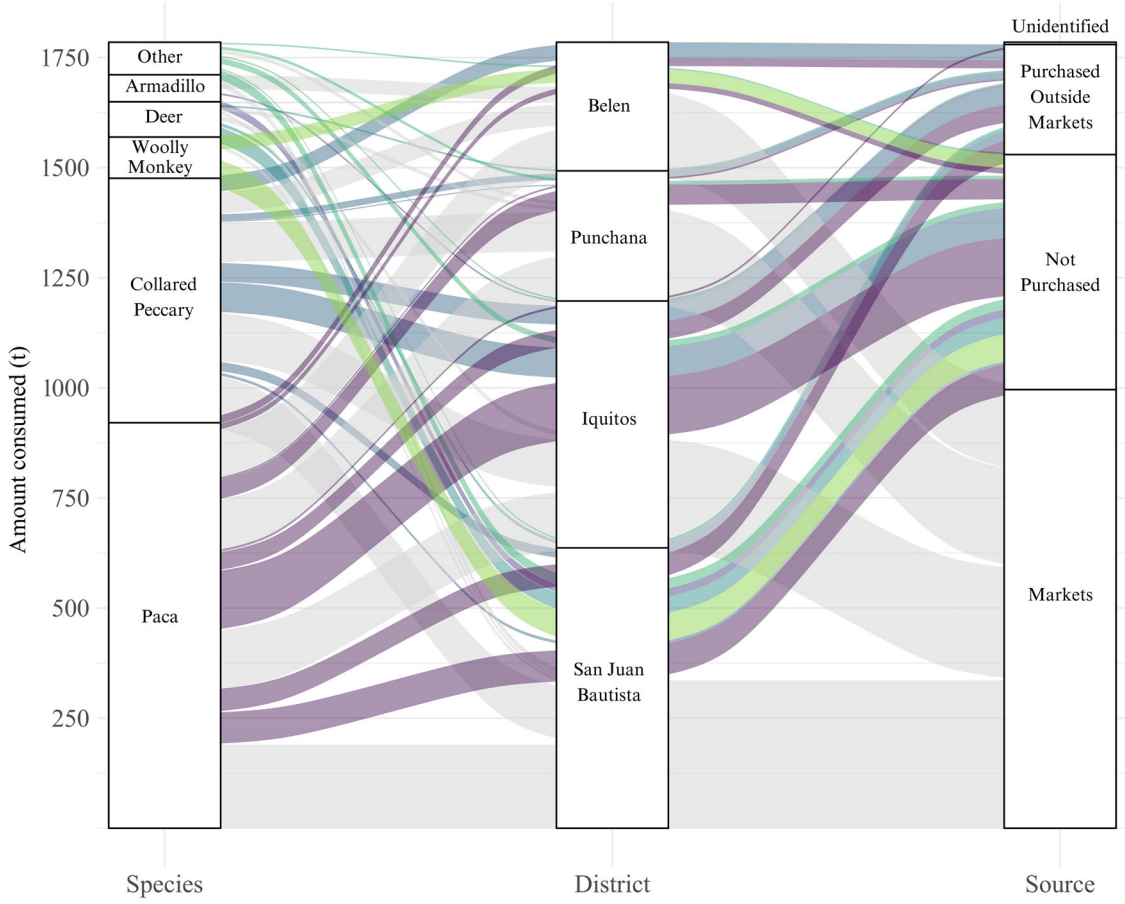

FIGURE 3 Distribution of projected species consumption by district and source, highlighting the informal supply chain (outside markets, colors) that may not have been captured in previous studies (other, tapir, white-lipped peccary, capybara, and agouti).

wild meat was consumed (El Bizri, Morcatty, Valsecchi, et al., 2020) or a 30-day period of household consumption of wild meat (Carignano Torres, Morsello, Orellana, et al., 2022; Carignano Torres, Morsello, & Parry, 2022). Though we used only a 7-day recall period, recall is still vulnerable to memory and desirability bias, particularly for illegal activities, which includes the sale of wild meat (Chaves, Valle, Tavares, von Mühlen, et al., 2021).

Iquitos has been the focus of studies on urban wild mammal meat consumption in the Peruvian Amazon since 1973 (Bendayán, 1991; Bodmer & Lozano, 2001; Bodmer & Pezo, 1999; Bodmer et al., 2004; Castro et al., 1976; Mayor et al., 2019, 2022; Moya, 2011) (Appendix S1). Our estimates of total wild meat consumption in Iquitos (1786 t annually, total) are substantially higher than those reported in recent studies (441.98 t in 2018; Mayor et al. [2022] [they do not report CIs]). Several methodological differences likely account for this discrepancy. First, our approach was based on household surveys rather than market monitoring, thereby we captured flows of meat that bypass formal trading outlets. Our surveys included urban and suburban towns connected to the city by the Iquitos–Nauta Road, which have not been considered previously, but people in these areas are engaged in the market economy of Iquitos.

