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# Biodiversity, food consumption and ecological niche dimension: a study case of the riverine populations from the Rio Negro, Amazonia, Brazil

**Andréa Leme da Silva · Alpina Begossi**

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**Abstract** In this study we perform an ecological analysis of the resources use in the diet of the *ribeirinho* populations of the Barcelos municipality, Rio Negro, Amazonas, Brazil. Data on food composition, seasonality, and origin took place during three field trips between 1999 and 2000. Data were gathered based on structured interviews and observations from a total of 320 meals of 114 randomly selected families and 164 fishing trips. The staple food of the studied populations is based on fish and manioc, although the food niche amplitude can vary according to the factors such as the access to imported food items, resources seasonality, and socio-economic conditions. The migration to urban centers along with the changes in subsistence activities (reduction of small-scale agriculture and specialization in commercial fishing) may result in changes in the food habits of *ribeirinho* populations from Rio Negro.

**Keywords** Amazonia · Diet · Fishing · *Ribeirinho* · Rio Negro

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A. L. da Silva
Department of Ecology, Universidade Estadual Júlio Mesquita Filho, Rio Claro, SP, Brazil

A. L. da Silva (✉)
Rua Madalena Barbosa Ferreira, 281, Campinas, SP 13096-430, Brazil
e-mail: andreale@unicamp.br

A. Begossi
Fisheries and Food Institute, Rua Coronel Quirino, 1636, Campinas, SP 13025-002, Brazil
e-mail: alpinab@uol.com.br

A. Begossi
Fisheries Management and Training Program, CAPESCA-PREAC-UNICAMP, Campinas, Brazil

## 1 Introduction

Ecological concepts applied to human populations have been used as a tool to understand their interaction with environment (Hardesty 1975). The analysis of human diet using ecological concepts such as diversity and niche can reflect aspects of spatial or temporal use of resources by a given population (Hanazaki and Begossi 2000). The niche breadth can be estimate by diversity indices (such as Shannon–Wiener and Simpson) (Magurran 1988). The food niche breadth in the fishermen communities of Atlantic Forest in the Southeastern Brazil (*caiçaras*) was studied by Begossi and Richerson (1992, 1993), Begossi (1992a), Hanazaki et al. (1996), and Hanazaki and Begossi (2000, 2003).

Contemporary research on food consumption among indigenous peasants, also called *caboclos* or *ribeirinhos* (Moran 1974, 1991; Parker 1985, for a recent debate see Adams et al. 2006), have identified several patterns which may be generalized to the whole region: heavy dependence on regional staple food items (e.g., manioc and fish); increasing dependence on commercial and/or imported products; high protein consumption relative to calories; high seasonal variety of secondary food items; and the possible appearance of an epidemic pattern, characterized by the overlap of moderate states of malnutrition and chronic diseases related to changes in food habit and activity level (e.g., obesity and diabetes, among others) (Adams 2002; Adams et al. 2005; Giugliano et al. 1981, 1984; Murrieta and Dufour 2004; Murrieta et al. 1999, 2004; Murrieta 1998, 1999; Rocha et al. 1993; Silva et al. 2006). Additional factors have influenced food consumption patterns over the last three decades in Amazonia, including the explosive growth of urban areas promoted at least partially by the decline of traditional subsistence activities such as extraction of forest products (e.g., rubber, gums, and fibers) and shifting cultivation (manioc), as well as by the intensification of commercial large-scale fishing and logging elsewhere (McGrath et al. 1993; Padoch et al. 1999).

Our study[1] intends to provide descriptive data analyzing the food consumption of a little known population settled in the blackwater ecosystems, which presents poor nutritional conditions differing from those found in other regions of Amazon (Moran 1991, 1993). We compare dietary patterns of consumption of riverine populations, taking into consideration the composition, origin, diversification, and seasonal variations on diet, using diversity indices to evaluate food resource utilization. As a contribution of resources use to the knowledge of local subsistence patterns, we address the following questions:

(a) Which factors account for differences on diet of the studied population (urban vs. rural, socioeconomic differences, seasonality, etc.)?
(b) How do people use the fish and game resources (including fish activities and consumption)?
(c) Is the abundance of fish mentioned by people related to the availability of fishing data? For example, do people consume fish according to its availability in the environment, or is the fishery directed to some preferred species?
(d) Which strategies of resources use can be considered in management?

[1] This study is derived from a doctoral research project carried out by the first author in the municipality of Barcelos (Rio Negro), which includes an analysis of the use of natural resources among *ribeirinho* populations (Silva 2003).

## 2 Study site and inhabitants

### 2.1 Study area

The Rio Negro is the most significant blackwater contributor to the Amazon system, which extends from the Colombian lowlands in the west to the Venezuelan portions of the Guiana Shields in the east. As catchment areas, the blackwater rivers in Brazil have the Tertiary shields of Guiana and central Brazil, which are among the oldest geological formations on Earth (Sioli 1985). The blackwater ecosystems of Central Amazonia are renowned for their oligotrophic (nutrient poor) status and lesser productivity of terrestrial, aquatic and human ecosystems (German 2004). The primary sources of biomass for these aquatic systems arise mostly from riparian forest (Goulding 1980; Goulding et al. 1988).

The level of water in the Rio Negro basin fluctuates significantly with the seasonality of rain, and it rises approximately 10–11 m per year. The annual temperature averages approximately 26°C, and the rainfall ranges from 2,500 to 3,000 mm per year (IBGE 1995). There are two major seasons: the dry season (*verão*) and the rainy season (*inverno*). The former extends from September to February and the latter from March to August.

