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Food consumption as an indicator of the conservation of natural resources in riverine communities of the Brazilian Amazon

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ABSTRACT

The present study analyzed and compared the daily consumption of foods of animal origin in eleven communities of the Lower Amazon, Trombetas and Purus Rivers, representing three different management systems and levels of conservation in the Brazilian Amazon. All food items of animal origin were weighed by at least 10% of the families in the study communities during a week in each period of the flood cycle between 2006 and 2008. Fish was the most important food, and was consumed during six days of the week, with an average rate of 169 $kg.person^{-1}.year^{-1}$. Game was second in importance, with 37 $kg.person^{-1}.year^{-1}$. This yearly rate of fish consumption is one of the highest in the world and is almost double the minimum recommended by the World Health Organization. The dietary patterns reflect both the isolation of the communities from large urban centers and the better preservation of the local environments due to the existence of protected areas. Environmental degradation may thus have effects on the health and food security of local populations. The study emphasizes the need for the implementation of public policies and participative management initiatives.

Key words: fish, game meat, management, deforestation.

INTRODUCTION

The harvesting of food is one of the key interactions between human populations and their environment. The exploitation of food or other resources found in the environment by human populations may provide important insights into the potential for managing local biodiversity.

Fishing and hunting may represent an important source of both food and income for forest-dwelling populations in the Tropics (Sirén and Machoa 2008). In many rural Amazonian communities, there are few opportunities for the generation of monetary income, and the ability of household members to obtain food from the natural environment is often essential for guaranteeing or ensuring their food security (Gross 1975, Bleil 1998).

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A number of ecological-anthropological studies are available on the subsistence behavior of hunter-gatherer populations (Lee and Devore 1968, Messer 1984, Ross 1987, Myers 1988). Some studies (Douglas 1966, Begossi et al. 2004, Pezzuti 2004, Silva 2007) have focused on food taboos, while others, such as the historical approach of Meggers (1971) and the more recent review of Adams et al. (2009), have analyzed the impact of the diet on the exploitation of natural resources.

Dietary practices in traditional, geographically isolated societies, reflect the diversity and abundance of local natural resources, and influence the health and quality of life of the population (Shrimpton and Giugliano 1979, von Halle 2002), in addition to its cultural identity and belief system (Messer 1984). In some cases, the composition of the diet may reflect income levels and the social conditions of the group (Burger et al. 1999). Bayley and Petrere (1989) have also emphasized the utility of monitoring the consumption of fish in communities as a way of estimating the productivity of local fisheries, and the economic and social importance of this resource in a given region.

Fishes are important components of the diet in many countries, contributing with 15% of all the animal protein consumed worldwide (FAO 2009). The global yearly per-capita consumption of fish has increased steadily in recent decades, from 9 kg in 1961 to 11.6 kg in 1971, 15.7 kg in 1997, and 17 kg in 2009. Most of this increase has occurred in developing countries (Delgado et al. 2003, FAO 2009).

In the Amazon basin, despite the increasing pressure from commercial fisheries in recent decades (McGrath et al. 1993, Isaac et al. 1998b, Crampton et al. 2004), fish are still the primary source of animal protein for most riverine populations. A fish-based diet, reduces the risk of disease (Zhang et al. 1999), and balances a diet that would otherwise be poor in protein (Dorea 2003).

A number of studies on the diet of rural inhabitants of the Amazon basin are available (Gross 1975, Shrimpton and Giugliano 1979, Giuliano et al. 1978, Cerdeira et al. 1997, Murrieta et al. 1999, 2008, Murrieta 2001, Murrieta and Dufour 2004, Leite et al. 2007). However, while most of these studies provide data on the composition of the diet and the frequency of different items, they do not provide consumption rates. This impedes more systematic extrapolations or comparisons among sites.

The present study analyzed and compared the daily consumption of foods of animal origin in communities representing three different management systems in the Brazilian Amazon basin.

The objective was to understand the role of cultural and ecological factors in the determination of the quality and composition of the diets of the different populations, and the influence of the resource management practices adopted in each region. The study sought to answer the following research questions: a) which foods are the main components of the diet? b) are there differences between regions? c) to what extent do seasonality, degree of isolation, and cultural and economic activities explain these differences? d) can management practices indirectly influence the dietary patterns of these populations?

MATERIALS AND METHODS

Ethical Statement

Data were collected by members of the families inhabiting riverine communities in the Brazilian Amazon. The participation of the families was voluntary. To ensure that we obtained the informed consent of each research participant, the aims of the study and how data were stored and used were explained to all the participants and leaderships during community meetings prior to the beginning of the study. Due to the participants' low level of literacy, we did not obtain written consent, because the participants might not have fully understood what they were signing. Participants' names and personal information were not recorded.

