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Effect of geographic isolation and temporal patterns on use of wildmeat and fishery resources in Eastern Amazonia, Brazil

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ABSTRACT. The advance of urbanization, the construction of large-scale projects, and the intensification of the extraction of natural resources are modifying the food consumption patterns of human populations in the Amazon. The influences of the population's economic integration and proximity to the market are crucial factors that shape various aspects of their livelihoods. We evaluated the influence of distance to the commercial center, temporal variation, and river flow on the diversity and composition of wild meat and fishes consumed in two RESEXs in Eastern Amazonia. The data came from the National Biodiversity Monitoring Program, coordinated by the Chico Mendes Institute for Biodiversity Conservation, which has been in progress since 2014. We found a significant presence of industrialized food in the diet of populations close to the urban center and a presence of fish and wild meat in the meals from populations that live farther away. The consumption of fish and hunting animals is decreasing over the years without an increase in the consumption of industrialized food, which may represent a case of food insecurity for these populations. The consumption of fishes presented seasonal variations, guided by the river flow. Fishing and hunting play a significant role in the sustenance of these populations, but their decline over time may exhibit a worrisome pattern.

Keywords: ribeirinhos; fishing; hunting; food security; extractive reserve.

Efeito do isolamento geográfico e padrões temporais no consumo de caça e recursos pesqueiros na Amazônia Oriental, Brasil

RESUMO. Os padrões de consumo de alimentos das populações humanas na Amazônia estão sendo modificados pelo avanço da urbanização e pela construção de projetos em larga escala, intensificando a extração de recursos naturais. As influências da integração econômica da população no mercado e sua proximidade com o mercado são fatores cruciais que moldam diversos aspectos de seus meios de subsistência. Avaliamos a influência da distância até o centro comercial, variação temporal e fluxo do rio na diversidade e composição da carne de caça e peixes consumidos em duas Reservas Extrativistas (RESEXs) na Amazônia Oriental. Os dados foram obtidos a partir do Programa Nacional de Monitoramento da Biodiversidade, coordenado pelo Instituto Chico Mendes de Conservação da Biodiversidade, em andamento desde 2014. Encontramos uma presença significativa de alimentos industrializados na dieta das populações próximas ao centro urbano e uma presença de peixes e carne de caça nas refeições das populações que vivem mais distantes. O consumo de peixes e animais de caça está diminuindo ao longo dos anos, sem um aumento no consumo de alimentos industrializados, o que pode representar um caso de insegurança alimentar para essas populações. O consumo de peixes apresentou variações sazonais, guiadas pelo fluxo do rio. A pesca e a caça possuem grande importância para a alimentação dessas populações, mas sua diminuição ao longo do tempo pode apresentar um padrão preocupante.

Palavras-chave: ribeirinhos; pesca; caça; segurança alimentar; reserva extrativista.

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Introduction

The traditional populations of the Amazon live a way of life intimately connected to the natural environment and closely dependent on available natural resources. These communities developed through a deep understanding of the characteristics and dynamics of the surrounding forest and river and strategies to better use resources considering the changes that this environment presents (Diegues, 2000; Huntington et al., 2017). The annual variations of the river flow and the duration of the flood/drought period influence biodiversity and productivity with consequences on the patterns of use of natural resources (Castelo, Issac & Thapa, 2015). Anthropogenic factors, such as the modification of the landscape and the advance of capitalist expansion fronts on traditionally occupied areas, urbanization, and the implementation of large-scale projects, also influence the entire socio-ecological system, with reflections on the use of natural resources by traditional populations (Diegues, 1994; Levis et al., 2017; Chazdon, 2003).

The financial insertion of traditional people in the market and the greater availability of processed and industrialized products has been transforming their diet (Pollan, 2008). Studies on the food transition in traditional Amazonian populations have contributed to understanding changes in consumption patterns and their results on populations and the environment, as well as their effects on the health of these populations (Amaral, 2012; Navas, Kanikadan, & Santos, 2015; Silva, Garavello, Nardoto, Mazzi, & Martinelli, 2017; Rodrigues, Oliveira, & Santos, 2020). Fishing and hunting are two frequent activities in the culture of Amazonian populations, who have vast knowledge about the natural history and ecology of the species used, thus being able to select the prey they prefer, which causes a decrease in the abundance of specific groups of animals (Alvard, Robinson, Redford, & Kaplan, 1997). Larger prey, or those that live in large groups, are preferred, as they will generate a greater energy return and less waste of energy, ammunition, and time when hunting (Constantino, 2016). This return can also consider cultural preferences and economic advantages (Begossi & Richerson, 1992; Hill et al., 1997).