### 2.2 Population

This study was carried out in the municipality of Barcelos, Rio Negro, Amazonas State, Brazil (Fig. 1), and included Barcelos proper and the rural communities of Piloto, Cumaru, and Carvoeiro, far from the city 20, 60 and 80 km, respectively. The town of Barcelos, a Carmelite mission founded in 1728, was the capital of Amazonas State from 1758 to 1791 and 1798 to 1803 (Leonardi 1999). According to Diegues (2002), Barcelos' total population of 24,121 inhabitants is split into 67% (16,168) living in its urban area and 33% (7,953) in the rural-river communities. In 1999, there were approximately 159 people living in Carvoeiro, 150 in Piloto and 72 in Cumaru.

The residents of the research sites include indigenous and non-indigenous populations (*Caboclos*). Most indigenous descendents were born within the Basin and descend from

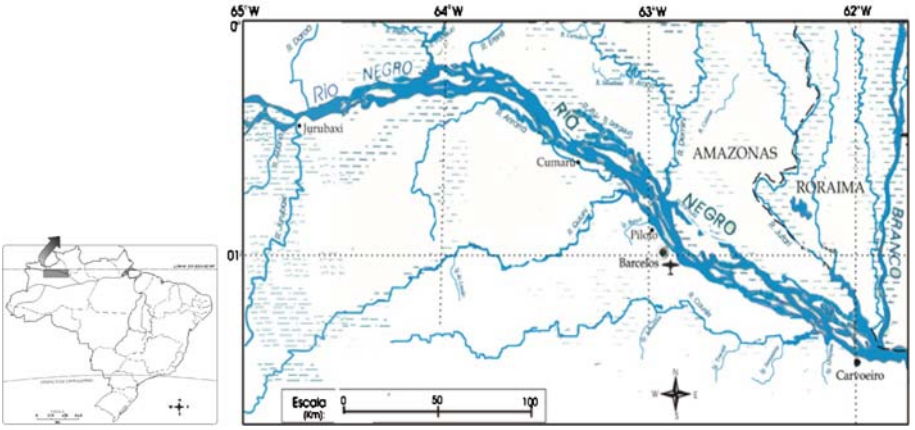


**Fig. 1** Study area

Tukano oriental (Tukano, Piratapuia, and Desana groups) and Aruak (Baniwa, Bare and Tariana groups) speaking societies (Ribeiro 1995). Eighty-two percent of the interviewed are native or migrated to these areas from close municipalities, including the Upper Rio Negro (Santa Isabel do Rio Negro and São Gabriel da Cachoeira) and Rio Negro tributaries (e.g., Padauiri, Preto, and Aracá rivers, among others). A relative strong internal migration and rural exodus have been observed during the last twenty-years (Silva 2003). Factors such as the decline of extractive activities, along with the wish for access to formal education, jobs and health care have led many rural inhabitants to migrate to urban centres (Leonardi 1999; Oliveira 1995).

*Ribeirinhos* from Rio Negro live along the river and have a livelihood based on multiple subsistence strategies which focuses especially upon commercial, artisanal, and ornamental fishing, seasonal hunting, slash-and-burn agriculture, extractive activities, such as *piaçaba* (*Leopoldina piassaba*) and Brazil nuts (*Bertolletia excelsa*), and more recently tourism-related activities (Emperaire 2000; Chao et al. 2001). The social and economic relations based on colonial heritage of patronage system (*aviamento*) (Santos 1980) still predominate for several extractive products in the Rio Negro basin (Meira 1994; Emperaire 2000). At the Barcelos town, fishing is the main economic activity, including targeting small fish species for aquarium trade (ornamental fisheries), as well as fishes to be sold in the city's market and other Amazon cities as food (Silva 2003; Silva and Begossi 2004). The large fishes such as *tucunarés* (peacock bass) (*Cichla* spp.), *carás* (Cichlidae, several species), and large catfishes are commercialised in huge urban centres, such as Manaus and São Gabriel da Cachoeira.

Interviewees were on an average 43 years old and 40% were illiterate. The average of persons per family is 6.5. Most men are full-time fishers in Barcelos (42%) and small agriculturalists in Carvoeiro, Cumaru, and Piloto (53%). About 54% of women from rural areas work in agriculture, while housekeeping consists on the main occupation (57%) of women in Barcelos (Silva 2003). Wage-based activities, which have been increasingly incorporated into the household economy, include mostly teachers, governmental employees, and retirees.

### 2.3 Methods

Dietary data were collected through interviews based on questionnaires using the method of 24-h recall method and observations (Lieberman 1986; Dufour and Teufel 1995). Sixty-seven interviews were performed during January–September 1999, including 41 interviewees in the urban area (26 men and 15 women) and 26 interviewees in the rural area (14 men and 12 women). Moreover, 40 households in the town of Barcelos and 10 households in the rural community of Carvoeiro were selected at random, and observed for food consumption through the entire day. Observations on food consumption were performed in the dry season (from September to December 2000) and in the rainy season (from March to June 2000), following Bayley (1982), Bernard et al. (1984), and Bernard (1994). The first author (ALS) performed the interviews and observations. To avoid influencing the meal of the day, the families to be studied were not informed prior to the research visit.

Samples of fishing trips, including species caught, were taken with fishermen, and fish species were collected for identification. G. M. dos Santos and J. A. S. Zuanon identified collected species, which are deposited in the Central Fish Collection of INPA (National Institute of Amazonian Research). Consulted literature included Goulding et al. (1988) and Ferreira et al. (1998). Birds and mammals were identified through field guides and

geographic distribution maps (Sick 1985; Emmons 1990). E. Z. F. Setz (State University of Campinas, São Paulo) revised the identified species of mammals.