All procedures were carried out according to the international practices for interviews with humans. To ensure that we obtained the informed consent of our research participant, the aims of the study and how data would be stored and used were explained to all the participants and leaderships during community meetings. The participation of the families was voluntary, anonymous and clearly explained. Due to the low level of literacy in the area, we did not obtain written consent, because the participants may not have fully understood what they have to sign. Participant's names and personal information were not recorded.

STUDY AREA

The climate of the Amazon region is marked by a characteristic rainy-dry cycle, in which the floodplain is inundated during the period of more intense precipitation. This flood pulse has a major effect on the availability and distribution of living organisms, and also affects the lifestyle of riverine populations. During the dry season, which coincides with the second half of the year, river levels decline, and the exposed floodplain is used for planting crops or grazing cattle. The harvest of cassava, hunting and fishing are all easier during this period. When the river floods, by contrast, the area of floodplain lakes and lateral channels increase considerably in size, and the surrounding forest remains flooded for several months. While this results in a considerable increase in the number of habitats and feeding resources for the aquatic fauna, the increase in the number of potential refuges reduces the efficiency of fishery activities (Junk et al. 1989).

The data were collected from eleven riparian communities in three distinct regions of the Brazilian Amazon basin (Fig. 1): 1) the lower Amazon River; 2) the Trombetas River, and 3) the lower Purus River.

In the first study area, four communities from the municipality of Santarem, state of Pará, were monitored (Fig. 1a). These communities contained a total of approximately 1200 inhabitants distributed in 240 families, of which, 24 (10%) participated in the study. The Lower Amazon is typical of the landscape of the Amazon basin, with ample floodplains and numerous muddy lakes. Fishing and raising livestock constitute the main economic activities. This area is assumed to be one of the most degraded parts of the Lower Amazon basin, based on its long history of occupation (Harris 2011), and is not protected by any conservation unit. The management of the local aquatic environments is based on well-established "fishing agreements", which restrict access to local fishery resources as a way of avoiding depletion. Despite being supported by a large proportion of the local population, these agreements, which have been acknowledged by the Brazilian government as a promising method of participatory management (Castro and McGrath 2003, Isaac et al. 1998a), tend to generate many conflicts.

Four communities of the Trombetas River (Fig. 1b), in the municipality of Oriximiná, state of Pará were also included in the study, of which two are located within the Rio Trombetas Biological Reserve (BR Rio Trombetas), while the other two are near the village of Porto Trombetas, in the area adjacent to the reserve. The total population of these communities is 1300 inhabitants, distributed in 282 families, of which 37 (13%) were included in the present study (IBAMA 2006). The BR Rio Trombetas is a biological reserve established by the Brazilian government in 1979 with the objective of protecting the region's abundant turtle population.

The inhabitants of these communities are descendants of native Amerindians or rebel slaves known as "quilombolas" who live on hunting, fishing, raising livestock, harvesting forest resources (mainly Brazil nuts), and cultivating subsistence crops. A bauxite mine was established in Porto Trombetas in 1979, but despite the environmental pressure generated by the mine, this region of the Trombetas River basin is still relatively isolated due to the existence of the reserve. Thus, for the purposes of the present study, this area was assumed to represent a relatively protected and well-conserved region.

Three communities were sampled in the third area, the lower Purus River in the state of Amazonas, two of which are located in the Piagaçu-Purus Sustainable Development Reserve, while the third was located adjacent to this reserve (Fig. 1c). The three communities contain approximately 230 inhabitants in 57 families, and data were obtained from 23 of these families (38%). This study area is relatively isolated from the region's main urban centers (it takes two days by motorized boat to reach it from Manaus) and therefore very well conserved. The area is characterized by lakes of different sizes, swamps and tropical forest, in addition to the river.

The inhabitants exploit aquatic resources such as fish, turtles, and alligators, in addition to subsistence agriculture and the extraction of timber and other forest products (Deus and Da Silveira 2003).

DATA COLLECTION

Data on the consumption of animal protein were collected between July 2006 and May 2008. The study used a participatory approach in which dietary intake was recorded by the subjects themselves. Members of each family that agreed to participate in the study were trained in the collection of data by the research team. The participants were required to record all the food items of animal origin consumed each day, and the weight of each item prior to cooking. Items were weighed on a 5 kg-capacity kitchen scale with a precision of 25 g. These data were collected during seven consecutive days in the four main periods of the flood pulse – receding water, low water, rising water and high water (Table I).

For this, to one chicken egg was assigned a weight of 50 g (Scherr and Ribeiro 2009) and turtle eggs, 23.97 g per unit (Pezzuti et al. 2008). Food sources were classified as fish, beef, poultry, pork, turtle meat, alligator meat, game meat, canned meat, chicken, chicken eggs, and turtle eggs.