In fishing, selectivity occurs mainly due to the economic return of this activity. When focused on subsistence, a greater diversity of species is consumed, but when focused on sale, species with greater economic value are targeted, with a single species corresponding to 50% of the total biomass of fish caught (Batista & Barbosa, 2008; Hallwass & Silvano, 2016). Fish has significant economic importance for the Brazilian Amazon, earning 389 million Brazilian reals per year (US$ 74 million) (Almeida, Lorenzen, & McGrath, 2004), with an estimated production of 138 tons of fish (Ministério da Pesca e Aquicultura [MPA], 2011).

With the advance of urbanization, the pressure caused on the populations of natural species becomes more intense near urban centers, where there is greater population density (Tregidgo, Barlow, Pompeu, Rocha, & Parry, 2017). Large urban agglomerations tend to exert greater pressure on hunting and fishing resources, mainly affecting species preferred for consumption, generating a depletion pattern (Cinner, Graham, Huchery, & Macneil, 2012; Tregidgo et al., 2017). The population density of large mammals and birds tends to decrease close to urban areas, changing the community dynamics, which will be dominated by smaller species (Peres & Palácios, 2007).

Extractive Reserves (RESEXs) are conservation units created with the aim of reconciling biodiversity conservation and improving the quality of life of the populations that reside in these areas. Popular participation in decision-making within Conservation Units (UCs) helps manage, supervise, and organize and is essential for their maintenance and development (Nobre & Schiavetti, 2013). Recognizing and analyzing consumption patterns is not only a way to value this knowledge but also a tool to propose new ways of using it and add different experiences to create rules and agreements in line with reality and, therefore, viable (Nobre & Schiavetti, 2013).

In this study, we evaluated the influence of the degree of isolation, considered here as the distance to the urban center, on the diversity and composition of wild meat and fish consumed in two RESEXs in the Terra do Meio, on the Rio basin Xingu, in Pará. We expect to find a more significant presence of industrialized food and a greater number of species being consumed by families located closer to the urban center due to greater pressure on the most intensively used species and an opposite trend in more distant communities (Isaac et al., 2015). We also expected to find greater fish consumption during the months with lower river levels when the aquatic life is concentrated in the remaining waterbodies (Lopes, Catarino, Lima, & Freitas, 2018). Finally, we expected minor variations throughout time due to the relatively short monitoring period, the still ecosystem integrity, and low human density.

Material and methods

Study area

The study was carried out in two federal Conservation Units (UCs), the RESEXs Rio Iriri and Riozinho do Anfrísio, located in a region of Terra do Meio, a territory of 7.9 million hectares in the central region of the state of Pará (Figure 1). Primary forests of the type Open Ombrophilous Mixed, Ombrophilous Open Latifoliate, Dense Alluvial Ombrophilous, and Dense Submontane Ombrophilous dominate the region. It has a hot and humid climate of type AW according to Koppen's classification, with winter occurring between December and May and summer between June and November, with an average annual temperature of 27°C (range: 22 - 32°C) and a relative humidity of 80% (Silva, 2007). The river flow has its lowest values from August to October and highest in February to March. Access to RESEXs occurs by river or an illegal branch (rural road) from the Transamazônica highway to Porto Maribel, on the Iriri River. This location is the closest urban center for riverine families, having small shops, a school, and a health clinic, and was the reference for the distances to the urban center used in this study.