Diversity indices (Shannon–Wiener Index), species evenness, and richness curves were assessed through the number of citations/observations per food item on meals. The calculation of the Shannon–Wiener index was made through the formula $H' = -\Sigma\, p_i \log p_i$ (base e), with $p_i$ as the proportional abundance of the $i$th species and $n_i$ is the number of individuals for the $i$th species (Magurran 1988), following earlier studies with other resources used (Begossi and Richerson 1993). Statistical comparisons of the Shannon–Wiener index were made through the $t$-test, where $N$ = number of quotations and $S$ = number of species (richness). The relationships between fish species caught and consumed were assessed using the calculation of a Spearmańs correlation coefficient (Zar 1996). The rarefaction curves allow us to compare the diversity of items used by different populations with different sample sizes (Begossi 1996). For the rarefaction method, rarefied sub-samples of individuals are taken at random of total. The formula given by Magurran (1988) is: $E(S) = \Sigma\, \{1 - [N_n - p_i/(N)]\}$, where $E(S)$ = expected number of species; $n$ = standardized sample size; $N$ = total number of individuals recorded in the sample to be rarefied; and $p_i$ = the number of individuals in the $i$th species in the sample to be rarefied.

## 3 Results and discussion

### 3.1 Fishing activities and gear

Data from 164 fishing trips were gathered, corresponding to 8.695 kg of fish caught. Fishing trips are performed by one to groups of 2–12 fishermen, with motorboats and paddled canoes, lasting 3 h to 1 week. The artisanal fishing is characterized by multispecificity and diverse technologies used. Most fishes are caught in the flooded forest with *zagaia* (a type of trident) and gill net (*malhadeira*) during the dry season, while *espinhel* (long line with several medium-size bated hooks) consists on predominant technology during the rainy season (Silva and Begossi 2004). Lure include fish, peaces of meat, shrimps, and several fruits and invertebrates (e.g., grasshoppers, spiders, and earthworm called *daracubi*) collected in the flooded forest. Silvano et al. (2007) brings further details on local knowledge of fruits and animals consumed by fishes from Rio Negro, which are also used as baits.

Fishing is both for subsistence and commerce. About 78% (out of 162) of fishermen reported that they had been fish a week or less prior to being interviewed. At Barcelos, about 53% of total caught fish was sold and 47% was consumed. Fishing is a subsistence activity at Carvoeiro village, since around 90% of fish is destined to consumption, excepting chelonians and dry *pirarucu* (*Arapaima gigas*), which are sold for boats or at Barcelos' market. The average catch per trip was 65 kg and 10 kg among urban and rural fishers, respectively. Fishing occurs in the riverbanks and flooded forest from the Rio Negro and its tributaries such as Demene, Caurés, Padauiri, and Quiuini rivers, which are also productive for chelonians and game.

### 3.2 Rio Negro fishes: diversity, abundance, and consumption

The diet of the studied populations (Barcelos, Carvoeiro, Piloto and Cumaru) is based primarily on fish and manioc products (Table 1). The meals are divided into two main

**Table 1** Most frequently consumed food items in the Rio Negro, Amazonas, Brazil ($n = 1{,}576$ records; food items present in at least 1% of meals)

| Food item (source) | Rural[a] | Barcelos | Total | Percentage of records in which item reported |
|---|---|---|---|---|
| Animal protein sources | | | | |
| Fish (local) | 110 | 163 | 273 | 17.32 |
| Game meat (local) | 19 | 40 | 59 | 3.74 |
| Frozen chicken (imported) | | 50 | 50 | 3.17 |
| Dairy products (imported) | 5 | 29 | 34 | 2.16 |
| Chelonians (local) | 2 | 20 | 22 | 1.40 |
| Sausage (imported) | | 12 | 12 | 0.76 |
| Chicken eggs (imported) | 1 | 9 | 10 | 0.63 |
| Chelonian eggs (local) | | 8 | 8 | 0.51 |
| Dry meat (jerky) (imported) | 3 | 3 | 6 | 0.38 |
| Cattle meat (imported) | 2 | 3 | 5 | 0.31 |
| Domestic pig (local) | 3 | | 3 | 0.19 |
| Carbohydrate sources | | | | |
| Manioc derivatives (local) | 110 | 262 | 372 | 23.60 |
| Rice (imported) | 25 | 121 | 146 | 9.26 |
| Bread (imported) | 7 | 78 | 85 | 5.39 |
| Coffee (imported) | 17 | 95 | 112 | 5.20 |
| Beans (imported) | 9 | 51 | 60 | 3.81 |
| Pasta (imported) | 4 | 29 | 33 | 2.09 |
| Biscuits (imported) | 5 | 8 | 13 | 0.82 |
| Others[b] | – | 31 | 31 | |
| Fruits (local) | | | | |
| Açaí (*Euterpe* spp.) | 10 | 22 | 32 | 2.03 |
| Banana (*Musa* spp.) | – | 26 | 26 | 1.65 |
| Mango (*Mangifera indica*) | 11 | 10 | 21 | 1.33 |
| Cashew (*Anacardium* sp.) | 2 | 16 | 18 | 1.14 |
| Bacaba (*Oenocarpus* sp.) | 3 | 14 | 17 | 1.08 |
| Brazil nuts (*B. excelsa*) | 7 | 9 | 16 | 1.02 |
| Pineapple (*Annanas* spp.) | 2 | 12 | 14 | 0.89 |
| Ingá (*Inga* spp.) | | 12 | 12 | 0.76 |
| Other fruits | 19 | 52 | 71 | 4.51 |
| Vegetables[c] (local and imported) | | 13 | 13 | 0.82 |
| *N* meals | 88 | 232 | 320 | |

[a] Carvoeiro, Piloto and Cumaru; [b]Margarine, powdered beverages, soft drinks, corn chips, powdered cocoa, mayonnaise, oatmeal, cornmeal cake, and popcorn; [c]Yam, potatoes, tomatoes, etc.

meals (lunch and dinner) and a number of secondary meals. Morning meals and *merendas* contain similar food items, usually consisting of coffee, manioc products and fruits (breakfast and *merendas*). The *merendas* (snacks) are usually taken at intervals between lunch and dinner.