DATA ANALYSES

Consumption rates were estimated by family and seasonal period in g.person^{-1}.day^{-1} by dividing the total amount of each type of food consumed (in g) during all sampled days in each seasonal period by the number of people participating in the meals in the same period in each family. A total of 262 samples were obtained, 85, 123 and 54 samples for the Lower Amazon, Trombetas and Lower Purus, respectively (Table I). The mean quantity of protein and calories in each type of food was estimated from an average conversion factor based on the tables published by Vasconcellos et al. (1991), Aguiar (1996), IBGE (1999) and NEPA (2006) (Appendix).

The relative frequency of the consumption of each food item was based on the formula $\%Fi = (\sum Ni / \sum Nti) \times 100$, where Ni = the number of days on which item i appeared on the diet of a given study area, and Nti = the total number of days sampled in the area.

The Kruskal-Wallis test was used to compare the consumption of each type of food between study areas and periods and a multi-comparison test was performed to evaluate the significance of the differences ($\alpha = 0.05$). A multivariate ANOSIM analysis and a Principal Component Analysis (PCA) were conducted to compare the composition of the diet between areas and periods, using the PRIMER 6.0 software (Clarke and Gorley 2006).

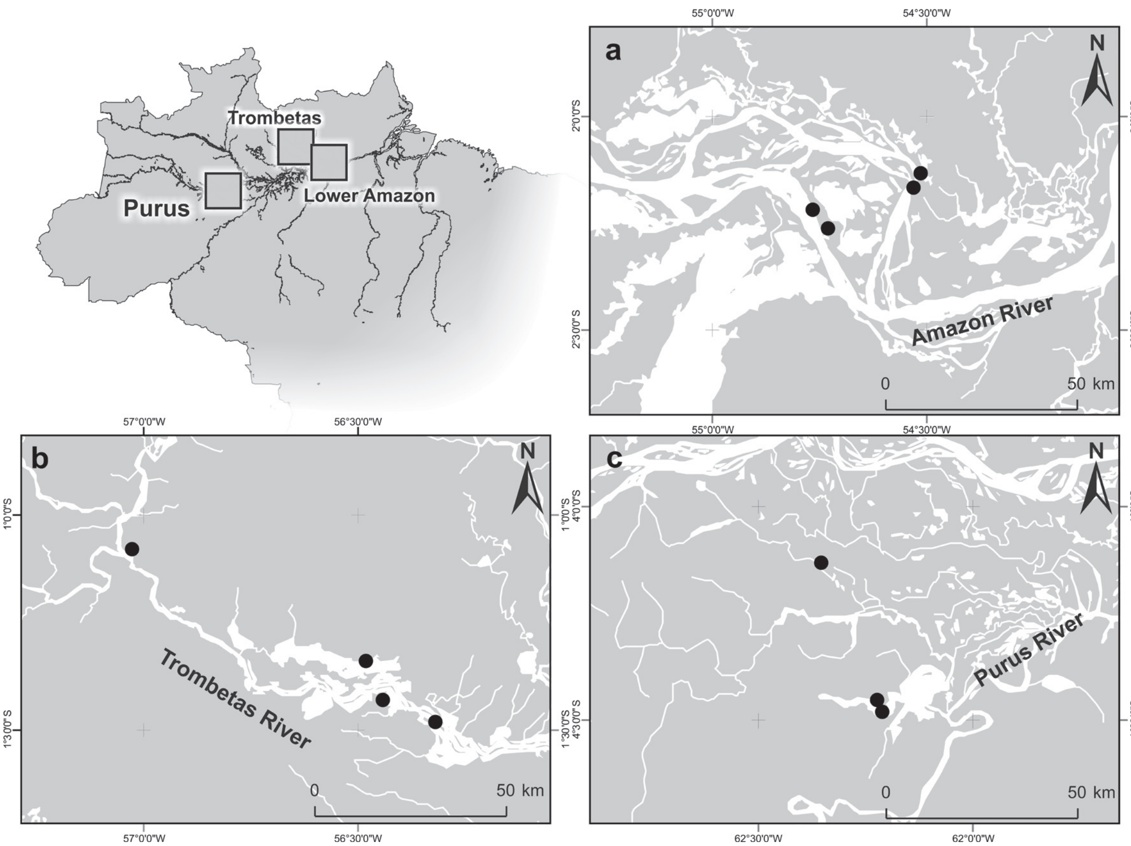

Figure 1 - Study areas: **a** - Lower Amazon River; **b** - Trombetas River; **c** - Lower Purus River.

TABLE I
Sampling effort in the three study areas by seasonal period.