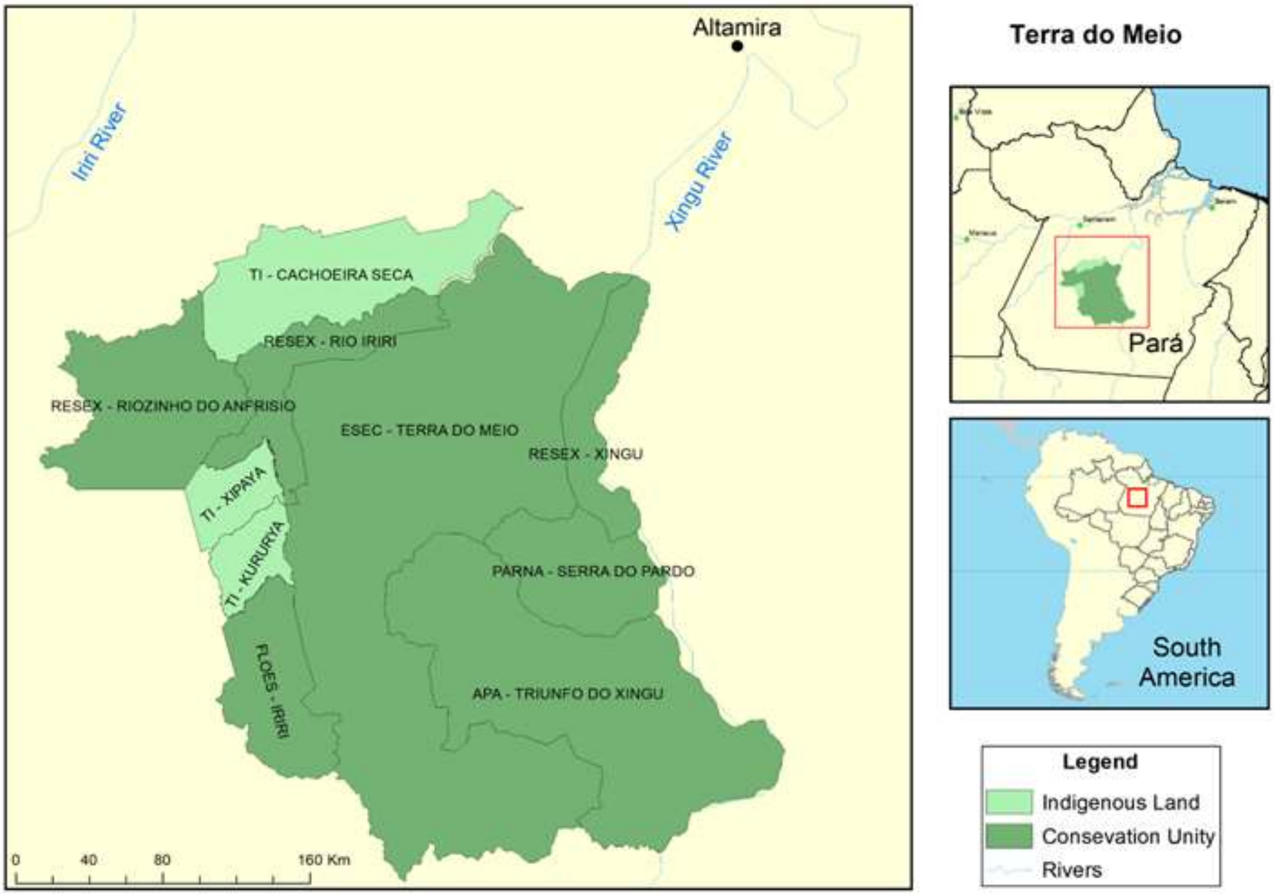

Figure 1. Terra do Meio Region (The authors).

Data collection and analysis

The data came from the National Participatory Biodiversity Monitoring Program (Monitor Program), coordinated by the Chico Mendes Institute for Biodiversity Conservation (ICMBIO) in a partnership with the University of Para, which has been in progress since 2014. Training workshops were held with the training of monitors who started to apply a fortnightly questionnaire to residents of households relatively close to their homes (Figure 2). The questionnaire addressed food-related questions the day before, including the origin (hunting, fishing, or farm animal), the species and weight of the animal consumed, and the presence of other food items in addition to animal protein. For the identification of animals, we used the ethnospecies classification, which, despite having less accuracy in identifying the species than the scientific nomenclature, is the most appropriate since the data were collected by the population itself, which named the animals consumed from their knowledge.

The communities selected for inclusion in this research were those for which the resident interviewers had easier and more direct internet access. The interviewers' proximity and intimate knowledge of the communities facilitated the establishment of trust-based relationships with the residents, thereby enabling a more comprehensive and in-depth data collection process. The data utilized in this study was collected up until the end of 2019 and was analyzed on a monthly and annual basis. The inclusion of the 'year' variable facilitates a comprehensive examination of consumption patterns over an extended temporal span. Having this extended vision is essential for elucidating long-lasting trends and seasonal fluctuations. Moreover, analyzing food consumption on a monthly basis helped to elucidate how seasonal variations can affect the dietary preferences and consumption patterns of populations on a smaller scale.

Figure 2. Map of the Iriri River and Anfrísio Small River Extractive Reserves (RESEX), highlighting the study communities in orange and the nearest commercial point to the RESEXs, the Maribel port, in black (The authors).