About 80 species of consumed fish were collected and identified at the studied populations. Fish account for 70% of the protein item consumed at the main meal. Animal

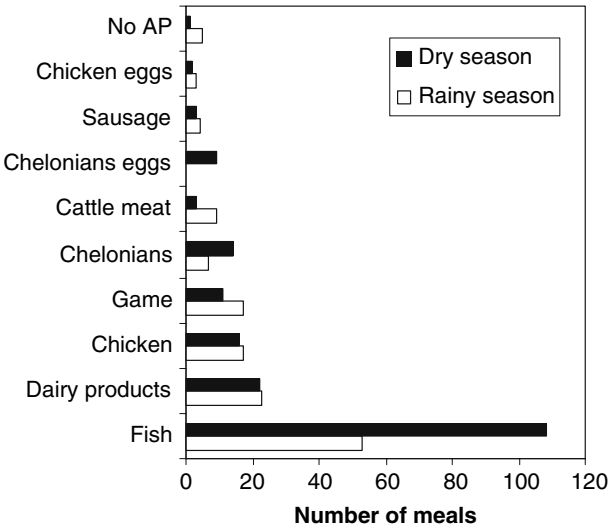


**Fig. 2** Seasonality of animal protein (AP) consumed at observed main meals ($n = 194$). Items present in at least 1% of meals

protein was not consumed only in 4% of meals (see Fig. 2). A correlation is observed for fish species mentioned as abundant (interviews) and consumed ($r = 0.67$, $n = 44$, $p < 0.05$).

Comparing the most captured fish and chelonians species with the most widely consumed ones, we can identify frequently captured species are part of the diet. We found a remarkable relationship between caught and consumed fish during the year (Spearman $r = 0.835$, $p < 0.001$), and between seasons ($r_{s\ \text{Dry season}} = 0.8580$, $p < 0.001$; $r_{s\ \text{Rainy season}} = 0.6816$, $p < 0.001$).

### 3.3 Fish preferences and taboos

Fishes cited as common and consumed by the interviewees include *tucunarés* and *carás* (Cichlidae), *aracus* (Anostomidae), *piranhas* and *pacus* (Serrasalmidae), and catfishes (Pimelodidae), including *surubim* and *pirarara* (Tables 2 and 3). We found a slightly correlation between fish cited as common and preferred for consumption ($r_s = 0.58$, $p > 0.05$). Factors others than abundance, such as coloration, consistency, flavor, smell, density (mostly the fat quantity), appearance (presence of blood, scale and teeth), and animal behavior (diet), are criteria chosen for the preference of some fish species.

Fish is consumed fresh, smoked (*moqueado*) or after being dried in the sun. Preferred fish for consumption (cited in more than 50% of interviews) are *pacu* (*Metynnis* spp., *Myleus* spp.) and *aracu* (*Leporinus* spp.). About 20% of the interviewees declared not food preferences with regard to the fish species. Tabooed species, locally called *reimoso*, include piranha (*Serrasalmus* spp.) and surubim (*Pseudoplatystoma fasciatum*). *Reimoso* is a food prohibited for consumption during illness, and for women in puerperium and menstruation (Begossi and Braga 1992; Begossi et al. 1999, 2004). Fish recommended to be eaten by ill persons are pacu, aracu, cará (several Cichlidae species, such as *Uaru* spp., *Heros* sp., *Satanoperca lilith*), and trahira (*Hoplias malabaricus*). Rays, electric fish, aruanã (*Osteoglossum* spp.), and jacundá (*Creinicichla cf. lenticulata*) are not eaten or not so appreciated.

**Table 2** Fish and chelonians caught on at least five fishing trips

| Local name | Scientific name | Number of fishing trips |
|---|---|---|
| Aracu | *Leporinus* spp. | 128 |
| Tucunaré | *Cichla* spp. | 101 |
| Piranha | *Serrasalmus* spp., *Prystobrycon* sp. | 67 |
| Pacu-galo | *Prosomyleus schomburgki* | 45 |
| Traíra | *Hoplias malabaricus* | 42 |
| Cará-baru, bararuá | *Uaru amphiacanthoides* | 28 |
| Aruanã | *Osteoglossum ferreirai* | 27 |
| Carauaçu, cará-pirarucu | *Astronotus cassiprinis* | 25 |
| Filhote | *Brachyplatystoma filamentosum* | 21 |
| Surubim | *Pseudoplatystoma fasciatum* | 19 |
| Cará-bicudo, cará-preto | *Satanoperca lilith* | 16 |
| Pirarara | *Phractocephalus hemioliopterus* | 16 |
| Pacu-branco | *Metynnis* sp. | 15 |
| Cabeçudo | *Peltocephalus dumerilianus* | 14 |
| Tartaruga | *Podocnemis expansa* | 14 |
| Cará-azulão, cará-papagaio | *Hoplarchus psittacus* | 13 |
| Araripirá | *Chalceus macrolepidotus* | 13 |
| Barba-chata | *Pirinampus pirinampu* | 13 |
| Irapuca | *Podocnemis erythrocephala* | 13 |
| Cará-peneira | *Heros* sp. | 12 |
| Mandubé | *Ageneiosus* spp. | 10 |
| Matrinxã | *Brycon* spp. | 9 |
| Pescada | *Plagioscion* spp., *Pachyurus* spp. | 8 |
| Pacu-tiuí | *Tometes* sp. | 7 |
| Pacu-riscado, boala | *Myleus schomburky* | 6 |
| Anujá | *Parauchnepilens* sp. | 6 |
| Jaraqui | *Semaprochilodus* spp. | 6 |
| Pirandira | *Hydrolycus* spp. | 6 |
| Jacundá | *Crenicichla* spp. | 5 |
| Mandi | *Pimelodus* spp. | 5 |
| Fishing trips | | 164 |
| Number of species | | 81 |

### 3.4 Food resources seasonality

The availability of natural resources changes according to the dynamics of the river waters within the Amazonian ecosystem (Moran 1993; Padoch et al. 1999). Consequently, we expect to find a higher availability and consumption of fish in the dry season and game animals when compared to the rainy season (Smith 1981; Moran 1991). In fact, we found the total consumption of fish from our results to be 20% less in the rainy season when compared to the dry season (see Fig. 2). Most consumed fish species in the rainy season are *pacus* (*Myleus* spp., *Metynnis* sp.) and *aracus* (*Leporinus* spp.), while *tucunaré* (*Cichla* spp.) is the species of fish most consumed in the dry season, representing 18% of the total fish consumed by the households surveyed.