Region	Period	Month/Year	Nr of estimates
Lower Amazon	Receding water	Jul/Aug/06	24
	Low water	Oct/Nov/06	21
	Rising water	Jan/07	19
	High water	Apr/07	21
Total Lower Amazon			85
Trombetas	Receding water	Aug/07	32
	Low water	Nov/07	29
	Rising water	Feb/08	32
	High water	May/08	30
Total Trombetas			123
Lower Purus	Receding water	Aug/Sep/06	13
	Low water	Nov/Dec/06	11
	Rising water	Jan/Feb/07	16
	High water	May/07	14
Total Lower Purus			54
Total			262

The modified Costello graphical method (Amundsen et al. 1996) was run for the assessment of the dietary strategies of the inhabitants of each study area. This method involves plotting the abundance and frequency of occurrence of each item. The relative abundance of item i was given by %Ai = (∑Ri/∑Rti) × 100, where Ri = the daily consumption rates of item i, and Rti = the daily consumption rate of all items in cases where item i was consumed. In the graph, the importance of an item can be evaluated according to its position on the diagonal, from the lower left (rare) to upper right (dominant), while the consumption strategy is represented on the vertical axis, ranging from the bottom (generalist) to the top (specialist). The reverse diagonal ranges from a high within-phenotype component (WPC) at bottom right, indicating a relatively narrow niche, to a high between-phenotype component (BPC), at upper left indicating a wide niche (Fig. 3a).

RESULTS

The members of all the families (the average family had five members) monitored during the present study consumed protein-based foods on a daily basis. Fish was by far the most important animal food, being consumed approximately six days per week, on average, or 302 days of the year. Game was consumed once every four days, on average, chicken eggs every five days, beef every eight days, and chicken once every 10 days. Other foods were consumed at much lower frequencies (Table II).

While the relative frequency of the different items varies among study areas, seasonal patterns are similar in all areas. The families from Trombetas consumed game, turtle, and pork more frequently than those in the other areas, while canned meat was eaten more frequently by families in the Purus region. Beef, poultry, and chicken eggs were consumed more frequently in the Lower Amazon. The consumption of alligator meat and turtle eggs was similar in all three areas.

TABLE II
Consumption (number of records and frequency of occurrence) of each food type per period and study area.

Region	Water level	Total	Alligator		Canned meat		Beef		Game meat		Fish		Chicken Egg		Pork		Poultry		Turtle		Turtle Egg	
			N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Lower Amazon	Receding water	165	3	1.82	6	3.64	18	10.91	7	4.24	150	90.91	28	16.97	3	1.82	18	10.91	1	0.61	0	0.00
	Low water	144	1	0.69	9	6.25	25	17.36	2	1.39	121	84.03	39	27.08	0	0.00	24	16.67	1	0.69	2	1.39
	Rising water	132	2	1.52	2	1.52	33	25.00	2	1.52	100	75.76	29	21.97	3	2.27	24	18.18	0	0.00	0	0.00
	High water	145	5	3.45	7	4.83	26	17.93	2	1.38	124	85.52	42	28.97	0	0.00	18	12.41	0	0.00	1	0.69
Lower Amazon All		586	11	1.88	24	4.1	102	17.41	13	2.22	495	84.47	138	23.55	6	1.02	84	14.33	2	0.34	3	0.51
Lower Purus	Receding water	80	0	0.00	1	1.25	0	0.00	15	18.75	77	96.25	12	15.00	0	0.00	0	0.00	3	3.75	1	1.25
	Low water	64	0	0.00	4	6.25	3	4.69	17	26.56	53	82.81	7	10.94	0	0.00	2	3.13	1	1.56	1	1.56
	Rising water	106	1	0.94	17	16.04	6	5.66	36	33.96	87	82.08	18	16.98	8	7.55	4	3.77	0	0.00	1	0.94
	High water	91	1	1.10	7	7.69	5	5.49	21	23.08	81	89.01	10	10.99	1	1.10	6	6.59	2	2.20	2	2.20
Lower Purus All		341	2	0.59	29	8.5	14	4.11	89	26.1	298	87.39	47	13.78	9	2.64	12	3.52	6	1.76	5	1.47
Trombetas	Receding water	221	3	1.36	0	0.00	26	11.76	92	41.63	191	86.43	46	20.81	12	5.43	29	13.12	2	0.90	5	2.26
	Low water	200	5	2.50	1	0.50	32	16.00	64	32.00	153	76.50	49	24.50	18	9.00	24	12.00	7	3.50	5	2.50
	Rising water	220	7	3.18	0	0.00	35	15.91	84	38.18	169	76.82	50	22.73	11	5.00	15	6.82	10	4.55	0	0.00
	High water	209	1	0.48	0	0.00	21	10.05	75	35.89	162	77.51	35	16.75	12	5.74	14	6.70	6	2.87	0	0.00
Trombetas All		850	16	1.88	1	0.12	114	13.41	315	37.06	675	79.41	180	21.18	53	6.24	82	9.65	25	2.94	10	1.18
All		1777	29	1.63	54	3.04	230	12.94	417	23.47	1468	82.61	365	20.54	68	3.83	178	10.02	33	1.86	18	1.01

The study populations exploited a wide range of protein sources, consuming an average of 669 g.person^{-1}.day^{-1}, the equivalent of 244 kg.person^{-1}.year^{-1}. Fish is the main food eaten, with an average of 462 g.person^{-1}.day^{-1} consumed overall, that is, 169 kg.person^{-1}.year^{-1}. Game is second in importance, with 102 g.person^{-1}.day^{-1} overall (37 kg.person^{-1}.year^{-1}) with beef and chicken following in third and fourth places, respectively (Table III).