The frequency of consumption based on food and origin (wild animal, farm animal, fish, industrialized product, and from the crops) was calculated using the following formula: consumption frequency = number of meals having the specific item / total number of meals x 100. A chi-square test was used to observe whether there is a difference in the frequency of consumption based on the origin of the items between the three meals (breakfast, lunch, and dinner). The Shannon index was used to calculate diversity. This index is calculated based on the relative abundance of different species in a given ecosystem. It considers both the number of species (species richness) and their relative abundance (species evenness), providing a measure of how equally individuals are distributed among different species within a community (Chao & Shen 2003).

The variation in consumption frequencies between the RESEXs was evaluated through a Non-Metric Multidimensional Scaling (NMDS), considering that the RESEX Rio Iriri is located closer to the urban center (Porto Maribel) and that the RESEX Riozinho do Anfrísio is located further away the same. NMDS is a technique that makes it possible to visualize and analyze the similarity or dissimilarity between objects or samples based on their characteristics or attributes so that the distance between points in space reflects the dissimilarity between the samples (Clarke 1993). A chi-square test was carried out with the frequency of consumption among the RESEXs for the origin of the food, for all foods from hunting and fishing, and for the most important species.

To assess the relationship of the temporal variables (year, month, and monthly variation) and the spatial variable (distance from the urban center) on the frequency of origins of food items, as well as on the richness and diversity of hunting and fishing and weight Generalized Linear Models with Poisson distribution were developed. The best models were chosen using the Akaike Criterion, with the most parsimonious models being selected for those with $\Delta AICc \leqslant 2$. All analyses were performed using the R program (R Core Team, 2020), and the NMDS was performed using the VEGAN package (Oksanen et al., 2020).

Results

A total of 14,622 meals were analyzed, registered with 251 family groups present in 65 communities, with 5022 (34%) corresponding to breakfast, 4961 (33%) to lunch, and 4639 (31%) to dinner. 119 food items were identified, with the most consumed being coffee (16%), manioc flour (11%), pacu branco (7%), rice (6%) and peacock bass (6%).

When evaluating the origin of food items, we found 24 items of industrialized origin, 34 ethnospecies of fish, 17 hunted animals (nine mammals, three reptiles, and five birds), five species of farm animals, and 28 types of crops from the countryside. Industrialized foods and foods from fisheries were the most consumed, with 38 and 34%, respectively. Items from hunting had a lower frequency but were still significant, corresponding to 10% of the food consumed. When analyzing meals separately, we found a difference between the frequency of consumption and item origin ($p < 0.05$), with a higher frequency of industrialized food items for breakfast (79%) and fish items for lunch (48 %) and at dinner (51%).

At RESEX Rio Iriri we found a greater consumption of industrialized items (42%), followed by food from fishing (31%). At RESEX Riozinho do Anfrísio there was a greater consumption of food from fishing (38%), followed by industrialized food (32%) (Table 2). However, no significant difference was found in the origins of food items between the RESEXs ($p = 0.61$).

Table 2. Relative frequency (FR, %) of consumption of food items consumed in the RESEXs Rio Iriri and Riozinho do Anfrísio, Terra do Meio, Pará (chi-square test: p = 0.61).

Origin	FR (%) Rio Iriri	FR (%) Riozinho do Anfrísio
Industrialized	42.3	32.2
Fishing	31.1	38.7
Farming	13.4	16.9
Hunting	11	10.5
Livestock	2.2	1.7

The most consumed ethnospecies of fish at RESEX Rio Iriri were pacu (34%), peacock bass (18%), and curimatá (10%), while at RESEX Riozinho do Anfrísio were peacock bass (16%), piranha (10%) and trairão (10%). For hunting items, the porcão was the most consumed in both RESEXs, with 35% FR in Rio Iriri and 40% in Riozinho do Anfrísio, followed by tracajá (16%) and tapir (9%) in Rio Iriri and paca (19%) and tapir (7%) in Riozinho do Anfrísio. The chi-square test indicated no difference in the consumption of fish ($p=0.23$) and cinegetic animals ($p=0.38$) consumed between the RESEXs; however, when considering only the eight most important species, we found a significant difference in fishing consumption ($p=0.0007$) and hunting ($p=0.05$). The non-metric multidimensional scaling performed allowed us to evidence a partial differentiation in the composition of meals (hunting, fishing, industrialized, Livestock, or farming) of the families of Riozinho and Iriri (Figure 3a). As for the frequency of consumption of fish and cinegetic ethnospecies (Figures 3b and 3c), the analysis indicates similarity in the items consumed within each of the RESEXs, with no evidence of the formation of distinct groups.