**Table 3** Fishes, chelonians and game animals consumed by families from Rio Negro, AM (included animals present on at least in five meals)

| Local name | Scientific name | Number of meals |
|---|---|---|
| Pacu | *Myleus* spp., *Metynnis* spp., *Tometes* sp. | 73 |
| Piranha | *Serrasalmus* spp., *Prystobrycon striolatus* | 37 |
| Aracu | *Leporinus* spp. | 35 |
| Tucunaré | *Cichla* spp. | 28 |
| Filhote | *Brachyplatystoma filamentosum* | 19 |
| Pirarara | *Phractocephalus hemioliopterus* | 18 |
| Traíra | *Hoplias malabaricus* | 18 |
| Cabeçudo | *Peltocephalus dumerilianus* | 17 |
| Paca | *Agouti paca* | 17 |
| Cará | *Hoplarchus psittacus, Satanoperca lilith*, *Uaru* spp., *Heros* sp. | 16 |
| Aruanã | *Osteoglossum* spp. | 14 |
| Tartaruga | *Podocnemis expansa* | 13 |
| Irapuca | *Podocnemis erythrocephala* | 11 |
| Anta | *Tapirus terrestres* | 11 |
| Peixe-boi | *Trichechis inunguis* | 9 |
| Matrinxã | *Brycon cephalus* | 8 |
| Queixada | *Tayassu pecari* | 7 |
| Pirandira | *Hydrolychus* spp. | 7 |
| Surubim | *Pseudoplatystoma fasciatum* | 7 |
| Araripirá | *Chalceus macrolepidotus* | 5 |
| Barba-chata, barbado | *Pirinampus pirinampu* | 5 |
| Jaraqui | *Semaprochilodus* spp. | 5 |
| Total items | | 355 |
| Total meals | | 320 |
| Number of food items | | 63 |

Aquatic turtles represent another important seasonal source of protein for these populations. After turtles spawn on the sandy beaches of the Rio Negro and its tributaries, fishermen harvest adult animals and chelonian eggs for consumption and trade. Amazonian populations appreciate such eggs as a delicacy since they diversify the diet, otherwise composed of fish (Rebêlo and Pezzuti 2000). The *irapuca* (*Podocnemis erythrocephala*), *tartaruga* (*Podocnemis expansa*) and *tracajá* (*P. unifilis*) are consumed especially in the dry season, while the *cabeçudo* (*Peltocephalus dumerilianus*) is more frequently available during the beginning and end of the rainy season. Other references to chelonian consumption among Rio Negro populations may be found in Pezzuti (2004).

Fishes and chelonians accounted for 36 species consumed in the dry season, against 22 species consumed in the rainy season. In this period, other protein items, such as game and imported protein such as canned meat, beef, and chicken, replace fish consumption. Common consumed game animals include terrestrial mammals such as peccaries (*Tayassu* spp.), paca (*Agouti paca*), and tapir (*Tapirus terrestris*) (Table 3). Less frequently recorded species include deer (*Mazama* spp.), small rodents (*Dasyprocta* sp., *Sciurus* sp.), monkeys (*Alouata* sp., *Cebus* spp.), and birds (*Chairina moschata*, *Crax* spp., *Mitu* spp., *Amazonas* spp.). Seasonal fruits rich in calories and protein content, such as nuts and palm fruits, can

**Table 4** Number and percentage of food items origin in the studied population

| Food source | Barcelos | | Rural communities[a] | |
|---|---|---|---|---|
| | *N* | % | *N* | % |
| Purchase | 606 | 65.1 | 93 | 31.2 |
| Cultivation | 107 | 11.5 | 101 | 33.9 |
| Fishing | 82 | 8.8 | 46 | 15.4 |
| Hunting | 15 | 1.6 | 8 | 2.7 |
| Gathering | 71 | 7.6 | 16 | 5.4 |
| Gift | 35 | 3.8 | 22 | 7.4 |
| Livestock | – | – | 3 | 1.0 |
| Other[b] | 5 | 0.5 | 3 | 1.0 |
| Undefined | 10 | 1.1 | 6 | 2.0 |
| Total | 931 | 100 | 298 | 100 |

[a] Carvoeiro, Piloto and Cumaru; [b]Include internal trade and borrowing

also replace meat during the fish scarcity. For example, *açaí´* (*Euterpe* spp.) is recorded among 52% of the meals consumed during the rainy season as compared to 12% of the meals during the dry season. Similarly, Brazil nuts (*Bertolletia excelsa*) are recorded in 33% of the meals consumed during the rainy season.

### 3.5 The source of dietary items

Table 4 profiles the origins of 1,229 food items the majority of which are obtained through purchase, cultivation, gathering, fishing, hunting, and gifts. Purchase is the most important source, with residents of the town of Barcelos accounting for 65% of total items consumed Dufour (1992), contrasting with 31% in the three rural communities studied (Carvoeiro, Piloto and Cumaru). Increased consumption of market and imported products among urban populations can be understood, at least partially, as a consequence of the changes in economic activities over time, coupled with increased access to consumer markets. The displacement of agricultural subsistence activities by commercial fishing has increased the acquisitiveness of urban households, while at the same time diminishing and nearly eliminating the local production of manioc flour. Furthermore, the purchase of imported food products is dependent on proximity to urban areas and on access to cash.