Differences among study areas were found in the average consumption of fish, pork, game, beef, poultry, and canned meat (Table IV). The consumption of turtle meat and eggs, chicken eggs, and alligator meat did not vary significantly among areas. The results indicated clearly that the consumption of game is more intense in the more isolated and less impacted regions (Trombetas and Purus), whereas in the third area (Lower Amazon), poultry is a more frequent alternative to fish. While significant differences were found in the composition of the diet among study areas (two-way ANOSIM: global R-statistic = 0.72, $P < 0.01$), no significant seasonal pattern was observed (global R-statistic = -0.05, $P > 0.05$).

TABLE III

Mean rate (g.person^{-1}.day^{-1}) and standard deviation (parentheses) of the consumption of different animal food items by the families of the three study areas (Amazon, Trombetas, and Purus). The mean protein (g) and calorie content are also given, with rates per 100 g shown in brackets.

Food type	Lower Amazon	Trombetas	Lower Purus	All Groups	Protein (g)	Calories (kcal)
Alligator	3.88 (13.03)	6.73 (22.67)	3.99 (27.26)	5.24 (21.16)	1.17 [22.34]	5.23 [99.81]
Canned Meat	2.68 (7.21)	0.07 (0.81)	7.05 (15.23)	2.36 (8.44)	†	†
Beef	51.06 (72.73)	49 (62.37)	10.7 (23.66)	41.8 (62.34)	8.89 [21.28]	88 [210.67]
Game Meat	6.31 (24.34)	163 (141.52)	114 (139.57)	102 (135.16)	19.00 [18.89]	110.70 [108.47]
Fish	416.39 (209.12)	490 (240.69)	469 (207.72)	462 (225.74)	87.00 [19.04]	770.00 [167.00]
Chicken Eggs	12.55 (19.37)	15.3 (23.14)	9.35 (15.72)	13.2 (20.65)	1.70 [12.95]	20.13 [153.00]
Pork	3.38 (19.44)	25.6 (54.76)	10.7 (41.26)	15.3 (44.38)	2.84 [18.57]	39.72 [259.43]
Poultry	55.75 (75.44)	37 (56.02)	16.5 (50.76)	38.9 (63.4)	7.22 [18.57]	73.09 [188.00]
Turtle	1.47 (9.86)	15.9 (58.54)	5.46 (21.33)	9.07 (42.06)	1.84 [20.30]	8.74 [96.32]
Turtle Eggs	0.18 (0.97)	0.71 (2.89)	0.27 (1.04)	0.45 (2.12)	0.07 [16.40]	0.95 [210.40]
Total	549.17 (233.67)	761 (238.7)	647 (244.44)	669 (255.22)	†	†
N	85	123	54	262	-	-

† = No data available for the conversion of values.

TABLE IV

Results of the Kruskal Wallis and multiple comparison tests for the analysis of food consumption rates among the study areas. Different letters indicates significant differences (α = 0.05), where a>b>c. Differences that were not significant are not presented here.

Food Type	Lower Amazon	Trombetas	Lower Purus	H	P
Canned meat	ab	b	a	33.11	0.0000
Beef	a	a	b	27.89	0.0000
Game meat	c	a	b	111.94	0.0000
Fish	b	a	ab	6.04	0.0489
Pork	b	a	ab	25.54	0.0000
Poultry	a	ab	b	22.36	0.0000
Total	b	a	b	37.41	0.0000

The PCA further confirmed the differences in the diets of the populations of the three study areas. The first two axes explain 69.3% of the variation in the data, with the distribution of the points emphasizing the differences in the consumption of game, which is relatively low in the Lower Amazon communities in comparison with the other two study areas. This analysis also highlights