The generalized linear models (GLM) showed that for the frequency of consumption, for the richness and diversity of fish, the variables year ($p<0.05$), month ($p<0.001$), and River Flow ($p<0.001$) (Table 3) had more significant influence (Table 4), with correlations indicating a slight and seasonal decrease in consumption over the months of the year (January to December) and a more pronounced decrease in consumption over the years (Table 4). The distance to the commercial center showed a positive relationship with the frequency of fishing consumption but a negative relationship with richness and diversity, indicating an increase in frequency with increasing distance but a decrease in the richness and diversity of fish consumed (Table 4).

The models with the weight of fish consumed showed the distance to the commercial center ($p<0.05$) and the River Flow ($p<0.05$) as the variables with a strong positive influence (Table 3), indicating an increase in the consumption of fishing items with the increase of the distance from the community to the commercial center and with the increase of the river flow (Table 4).

The distance to the urban center had an effect on the frequency of wildmeat consumption in all more parsimonious models with $p<0.001$ (Table 5), with a strong negative influence (Table 6), indicating a decrease in its consumption with increasing distance from the nearest available market. Hunting richness and diversity follow the same pattern, with distance negatively influencing these variables. This same pattern of richness and diversity was found for fishing. When analyzing the models based on the weight of game consumed, we have the month as the only variable in the most parsimonious model, indicating a decrease in the biomass of game consumed over the months of the year.

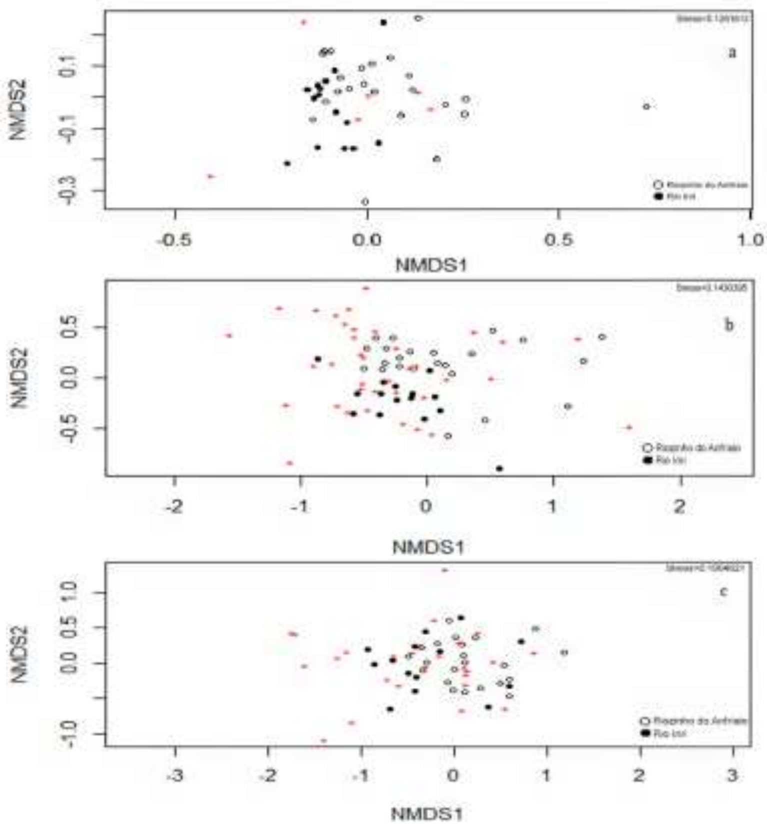

Figure 3. Non-metric Multidimensional Scaling (NMDS) based on food items consumed by the communities of the RESEXs Rio Iriri and Riozinho do Anfrísio in Terra do Meio, Pará (stress=0.1261612) (a), species composition of fish consumed (stress=0.1430395) (b) composition of wildmeat consumed (stress=0.1904621) (c).

Table 3. List of the best models and the respective information criteria of Akaike (AIC) and ΔAIC for Relative Frequency (FR, %), Richness, Diversity and the weight of Fish consumed in RESEXs Rio Iriri and Riozinho do Anfrísio, Pará. Predictors: Year, Month, Distance to Maribel harbor, River Flow = Monthly Average of River Flow on Iriri River. Significance levels = '***' 0.001 '**' 0.01 '*' 0.05.