Cultivation, a primarily female activity, is the second most important food source. Plants cultivated in swidden-plots (*roças*) include manioc, pineapple, banana, sugarcane, *cupuaçu*, and potatoes. About twelve sub-products from different varieties of sweet and bitter manioc (*Manihot esculenta*) are processed for informants. Women also cultivate vegetables at homegardens (*quintais*), such as salad greens, herbs, and other vegetables, which are added to the main dishes (e.g., meat, beans, rice) in order to improve and diversify their taste.

In addition to the cultivation, gathering of fruits, chelonian eggs, honey, and other products, is used to complement meals and these items can also be eaten as snacks. Men and children dedicate themselves to gathering nuts and palms from non-flooded forest (*floresta de terra-firme*). For further details on plants knowledge and use in the Rio Negro see Silva et al. 2007.

As shown in Table 4, 33% of food items consumed are obtained through cultivation in rural households, contrasting with only 11% of urban consumers. Rural consumers show higher autonomy in the production of staple food items, including manioc flour, while urban consumers are more dependent on imported manioc and other market food products. About 70% of the manioc flour that supplies Barcelos comes from Manaus and the rural communities of the Negro, Quiuini and Unini rivers.

Fishing and hunting, which are primarily male activities, play a significant role in the diet of these populations; the latter displays a higher frequency of consumption among rural households (18%) in comparison with urban ones (9.4%). The higher consumption of imported protein items purchased from Manaus (e.g., chicken, beef), which are transported to cities from Rio Negro by boat (*recreios*), coupled with the more frequent purchase of fish and game explains the lower percentage of food items obtained by fishing at Barcelos town.

Trade, borrowing, and other food sources are used opportunistically, including in emergency situations such as food scarcity. Domestic livestock provides a limited production of meat, since the inhabitants of the studied villages raise few domestic animals to meet dietary requirements. Some families own a limited number of pigs and chicken, although most of them are brought from urban (Manaus) or rural areas nearby and consumed within a short period of time.

Gifts such as fish, game, manioc, and fruits are a more common source of food in rural households (7.4%) than in urban ones (3.8%). Families usually distribute surplus game and fish among the households of relatives, *compadres* (godparents), and close friends. According to Murrieta (1998), such reciprocity nets are associated with the social dynamics of the *Amazonian* societies. The cooperative character of these exchange systems plays an important maintenance role for subsistence system stability under seasonal variations, helping to guarantee a measure of food security in unexpected situations.

### 3.6 The amplitude of the food niche on diet

Consumption of imported items was more frequent in urban households (Table 5 and Fig. 3). Industrialized and imported animal protein (e.g. sausage, cattle meat, frozen chicken, dairy products, especially powdered milk) products account for 134 items consumed among urban households against 13 items among rural ones (Table 2). Consumption of beef is uncommon, being relatively expensive; in Barcelos it sold for USD 5 per kg in 1999, as compared to fish (USD 0.5–1.0 per kg), chicken (USD 0.9 per kg), and game animals (USS 1.2 per kg).

Carbohydrate imported sources such as rice, beans and wheat derivatives (e.g., pasta, bread, and biscuits) accounted for 287 records in urban families, contrasting with only 50 records in the rural households (Table 2). Although not quantified on meals, sugar and cooking oil are largely employed in the preparation of meals. Large quantities of sugar are consumed with coffee, fruit juices and desserts, while cooking oil is mainly used to prepare fried and boiled fish. Other processed food items, especially pastas, are predominantly consumed on weekend meals and special occasions. The low values observed for the consumption of beans contrasted sharply with the emphasis placed on this food item by rural households during interviews.

Concerning to interhousehold variations, we observed a higher consumption of imported protein items (e.g., chicken, cattle meat, milk) and non-protein items occurred among families with higher income, such as commerce and wood-logging (families 19, 21,

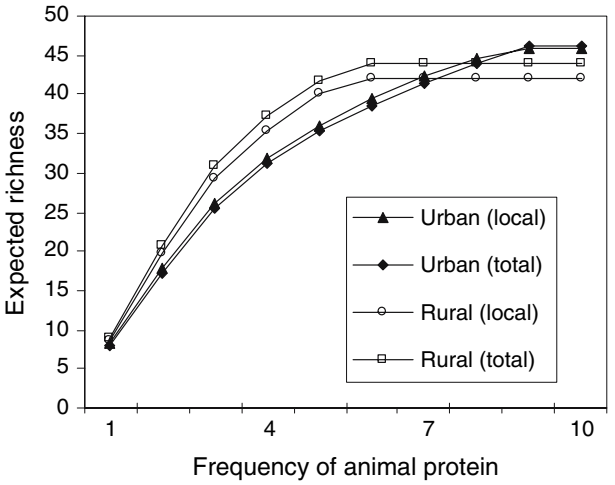


**Fig. 3** Rarefaction curves for animal protein locally produced (local) and imported items (total). Samples of 193 meals in urban households (Barcelos) and 127 in rural households (Carvoeiro, Piloto e Cumaru), including interviews and observations

**Table 5** Animal protein diversity of consumed items, including interviews and observations (Rural = Carvoeiro, Piloto, and Cumaru; Shannon–Wiener diversity indices on the base e)

| Local | Barcelos | Rural |
|---|---|---|
| Local protein | | |
| Richness | 46[a] | 40[a] |
| H′ (evenness)[c] | 3.30 (3.82) | 3.40 (3.68) |
| Local + imported protein | | |
| Richness | 52[b] | 44[b] |
| H′ (evenness) | 3.27 (3.95) | 3.51 (3.78) |
| Number of meals | 232 | 88 |

*t* tests: Differences of two diversity indices (Zar 1984, p. 146), [a]Local protein ($t = 0.28$, $p > 0.1$, df = 111), local + industrialized protein ([b]$t = 0.23$, $p < 0.1$, df = 114)

[c] Evenness = H/lnS

22 and 38) (Appendix 1). Conversely, families with lower diversity of industrialized items were fishermen-agriculturalists, who have lower acquisitive power. The larger niche (high diversity) of families 25, 36, 47, and 50 might be related to the fact that these families include full time fishermen, who have access to a higher diversity of fish when compared to fishermen-agriculturalists. Family 5 had none protein source, since a woman is the head of the household and was involved in agricultural activities at the time of this research. Moreover, retirement pensions (minimum wage) include 27% of the total number of surveyed households, which represents a particularly important source of income among households with elderly members, especially in extended families. Such income may be a strategic way to overcome environmental risks and to increase the ability to capitalize regardless of the environmental constraints, as also observed by Castro (2000) in the floodplain communities of the Middle Solimões River.