Second, we incorporated purchased and unpurchased sources, including kinship-based exchanges and gifts, representing a large proportion of consumption. Finally, we applied seasonal adjustments that may have inflated annual projections, and as mentioned, recall-based reporting is vulnerable to under- and overestimation. We sampled for only one season, and the correction for seasonality may not be exact. For these reasons, the absolute magnitude of our estimates should be interpreted with caution, and we recommend that future researchers sample consumers across multiple seasons.

The relative patterns in our study that emerged were more robust than market studies only because almost half of consumption was derived from informal flows outside markets and species composition was broader than market surveys suggest. Regardless of absolute tonnage, these findings demonstrate that market-based studies alone underestimate the role of wild meat in urban food systems. Our results showed that wild meat significantly contributed to household diets, though further research is needed to understand how critical wild meat is for food security.

We reported seven species being directly sourced from markets. All these species have been reported as consumed in other studies of wild meat consumption in Iquitos from 1986 to

2018 (Bendayán, 1991; Bodmer & Lozano, 2001; Bodmer & Pezo, 1999; Bardales García et al., 2004; Bodmer et al., 2004; Mayor et al., 2022). However, 24 mammal species were initially reported as eaten in the wild meat consumption literature in Iquitos (Bendayán, 1991). In the most recent study in 2018, 13 mammal species were reported by Mayor et al. (2022). It is possible that the consumption rates of species reported by Mayor et al. (2022) that were not found here are low enough that they were missed in our sampling of consumers.

In the first studies on wild meat consumption in Iquitos, the collared peccary and lowland paca were the most consumed species (Castro et al., 1976; Mayor et al., 2022). We also found that the most important species sourced from markets were the lowland paca and collared peccary. They comprised 92.96% of all wild mammal meat obtained from the Belen and Modelo markets and 90.95% of wild meat obtained from all markets by weight, a consumption that was higher than that reported for 2018 (Mayor et al., 2022). The white-lipped peccary represented only 0.32% of all wild mammal meat sourced from the Belen and Modelo markets, in contrast to the results of Mayor et al. (2022). We did not observe an increase in the amount of white-lipped peccary being sold in markets.

Our results demonstrated the importance of other, nonmarket sources of wild meat consumption in the city of Iquitos. For example, nine species were not purchased. Markets did not supply meat from woolly monkey and capybara at all. In previous research, woolly monkey was obtained from markets, and its estimated annual consumption was 526 kg or 66 woolly monkeys (Mayor et al., 2022). We estimated the consumption of 93.54 t of wooly monkeys, which represents about 11,690 individuals. This result suggests that woolly monkey meat is traded almost entirely outside of markets. Thus, by focusing on markets as the sole source of wild mammal meat, as previous studies have done, the real impact of its consumption in Iquitos would have been lost, which has significant conservation and sustainability implications for the species. Differential consumption of species was described by Chaves et al. (2023) in Brazil along similar lines. Some species, such as paca, were broadly consumed, whereas others, such as primates, were consumed by people who maintain stronger ties to rural culture or who were more food insecure. Other rarer and more expensive species were only eaten by wealthy consumers. To date, no published data exist on the economic importance of nonmarket sources of wild meat in Iquitos. We found an estimated total of about USD762,320 spent purchasing wild mammal meat from nonmarket sources.

Given the diversity of sources represented in the data, we believe our results represent a complex supply chain of wild meat flowing to the city. On one side of the chain, meat flows from rural hunters to middlemen in port towns (Griffiths & Gilmore, 2022) who then take the meat to market in the city and sell it at a high price—potentially to wealthier consumers (Chaves et al., 2019). This side of the supply chain focuses on those species that are the most preferred and the most expensive: the paca and collared peccary. We captured the other side of the supply chain for the first time: a flow that is characterized by social ties and connections, and smaller nonmarket purchases. On this side of the supply chain, consumers obtain meat from parcels that have been shipped from rural areas that often contain nonpreferred species, such as woolly monkeys, tapir, capybara, and white-lipped peccaries. They may go hunting themselves or receive meat as a gift while they are traveling in a rural area, which they then bring home (Chaves et al., 2019; El Bizri, Morcatty, Valsecchi, et al., 2020; Morsello et al., 2015; Parry et al., 2014; van Vliet et al., 2015). They may be invited to dine at a neighbor's house, where they are served meat. Collectively, these sources contribute a major stream of wild meat to the food security of the city. Carignano Torres et al. (2021) described the wild meat parcels piece of this supply chain, noting that rural hunters in that study sent significant portions of their harvests to relatives living over 50 km away.