Dependent Variable	Models Description	AIC	ΔAIC
FR Fish	Year**+Distance+Month	6790.8	0
	Year*+Distance+Month***+River Flow***	6792.3	1.5
	Year+ Distance+River Flow	6792.5	1.7
Fish Richness	Year+Distance+Month***+River Flow*	3938	0
Fish Diversity	Year*+ Distance+Month***+River Flow***	942.07	0
Fish (kg)	Distance*+River Flow*	168.12	0
	Distance+Month+River Flow	170.02	1.9

Table 4. Statistical summary of models for Relative Frequency (FR, %), Richness, Diversity and kilos of fish consumed at RESEXs Rio Iriri and Riozinho do Anfrísio, Pará. Predictors: Year, Month, Distance to harbor by Maribel and River Flow = Monthly average of River Flow in the Iriri River.

Dependent Variable	Model Ranking	Intercept	Year	Distance	Month	River Flow
FR Fish	1	9044.104	-4.46896	0.05909	-0.57212	-
	2	0.009.28	-4.59	0.0592	-0.434	0.00438
	3	0.009.20	-4.55	0.0592	-	0.00978
Fish Richness	1	203.8102	-0.09608	-0.00735	-0.1904	-0.00352
Fish Diversity	1	0.6.56	-0.0312	-0.0000999	-0.0251	-0.000513
Fish (kg)	1	0.137254	-	0.004349	-	0.001559
	2	0.439033	-	0.004237	-0.0148	0.001392

Table 5. List of the best models and the respective Akaike (AIC) and ΔAIC information criteria for the Relative Frequency (FR, %) of consumption, Richness, Diversity and Weight (kg) of Wildmeat consumed. Predictors: Year, Month, Distance to Maribel Port and River Flow = Monthly Average River Flow on the Iriri River. Significance levels = '***' 0.001 '**' 0.01 '*' 0.05.

Dependent Variable	Models Description	AIC	ΔAIC
FR Wildmeat	Year+ Distance***+Month*+River Flow***	6341.6	0
	Year+ Distance***+Month	6343.5	1.9
	Year+Distance***	6343.6	2
Wildmeat Richness	Year+ Distance***+Month***+River Flow***	3917.2	0
Wildmeat Diversity	Year+ Distance***+Month*+River Flow***	1647.3	0
Wildmeat (Kg)	Month*	98.752	0
	River Flow	99.743	0.991
	Month+River Flow	100.27	1.518
	Distance+Month	100.75	1.998

Table 6. Statistical summary of models for Relative Frequency (FR, %) of consumption, Richness, Diversity and Weight (kg) of Wildmeat consumed, at RESEXs Rio Iriri and Riozinho do Anfrísio, Pará. Predictors: Year, Month, Distance for the port of Maribel and River Flow = Monthly average of River Flow on the Iriri River.

Dependent Variable	Model Ranking	Intercept	Year	Distance	Month	River Flow
FR Cinegetic	1	0.00384	-1.89	-0.0184	-0.513	-0.00853
	2	0.00430	-2.13	-0.0182	-0.244	-
	3	0.00396	-1.96	-0.0183	-	-
Cinegetic Richness	1	203.810	-0.096076	-0.007354	-0.190395	-0.003523
Cinegetic Diversity	1	14.7608	-0.00624	-0.00176	-0.02524	-0.00087
Cinegetic (Kg)	1	3.73393	-	-	-0.15695	-
	2	0.077012	-	-	-	0.002441
	3	2.257556	-	-	-0.11358	0.001115
	4	3.689654	-	0.000217	-0.15462	-

For industrialized foods, distance was the strongest factor (Table 7), being the only variable in the most parsimonious model and appearing in all others, with $p<0.001$ (Table 8). The relationship was negative; that is, the consumption of processed foods was higher close to the commercial center.

Table 7. List of the best model set and their respective Akaike Information Criteria (AIC) and ΔAIC for the frequency of consumption (FC, %) of Industrialized foods consumed. Predictors: Year, Month, Distance to the Maribel port, and River Flow = Monthly Mean River Flow in the Iriri River. Significance levels = '' 0.001 '' 0.01 '' 0.05.

Dependent Variable	Models Description	AIC	ΔAIC
FR Industrialized Food	Distance***	6521	0
	Distance***+Month	6522.1	1.1
	Year+ Distance***	6522.5	1.5
	Distance***+River Flow	6522.9	1.9

Table 8. Statistical summary of models for frequency of consumption (FC, %) of Industrialized foods. Predictors: Year, Month, Distance to the port of Maribel and River Flow = Monthly average of River Flow in Rio Iriri, in RESEXs Rio Iriri and Riozinho do Anfrísio, Pará.