## 4 Discussion

### 4.1 Fish diversity and consumption

In the Amazon, a high diversity is known for characiform and siluriform (catfishes) fishes (Lowe-McConnel 1987). These orders also show a high diversity at Rio Negro (Goulding et al. 1988), as well as Upper Juruá (Begossi et al. 1999), Machado, Marmoré, and Guaporé rivers (Santos 1986/87), Rio Branco river in Roraima (Ferreira et al. 2007), and Guapo river in Ecuador (Ibarra and Stewart 1989). In our study, were found 81 species of consumed fish (Table 3). The consumption of high fish diversity is not surprisingly, since Rio Negro has more than 400 fish species (Goulding et al. 1988), more diverse than the ichthyofauna of other main Amazon rivers, such as Tocantins with 265 species (Santos et al. 1984), and Juruá with 115 species (Begossi et al. 1999).

Small-scale artisanal fisheries are widespread in the Amazon, providing for about 60% of total commercial fish landings and sustaining the majority of human communities (Bayley and Petrere 1989). At Rio Negro, subsistence fisheries are multi-specific, involving high diversity of species catches. Such variation occurs due to the different technologies use, which can be considered a diversification strategy (McCay 1978).

Fish account about 70% of the items consumed at main meals among studied population. The importance of fish as a main protein source has been documented for other Amazonian Caboclo societies (Adams et al. 2006; Beckerman 1993; Batista et al. 1998; Cerdeira et al. 1997; Fabré and Alonso 1998; Murrieta 1988, 1999, 2001; Murrieta and Dufour 2004; Murrieta et al. 2006), as well as Indian populations (Chernela 1985, 1989; Dufour, 1983, 1987, 1994).

Correlations between fish abundance and consumption were found among studied populations at Rio Negro. The positive correlation among fish considered as abundant and consumed, also observed among riverine inhabitants of the Extractive Reserve of the Upper Juruá, show that the perception of abundance by people might be associated with fish species that they often see and use (Begossi et al. 1999).

Several tabooed species at Rio Negro, locally called *reimoso*, have also been observed in other Brazilian fishermen, including Upper Juruá (Begossi et al. 1999), Tocantins river (Begossi and Braga 1992), and Búzios Island (Southern Brazilian coast) (Begossi 1992b) and Negro (Begossi et al. 2004). Food taboos may serve as conservation (Colding and Folke 1997). Begossi et al. (1999) stress that the use of food taboos as a role to minimize consumption is a management procedure based on a local accepted behavior.

### 4.2 Resources seasonality

Several authors have highlighted the diversity of the resource utilization as an important process of adaptability with regard to changes in Amazonian seasonality (Moran 1993; Murrieta and Dufour 2004). At Rio Negro, the coping strategies to deal with resource seasonality include higher fish and chelonian consumption during the dry season, contrasting with higher consumption of game meat and fruits collected in the forest with high energetic and protein value, such as Brazil nuts (*Bertolletia* spp.) and palm fruits (*Euterpe* spp.), in the rainy season.

Seasonal variations regarding to the captured and consumed fish species include predominate consumption of *tucunarés* and *carás* (Cichlidae) during the dry season, and *pacus* (Serrasalmidae) and aracus (*Anastomidae*) in the rainy season. The fishing

productivity is lower in the winter, when capture is more diversified, including smaller size and less valuable species, like *mandis* (several species of small catfishes). The artisanal fishing strategies along with the seasonal variations of the captured species can be considered a management practice appropriated to the tropical ecosystems, since they explores a high diversity of fishes, diluting the pressure about determined species (Silvano 2004).

### 4.3 The amplitude of the food niche on diet

In our study, variations in the food niche amplitude (diversity) among the studied families are probably associated with several factors, such as resources availability, access to market products, economic activity, trade networks, and socioeconomic differences. Particularly, the current displacement of small-scale agriculture by commercial fishing specialization at Barcelos, along with the reduced availability of agricultural land nearby the town, may contribute to a reduction in self-sufficiency of the food production among the urban families. Contact with national society and abandonment of traditional practices (e.g., agriculture, hunting and gathering) might be related to qualitative and quantitative deterioration of both diet and nutritional status observed in other Amazonian societies (Santos and Coimbra 1998).

Comparative studies regarding the fish consumption patterns of other fishing communities, such as those on the Brazilian coast and other riverbanks, show that dependence on local resources by these communities can vary according to a number of factors such as the type of economic activity, the degree of involvement with the consumer market, and the accessibility to industrialized products. For example, Hanazaki and Begossi (2000, 2003) observed a decrease in the consumption of fish associated with an increase in tourism-related activities and restrictive laws among the fishing communities from the Atlantic Forest coast of Brazil. Siqueira (1997) and Murrieta and Dufour (2004) also show variations in fish consumption among different Amazonian *Caboclos* populations of the Solimões River related with changes in economic activities and significant access to consumer markets, which not necessarily represented an improvement in the nutritional quality of these populations.

Changes in dietary patterns as a consequence of urbanization might include the addition of items rarely consumed before, food with a low nutritional quality, or even a substitution of items instead of an addition, as demonstrated by Leonard and Thomas (1988), who analyzed the changes in the food patterns of the Peruvian Andes. Fitzgerald et al. (1992) showed that within the peri-urban areas of poorer countries, greater dietary diversity contributes little to the ingestion of energy and protein and that the limited nutritional resources and knowledge may lead to consequent nutritionally inferior food choices.