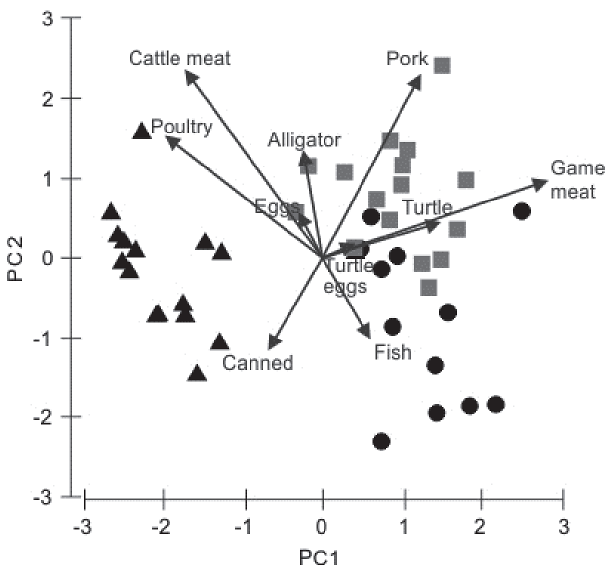

Figure 2 - Distribution of the first two main components according to the consumption of different food items by the three studied populations (Trombetas: squares; Purus: circles; Amazon: triangles).

the reduced consumption of beef and chicken by the Purus communities and of canned meat by those of the Trombetas River. The Trombetas communities are characterized by the relatively high consumption of turtles and turtle eggs, pork, and alligator, in addition to game and fish (Fig. 2).

The modified Costello approach (Fig. 3a) also emphasizes the specialization of the studied populations in the consumption of fish, which has high consumption rates (F > 79%) and specific abundance (Pi > 75%). In the Purus and Trombetas communities (Fig. 3c, d), game is the second most important item, contributing 25% of the frequency of items, and partly substituting the beef and poultry consumed in the Lower Amazon (Fig. 3b).

DISCUSSION

Fish appears to be the most important source of animal protein for the inhabitants of the riverine communities of the Brazilian Amazon (Isaac and Almeida 2011). The results of the present study confirm the importance of fish in the diet of these communities, where it represented 64-76% of animal food items, and 79-87% of the weight ingested, with a mean of 462 $g.person^{-1}.day^{-1}$. This is one of the highest values reported for Amazonian populations, corresponding to an annual consumption of 169 kg, more than double the average annual consumption of fish in Japan and other countries with a fish-based diet. In Japan, annual fish consumption has ranged from 70 to 62 kg between 1973 and 1997 (Delgado et al. 2003). In riparian communities on the Negro River, in the northwestern Amazon basin, fish also contributed 70% of the protein items consumed in the main meal (Silva and Begossi 2009).

Giuliano et al. (1978) and Shrimpton and Giuliano (1979) reported that residents of the city of Manaus consumed an average of 122 g of fish per day, while Amoroso (1981) recorded a rate of 94.5 g per day in a poor neighborhood of the same city. In the neighboring city of Itacoatiara, in the State of Amazonas, Smith (1979) estimated a mean consumption of fish of 146 g per day. In the indigenous Tukano communities of the blackwater upper Negro River, Chernela et al. (1989) recorded an average fish consumption of 68 g per day. By contrast, Cerdeira et al. (1997) recorded a mean daily rate of 369 g per person among families of the Lago Grande de Monte Alegre lake system in the Lower Amazon. In coastal fishing communities of southeastern Brazil, the frequency of fish on the diet – 60-68% – is generally lower than that of the riverine communities of the Amazon basin (Begossi and Richerson 1992, 1993, Hanazaki et al. 1996).