Dependent Variable	Model Ranking	Intercept	Year	Distance	Month	River Flow
FC of Industrialized food	1	41.84578	-	-0.04479	-	-
	2	43.01655	-	-0.04481	-0.17034	-
	3	720.4096	-0.3366	-0.04457	-	-
	4	40.98634	-	-0.04479	-	0.000854

Discussion

Fishing and hunting are vitally important to the region's populations, accounting for half of all items consumed and predominate if we consider just food of animal origin. Besides being great sources of protein, these also provide micronutrients such as iron, zinc, some vitamins, and fatty acids (Sartori & Amancio, 2012).

However, there has been a decrease in the consumption of these resources over the years, which has not been accompanied by an increase in protein sources from processed foods or domestic animals, which indicates a loss of food security (Kepple & Segal-Corrêa, 2011). Our study site is situated within the area of indirect influence of the Belo Monte hydropower plant, whose environmental mitigation programs include the indigenous lands of the region since 2012 but not the reserves, with no reasonable explanation. Many changes in fisheries along Xingu and its major tributaries were detected during the construction and operation of Belo Monte, both by the official fisheries monitoring program (Keppeler et al., 2022; Montag et al., 2023; Programa de Incentivo a Pesca Sustentável [PIPS], 2022). The negative impacts of damming rivers on aquatic environments, biodiversity in general, ichthyofauna, ecological productivity, fisheries, food security, and local and regional livelihoods are known worldwide (Chaudhari et al., 2021; World Commission on Dams [WCD], 2000), and the decommissioning of dams is growing after growing understanding that net losses overcome economic benefits (Moran, Lopez, Moore, Müller, & Hyndman, 2018).

Food security refers to the availability, access, and utilization of sufficient and nutritious food to meet a population's nutritional and dietary needs (Valente, 1997). Forests play a crucial role in providing a variety of healthy foods. These culturally valued products are integral to local food systems and food sovereignty and occasionally act as a ‘safety net’ in times of scarcity (Wunder, Börner, Shively, & Wyman, 2014). However, global transformations, such as urbanization and the expansion of market-oriented economies, are instigating a paradigm shift in dietary behaviors on a global scale. This shift is characterized by the replacement of locally cultivated foodstuffs with industrialized and processed food products (Popkin, 2006).

The changes caused by the advance of capitalist activities to the detriment of subsistence extractivism, together with liberal development policies in the region, have affected the environment and are modifying the forms of production of traditional populations (Silva, 2011). Obtaining protein sources from processed foods in the current economic situation of traditional populations is unrealistic, as they have low income or, often, no income at all and survive with the sale of natural products and the help of government programs (Lira & Chaves, 2016). Nunes, Peres, Constantino, Santos and Fischer (2019) analyzed models where bush meat would be replaced by beef and found that not only would purchase prices be impossible for these populations, but also projected damage to the forest with increased pastures and the production of other inputs, such as flour, thus highlighting the importance of faunal resources for the food security of these populations.

Fish consumption is directly linked to the food security of the riverine population, being the primary source of protein consumed in much of the Amazon region (Almeida et al., 2004; Lira & Chaves 2016). However, the overfishing of larger species, which have slower growth and therefore become more vulnerable, can affect the food security of these populations, who will have to consume smaller species and will spend more time and effort in capturing and consuming them (Welcomme et al., 2010). Larger fish have a greater biomass and a shorter processing time due to the size of the bones (Begossi, Salivonchyk, Hanazaki, Martins, & Bueloni, 2012).

The preference for certain species in hunting and fishing generates a pattern of species depletion close to the urban center (Cinner et al., 2012; Tregidgo et al., 2017), as evidenced in this study. In this context, the pressure on natural resources is intensified near the urban center, causing a decrease in the abundance of preferred species and directing pressure to species that would otherwise be neglected, such as smaller species with less commercial value (Parry, Barlow, & Pereira, 2014). The intensive exploitation of large fish species, characterized by their slow growth and greater vulnerability to overfishing, has led to a significant decrease in their populations and, in critical circumstances, has even led to the local extinction of these valuable species (Welcomme, 1999). As a result, there is a substitution with smaller and lower-value fish species in multi-species fisheries, which directly impacts consumption, increasing the richness and diversity of the consumed species (Parry et al., 2014).