## 5 Conclusions

The predominance of the basic staple foods (fish and manioc derivatives) as core dietary items among the studied populations reflects patterns of the main repertoire of other Amazonian populations (Begossi et al. 2001; Murrieta, 1998, 1999, 2001; Adams 2002, 2005). Consumption of secondary items on diet may vary according to the resources seasonality, socioeconomic conditions, trade networks (*aviamento*), and wage-based sources (e.g., retirement and public jobs).

Out-migration from rural areas to urban centres in the Rio Negro has influenced the displacement of multiple subsistence activities to a specialization in commercial fishing and harvesting-related activities of the palm fruits, which in turn increases the purchasing power and access to consumer-market products. Notwithstanding, the displacement of agriculture has reduced autonomous staple food production (e.g., manioc flour) thus promoting a higher dependency on the market economy.

Changes in food habits among different human populations arising from urbanization have positive aspects such as a diversification of the diet, and negative aspects such as a reduction in self-sufficient food production which can result in serious chronic malnutrition in developing countries (Holmes and Clark 1992; Pelto and Pelto 2000). Within the Rio Negro region, the extent of these changes at the ecological, social, and nutritional levels should be investigated in order to promote conservation in the quality of diet of the local populations.

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## Appendix

**Appendix 1** Frequency of food items consumed per family—number 41 to 50 shows rural families

| Family | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Non-animal imported items[a] | 12 | 10 | 12 | 2 | 3 | 6 | 12 | 5 | 5 | 4 | 5 | 8 | 5 | 12 | 10 | 8 | 12 | 9 | 15 | 9 | 16 | 17 | 15 | 14 | 8 |
| Local protein items | 5 | 6 | 5 | 3 | | 9 | 3 | 3 | 5 | | 2 | 5 | 6 | 4 | 7 | 7 | 4 | 3 | 5 | 8 | 7 | 7 | 6 | 1 | 11 |
| Animal imported items[b] | 3 | 3 | 1 | 1 | | 3 | 5 | 1 | 2 | 2 | 2 | 4 | 1 | 2 | | 1 | 4 | 2 | 2 | | 2 | 3 | 4 | 7 | 2 |
| Total of items | 20 | 19 | 18 | 6 | 3 | 18 | 20 | 9 | 12 | 6 | 9 | 17 | 12 | 18 | 17 | 16 | 20 | 14 | 22 | 17 | 25 | 27 | 25 | 22 | 21 |
| Number of meals | 6 | 6 | 4 | 4 | 4 | 4 | 6 | 4 | 4 | 4 | 4 | 6 | 4 | 4 | 6 | 6 | 4 | 4 | 4 | 4 | 6 | 4 | 4 | 6 | 6 |
| Protein richness | 6 | 6 | 5 | 3 | – | 8 | 6 | 3 | 4 | 2 | 3 | 5 | 3 | 5 | 6 | 6 | 6 | 4 | 6 | 7 | 7 | 8 | 6 | 3 | 9 |
| Shanon (base e) | 1.7 | 1.7 | 1.6 | 1.3 | – | 2 | 1.7 | 1.3 | 1.4 | | 1 | 1.5 | 1.1 | 1.6 | 1.7 | 1.7 | 1.7 | 1.3 | 1.7 | 1.9 | 1.9 | 2 | 1.8 | 1 | 2.1 |
| Activities | fa | fa | fa | fa | a | f | f | far | f | fa | fa | fe | fa | fe | fer | f | f | fa | fw | far | cfh | cf | fr | f | fr |

| Family | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Non-animal imported items[a] | 1 | 8 | 10 | 13 | 11 | 5 | 8 | 15 | 8 | 6 | 7 | 5 | 11 | 6 | 9 | 7 | 7 | 2 | 2 | 4 | 3 | 4 | 2 | 6 | 7 |
| Local protein items | 2 | 8 | 4 | 2 | 4 | 2 | 3 | 4 | 6 | 6 | 15 | 3 | | 4 | 5 | 8 | 8 | 5 | 6 | 3 | 6 | 10 | 7 | 10 | 11 |
| Animal imported items[b] | | 2 | 3 | 2 | | 2 | 2 | | 3 | 1 | | 3 | 6 | 4 | 5 | 2 | 1 | | | 1 | 3 | | | 2 | |
| Total of items | 3 | 18 | 17 | 17 | 15 | 9 | 13 | 19 | 17 | 13 | 22 | 11 | 17 | 14 | 19 | 17 | 16 | 7 | 8 | 8 | 12 | 14 | 9 | 18 | 18 |
| Number of meals | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 6 | 4 | 4 | 4 | 4 | 6 | 6 | 4 | 4 | 6 | 6 | 4 | 4 | 6 | 6 |
| Protein richness | 1 | 5 | 4 | 3 | 4 | 3 | 4 | 2 | 6 | 6 | 11 | 5 | 5 | 8 | 7 | 7 | 8 | 5 | 3 | 4 | 5 | 6 | 6 | 7 | 6 |
| Shanon (base e) | – | 1.6 | 1.4 | 1.1 | – | 1 | 1.3 | 0.6 | 1.7 | 1.7 | 2.3 | 1.6 | 1.6 | 2 | 1.9 | 1.9 | 2 | – | 1.1 | 1.3 | 1.6 | 1.7 | 1.7 | 1.9 | 1.8 |
| Activities | fr | far | fa | f | fa | far | fer | fr | fr | fa | far | fa | wf | fa | far | fa | far | a | f | fa | far | far | fa | far | fa |

Activities include f = fishing, a = agriculture, r = retirement, e = extractivism (açaí, Brazil nuts, piaçava), w = wood logging, h = hunting, c = commerce, t = tourism;
[a]Coffee, wheat derivatives, rice, beans, and others; [b]Milk, chicken, sausages, eggs, and cattle meat

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