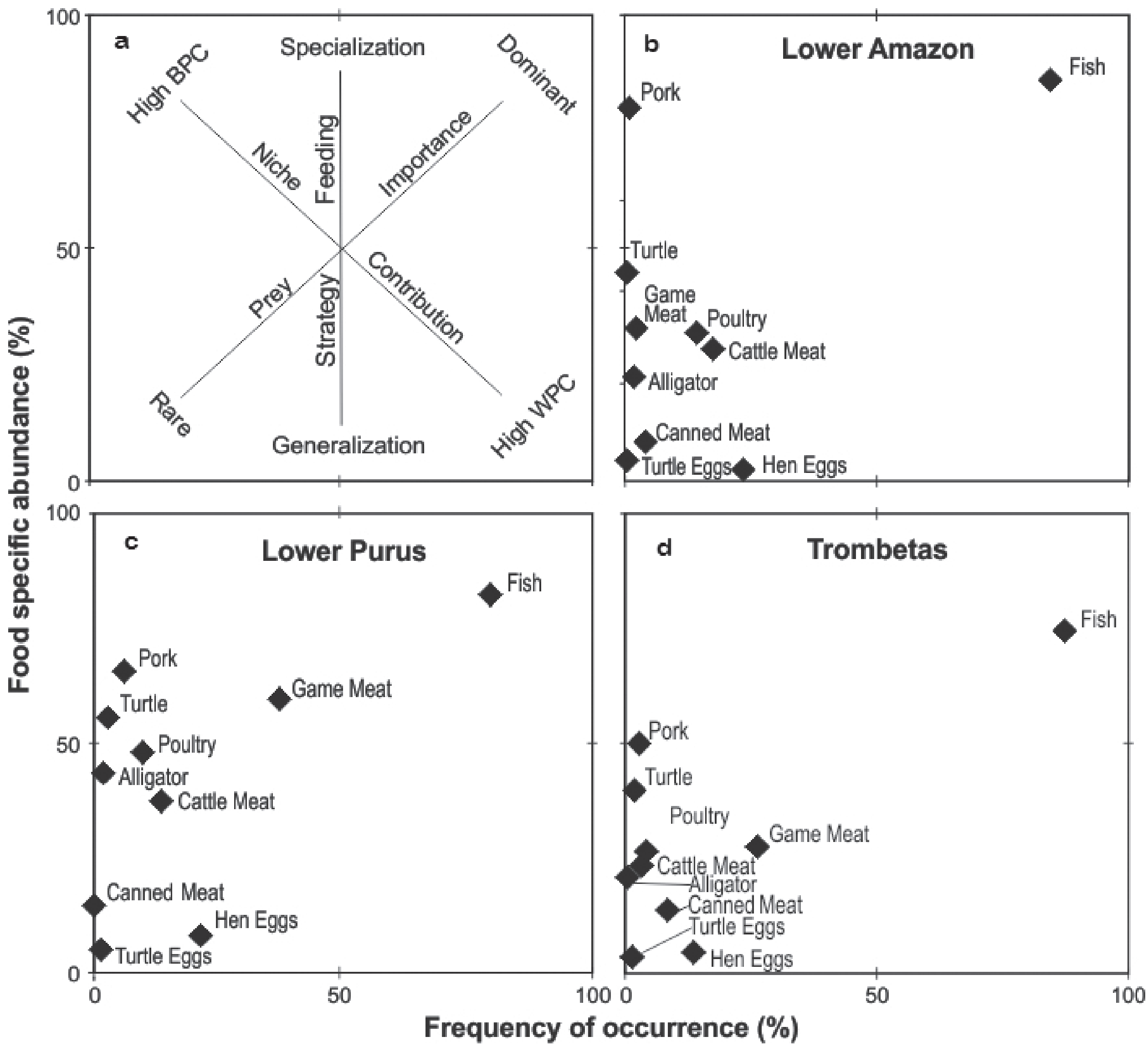

Figure 3 - (**a**) Explanatory diagram of the modified Costello method (BPC: between-phenotype component; WPC: within-phenotype component). (**b-d**) Variation of feeding strategies in the study areas.

Because of the excellent nutritional qualities of fish, the World Health Organization (WHO 2003) recommends an annual per capita consumption of at least 12 kg. Assuming a mean requirement of approximately 50 g of protein per day (WHO 2007), the 87 g of fish protein ingested per day in the present study, on average, would represent almost double the recommended minimum. In the rest of Brazil, by contrast, annual consumption is considerably lower, with an average of 6-9 kg per person, approximately half the rate recorded worldwide (FAO 2009, MPA 2010).

The mean value of 770 kcal of energy provided by the fish component of the diet is well below the daily minimum requirement of 1500 to 2500 kcal recommended for adults (FAO 2004). However, rural populations in the Amazon region consume large quantities of carbohydrates in the form of sugar and cassava meal. Murrieta (2001) found that families in the Lower Amazon obtained between 17% and 26% of their total energy intake from fish, while cassava meal provided 25-34%.

Considerable differences were recorded among areas in the present study. While all communities usually consume much more fish, Trombetas communities appear to have access to additional protein sources, like turtles and alligator. The consumption of fish in the Purus communities was supplemented with game meat. In both cases, the observed dietary patterns appear to reflect both, the isolation of the communities from the major urban centers and the better preservation of local environments. The legislation governing the two protected areas (BR Rio Trombetas and Piagaçu-Purus Sustainable Development Reserve) prohibits the commercialization of their natural resources, which may contribute to the preservation of abundant fish and game resources.

In contrast, the communities of the third study area (lower Amazon) rarely consume game, which probably reflects the depletion of this resource within the study area, which is located near several urban centers, including the city of Santarem. Forests in this region were cleared initially for the cultivation of cocoa (*Theobroma cacao*) in the beginning the nineteenth century, followed by jute (*Corchorus capsularis*) in the twentieth century, and more recently, cattle ranching (Goulding et al. 1996, Castro 2002, Harris 2011). Fish stocks, nevertheless, appear that have been less affected, and this resource still underpins the subsistence of local communities. In this context, effective local fishing agreements may be essential to the subsistence security of local communities, and may require government intervention in order to ensure the sustainability of fish stocks (McGrath et al. 1993).

The present study indicates that consumption rates of natural resources may be used as a reliable indicator of their availability and, of the conservation level of local ecosystems (Hilton-Taylor 2000, Robinson and Bennett 2000, von Halle 2002). In a review of 25 studies involving 41 communities from the Brazilian Amazon basin, Isaac and Almeida (2011) found that the populations located on nutrient-rich whitewater rivers tended to consume larger quantities of fish than those living on clear-or blackwater rivers, which are considered to be less productive (Sioli 1968, Henderson and Crampton 1997).