The demand for smaller or economically less valuable fish species can serve as an indicator of an environment undergoing transformations due to human influences. These influences, such as overexploitation and habitat degradation, have the potential to lead to a scarcity or decline of fish species that were historically preferred by fishermen (Begossi, 1997; Jerozolimski & Peres, 2003). Such shifts in fish species preference underscore the profound impact of human activities on our natural ecosystems and can reveal the need for conservation and sustainable management efforts.

In the region, we can observe a change in the eating pattern, with food from natural resources being consumed less frequently near the urban center and a decrease in the consumption of fishery resources over the years. This process of food transition affects traditional populations throughout the Amazon, changing their way of life by introducing new products for consumption and changing their way of relating to natural resources (Navas et al., 2015). This change brings positive and negative points for the population. On the one hand, access to processed foods with higher levels of sugar and fat leads to an increase in the rate of diseases such as diabetes and blood pressure problems (Monteiro, Mondini, Souza, & Popkin, 1995; Popkin, 2006). On the other hand, these resources can be used to supply other natural resources in times of scarcity and provide new sources of nutrients (Silva & Garavello, 2012).

The distance between local communities and markets is a critical factor that significantly influences fishing practices and dietary choices adopted by these communities. Markets, especially smaller ones, play an undeniably important role, even though they often cater to a smaller number of consumers compared to distant large commercial centers (Margulis, 2004). This is due to their strategic location, commonly near forested areas and fishing locations.

Variations in fish consumption throughout the year, correlated with dry and wet seasons, are intricately linked to fluctuations in river levels and their impacts on fish populations (Welcomme, 1990). During the dry season, river levels decrease significantly, creating more confined aquatic environments. This reduction in water volume can influence fish migration, reproductive behavior, and food availability for fish species (Freitas, Siqueira-Souza, Humston, & Hurd, 2013). In contrast, the wet season is characterized by a substantial increase in river levels due to heavy rains and flooding (Mérona & Gascuel 1993). This expands aquatic habitats, creating new breeding and feeding areas for fish. During the wet season, many fish species benefit from the availability of food resources and favorable conditions for reproduction. Contrary to our expectations, fish consumption decreased in the last months of the year, corresponding to the drought-to-flood transition period. This pattern is different from that found in the Amazon. However, according to Halwass (2011) it may be due to other factors, such as the use of specific methods for each season or other occupations by fishermen, such as extracting some other natural resource. It is important to note that riverine communities often develop adaptive subsistence strategies that take into account seasonal variations and livelihood opportunities (McGrath, Castro, Futemma, Amaral, & Calabria, 1993). Therefore, the decrease in fish consumption in the last months of the year may be the result of a combination of factors, including seasonal fishing methods, alternative subsistence activities, and specific cultural practices adopted by local communities. We suggest that the observed pattern may be explained by the deep fishermen’s knowledge of fish behavior and diet (Hallwass 2011), allowing fishermen to use adequate bait and capture fish in specific habitats in the floodplains.

Conclusion

This research makes contributions by assessing food insecurity within the populations residing in Reserve Extractive Reserves (RESEXs). The study reveals a concerning trend of decreasing consumption of fishing and hunting, which are traditionally vital protein sources for these communities. Importantly, this decline is not offset by the adoption of alternative protein sources. This insight serves as a crucial indicator of the food security challenges faced by these populations and provides valuable information for policymakers and organizations seeking to address and alleviate these issues. We identified a notable shift toward increased consumption of industrialized foods, particularly during breakfast. This dietary transition sheds light on the changing nutritional habits of these communities and holds significance for designing effective interventions to promote healthier eating choices and improve overall nutritional well-being.

The critical role played by the proximity to commercial centers is a significant variable influencing food choices within these regions. It is revealed that the frequency of consuming fishing, hunting, and industrialized foods is directly affected by the distance to commercial centers. This finding offers valuable insights for local and regional governance, emphasizing the importance of enhancing access to diverse and nutritious dietary options for these populations.

Our study has unveiled a meaningful relationship between the proximity of communities in Extractive Reserves (RESEXs) to commercial centers and the biodiversity of hunted species. We observed a pattern where more isolated communities exhibit a greater species abundance, whereas urban centers experience species depletion. This discovery underscores the intricate interplay between dietary choices and their significant ecological consequences. These findings carry substantial implications for conservation efforts, policymaking, and sustainable practices, emphasizing the need for comprehensive approaches that not only address food security but also acknowledge the intricate dynamics of ecosystems and biodiversity preservation. By understanding these relationships, we can work toward the well-being of both these communities and the environments upon which they depend in the long term.

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