With rural-to-urban migration, the new wave of urban dwellers in Iquitos largely comprises members of multisited households who continue to depend on rural resources and products (Padoch et al., 2008). Rural migrants retain their rural needs and preferences, and wild meat consumption is often part of their culture (Padoch et al., 2008), a theme that is described by Chaves, Valle, Tavares, Morcatty, et al. (2021) in Brazil. The supply of wild meat from their rural kin, community or other affinities is described as an economy of affection by WinklerPrins and de Souza (2005). Both Chaves, Valle, Tavares, Morcatty, et al. (2021) and Lemos et al. (2025) describe an "urbanization gradient" where wild meat consumption decreases as urbanization increases—both closer to the core of urban centers and as residents live in urban centers for longer.

From a conservation perspective, the consumption levels we found reported serious concerns about sustainability, particularly for primates and other large-bodied species. Woolly monkeys, for example, were among the most frequently consumed taxa in our dataset, yet their slow reproductive rates make them highly vulnerable to overhunting (Bowler et al., 2014; Peres, 2000) and they are listed as vulnerable with decreasing populations on the International Union for Conservation of Nature (IUCN) Red List (Stevenson et al., 2021). If harvest levels approach even the lower end of our estimates, current offtake is unlikely to be sustainable for several species. The lowland paca and collared peccary have relatively high reproductive rates compared with other species (Mayor et al., 2017), and the large sales of these species may be more sustainable (Spironello et al., 2023); both are Least Concern species with stable populations on the Red List. However, little is known about where wild meat sold in Iquitos comes from, and how sustainable the hunting of specific species is in those areas. Furthermore, even these species may be increasingly vulnerable to extirpation. For example, recent widespread adoption of new hunting technologies (Bowler et al., 2020) and misalignment of harvesting with life-history periods during which species are particularly vulnerable, such as pregnancy (El Bizri et al., 2018), can create an unsustainable local system even for these resilient species. This underlines the urgency of developing monitoring systems that track formal and informal flows and incorporate sustainability indicators into management frameworks. Community-based

initiatives, including adaptive management in community-based conservation systems, that engage consumers in urban and peri-urban areas and rural suppliers are critical (Lemos et al., 2025). Rather than treating wild meat solely as an illegal or marginal activity, policy must recognize its role in food security while addressing the ecological risks of unsustainable harvests. Integrating our findings into adaptive management systems could provide early-warning indicators of overexploitation and support targeted conservation interventions. The consumption of species that may be sustainable, such as the paca and collared peccary, offers a useful alternative to cattle ranching and other harmful domestic protein sources that are responsible for habitat loss and fragmentation throughout the Amazon, if it is managed appropriately.

There has been a widespread call for closing wet markets that commercialize wild meat to avoid the risk for zoonotic disease spread, such as with COVID-19 (Aguirre et al., 2020). Informal and kinship-based distribution of wild meat also has important public health implications. Unlike market chains, where animals are often butchered and handled by a small number of intermediaries, informal exchanges distribute raw or minimally processed carcasses directly among households. This can increase the number of people exposed to blood, tissues, and pathogens during butchering and preparation. Moreover, sharing within kin networks often occurs without the sanitary oversight or storage facilities available in commercial outlets, which may heighten the risk of foodborne illness or zoonotic spillover. Although our study was not designed to assess health outcomes, these findings highlight that informal supply chains may represent distinct disease transmission pathways compared with markets. Recognizing this dimension is essential for designing integrated policies that safeguard food security and human health.

Our results showed that urban wild meat consumption in Iquitos is far more extensive and socially embedded than market surveys suggest. By documenting the significance of informal and kinship-based flows, we found that wild meat contributed substantially to food security and cultural practices in Amazonian cities. At the same time, the scale of extraction raises urgent questions about sustainability for vulnerable species, and informal distribution pathways pose potential risks for zoonotic disease transmission. We therefore recommend that monitoring systems expand beyond markets to include household surveys and community-level reporting and that particular attention be paid to species most at risk. Policy interventions should aim to balance the role of wild meat in food security with conservation imperatives, recognizing that effective management must integrate ecological, social, and health dimensions. Future research should prioritize longitudinal monitoring to track changes in consumption patterns and evaluate the effectiveness of adaptive management approaches.

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ORCID

Brian M. Griffiths https://orcid.org/0000-0001-9522-7731

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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