In addition to providing a measure of the abundance of resources, dietary data could be used as indices of impact, given that they tend to reflect the abundance and diversity of the resources available in the environment. Indices of this kind can be useful for the development of public policy and social and environmental planning, which can contribute to the preservation of local biodiversity, while allowing for the sustainable exploitation of resources (Hendy et al. 1995).

The results of the present study also indicated that dietary data could provide insights into socio-economic and cultural conditions. Communities that are located closer to urban centers can participate more systematically in the local market economy, and thus depend less on natural resources, which are replaced by industrialized products, such as canned meat, even if they are still not consumed in large amounts. In the Amazon and Trombetas study areas, beef was also an alternative to fish, due to the importance of livestock in household economic strategies.

This study also confirmed that the populations analyzed have access to an adequate supply of animal protein, which contributes to their physical health and social welfare. The communities associated with protected areas maintain a more traditional a diverse diet, which can ensure the food security of these populations. In particular, these areas provide access to more abundant game populations, which have been depleted in the Lower Amazon region. Bodmer (1995) observed that game animals harvested in conservation areas tended to be relatively large, and thus provided a larger quantity of consumable protein than those hunted in unprotected areas, guaranteeing a more optimal extraction of the resource. Almeida et al. (2006) recorded higher fishery productivity in lakes with fishing agreements than in those with no regulations. Furthermore, the management of tambaqui (*Colossoma macropomum*) and pirarucu (*Arapaima gigas*) stocks in lakes of the Brazilian Mamirauá Sustainable Reserve, led to an increase in their populations (Viana et al. 2004, 2007, Silvano et al. 2009). This type of reserve permits the exploitation of natural resources by local populations, based on the establishment of an integrated management plan involving local communities and government agencies.

The considerable distances between some communities in the Amazon basin tend to affect not only the isolation and protection of natural resources, but also the economy of local populations and their access to public services. Since more isolated regions are subject to higher transportation costs for the use of urban goods and services (Parry et al. 2009), the maintenance of natural resources is not only beneficial to the environment, but also contributes to the food security of local communities.

Ultimately, the importance of fish on the diets of the communities in all three studied areas underscores the need for the implementation of public policies and management measures that ensure the long-term availability of this resource. Clearly, any reduction in the supply of fish would have profoundly negative effects on the health and food security of local populations, and severe long-term consequences.

CONCLUSIONS

Fish is the most important animal protein source of the riverine inhabitants of the Brazilian Amazon and may help ensure the health and food security of these populations. Fish consumption rates are among the highest in the world. The consumption of game meat is higher in better conserved regions and in more isolated communities. Studies of the abundance and diversity of animal protein sources and consumption rates can be used as a reliable criterion for the planning of conservation and management initiatives.

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RESUMO

O presente estudo analisou e comparou o consumo diário de alimentos de origem animal em onze comunidades dos rios do Baixo Amazonas, Trombetas, e Purus, representando três diferentes sistemas de manejo e níveis de conservação na Amazônia brasileira. Todos os alimentos de origem animal foram pesados em pelo menos 10% das famílias das comunidades estudadas, durante uma semana em cada período do ciclo hidrológico, entre 2006 e 2008. O peixe foi o alimento mais importante, sendo consumido seis dias por semana, com uma taxa média de 169 kg.pessoa^{-1}.ano^{-1}. Carne de caça foi o segundo alimento em importância, com 37 kg.pessoa^{-1}.ano^{-1}. A taxa anual de consumo de peixe é uma das mais altas do mundo e é quase o dobro do mínimo recomendado pela Organização Mundial da Saúde. Os padrões alimentares refletem ambos o isolamento das comunidades dos grandes centros urbanos e a melhor preservação dos ambientes locais em função da existência de áreas protegidas. A degradação ambiental pode assim ter efeitos sobre a saúde e segurança alimentar das populações locais. Este estudo

enfatiza a necessidade da implementação de políticas públicas e iniciativas de manejo participativo.

Palavras-chave: pescado, carne de caça, manejo, desmatamento.

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APPENDIX

Average conversion factor used to estimate protein and calories contents in 100 g of food. Adapted from Vasconcellos et al. (1991), Aguiar (1996), IBGE (1999), and NEPA (2006).

	Protein (g)	**Calories (Kcal)**
Poultry	18.57	188.00
Pork	18.57	259.43
Beef	21.28	210.67
Game Meet	18.89	108.47
Turtle	20.30	96.32
Chicken Eggs	12.95	153.00
Turtle Eggs	16.40	210.40
Alligator	22.34	99.81
Fish	19.04	167.00