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Feeding habits of giant otters *Pteronura brasiliensis* (Carnivora: Mustelidae) in the Balbina hydroelectric reservoir, Central Brazilian Amazon

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ABSTRACT. This study aimed to identify the diet of giant otters, *Pteronura brasiliensis* (Zimmermann, 1780) in the Balbina reservoir (01°55'S, 59°29'W), to compare it with literature data on the diet of giant otters from non-dammed areas, and to verify the effects of the seasonal changes in water levels on the feeding habits of Balbina otters. A total of 254 feces samples were collected and identified according to the lowest possible taxonomic level. Teleostei fish were present in 100% of the samples; two samples also presented monkey fur (n = 1) and sloth fur (n = 1), suggesting that the diet of *P. brasiliensis*, in the reservoir, is almost exclusively based on fish. Ten fish families were identified in our samples, six of which were exclusive to the Balbina Lake (not present in the diet of giant otters from non-dammed areas). These six fish families, however, were present in less than 3% of the samples. The fish families with highest representation in the diet of giant otters from non-dammed areas also appeared with higher frequencies in the Balbina Lake, suggesting that the otters have not changed their diet substantially after the implementation of the reservoir. During the high-water period, when the fish are dispersed into the flooded forest and are not very easy to catch, the otters seem to have an opportunistic feeding habit. By contrast, during the low-water period, when prey items are widely available and easier to catch in the reservoir, their feeding habits are more selective.

KEY WORDS. Amazon basin; aquatic mammal; conservation; dam; diet.

The giant otter, *Pteronura brasiliensis* (Zimmermann, 1780) (Mustelidae) is listed as an endangered species by The World Conservation Union (Iucn 2008). Among the main threats currently faced by this species are habitat degradation due to human population expansion, water contamination, theft of cubs for illegal wildlife trade, and the unregulated tourism industry (Carter & Rosas 1997, Rosas 2004, Rosas *et al.* 2008).

The construction of large hydroelectric power plants is also generally believed to represent a threat to the local fauna due to massive and indiscriminate habitat destruction (Cabral *et al.* 2008). Until recently, the construction of hydroelectric reservoirs has been considered a potential threat to giant otters, not only because dams are believed to cause population bottlenecks, but also because of the generalized environmental changes that take place after damming a river (Rosas *et al.* 1991). However, despite their environmental damage, recent studies have shown that hydroelectric reservoirs in the Amazon have the potential to sustain stable and healthy populations of giant otters if at least two conditions are met: first, the otters must have been present in the area before the construction of the dam; second, human occupation in the reservoir area must be limited (Rosas *et al.* 2007).

Feeding is one of the fundamental aspects of the ecology of a species, and the main ecological factors that determine the evolution of feeding behaviors are feeding type and the quantity and distribution of food items, among others (Staib 2005). According to Duplaix (1980) and Schweizer (1992), giant otters are opportunistic predators, catching prey according to their availability. Captive giant otters eat on average 10% of their body weight per day (Carter *et al.* 1999). If this percentage can be extrapolated to free-ranging individuals, an adult giant otter may eat up to 3kg of food (mainly fish) per day.

Even though the diet of giant otters is mainly based on fish, other prey such as crustaceans, mollusks, birds, reptiles, amphibians and small mammals may also be present (Duplaix 1980, Rosas *et al.* 1991, Rosas *et al.* 1999). Vertebrates such as anacondas under 3m long, small caimans and turtles have also been found in the diet of this otter (Kruuk 2006). However, despite there being a large amount of information on the variety of food items consumed by giant otters, there is little information on the seasonal variations in their feeding habits.

In this study, we conducted a survey of the food items present in the diet of the giant otters living in the Balbina hydroelectric reservoir, Uatumã River, with two main goals in mind: 1) to compare the diet of the giant otter population in the dam with literature data on the diet of conspecifics living in other Amazonian regions that are not impacted by the presence of hydroelectric power plants; 2) to ascertain whether otters in the reservoir feed on the same prey items throughout the year or whether their prey choices change according to prey availability throughout the hydrological cycle (low and high water).

MATERIAL AND METHODS

The study area covers approximately 450km^2, representing about 10% of of the Balbina reservoir (01°55'S, 59°29'W), which has a total area of approximately 4,438 km^2 (FUNCATE/INPE/ANEEL 2000). The reservoir is located in the central part of the state of Amazonas, municipality of Presidente Figueiredo, Brazil (Fig. 1). Field trips to the study area were carried out every two months, from 2001 to 2007, each one lasting eight to ten days. An aluminum boat with an outboard engine of 40 HP was used to inspect the river banks to locate communal latrines and other evidence of the presence of otters, which had previously been recorded and marked using GPS equipment (ROSAS *et al.* 2007). A total of 254 fecal samples were collected from giant otter communal latrines and stored in plastic bags, labeled in the field (date and geographical coordinates) and taken to the laboratory for cleaning and sorting. Each fecal sample was washed with running water in a fine-mesh sieve. After washing, the samples were placed in plastic trays and left to dry out at room temperature. Once dried, all hard structures, such as otoliths, teeth, mandibles, and fin spines, were sorted using a stereoscopic microscope (magnification = 3x), and identified to the lowest taxonomic level possible.

The data analysis was based on the frequency of occurrence (FO) of the prey categories (number of times a certain type of prey occurred in the samples in relation to the total number of samples examined, expressed as a percentage): FO = (n1 x 100)/N), where "n" is the number of times a type of prey was found and "N" is the total sample number.

For the seasonal variation analysis of the diet of the giant otters in the reservoir, we collected only fresh fecal samples (with the characteristic odor and color of recent feces) during two consecutive years (2006-2007), totaling 75 samples. This procedure was adopted to make sure that we collected only feces from each specific season. These seasonal samples were also included in the 254 fecal samples used to describe the feeding habits of the otters in the reservoir. Water level measurements from a ruler located at the Balbina dam indicated that the low-water season is from December to May and the high-water season is from June to November.

The results obtained were compared with information on the feeding habits of giant otters previously described from other areas of the Amazon and the Pantanal (19°32'S, 56°40'W) regions without hydroelectric reservoirs (SCHWEIZER 1992, SCHENCK 1999, ROSAS *et al.* 1999, STAIB 2005). A chi-square test was applied (χ^2) (p = 0.05; df = 1.0) to determine whether there was a significant difference between the frequency of prey items consumed by the otters in the dam and the frequency of prey items observed in the diet of otters from at least one other area (Xixuaú creek) in the Brazilian Amazon region with no hydroelectric influence (ROSAS *et al.* 1999).

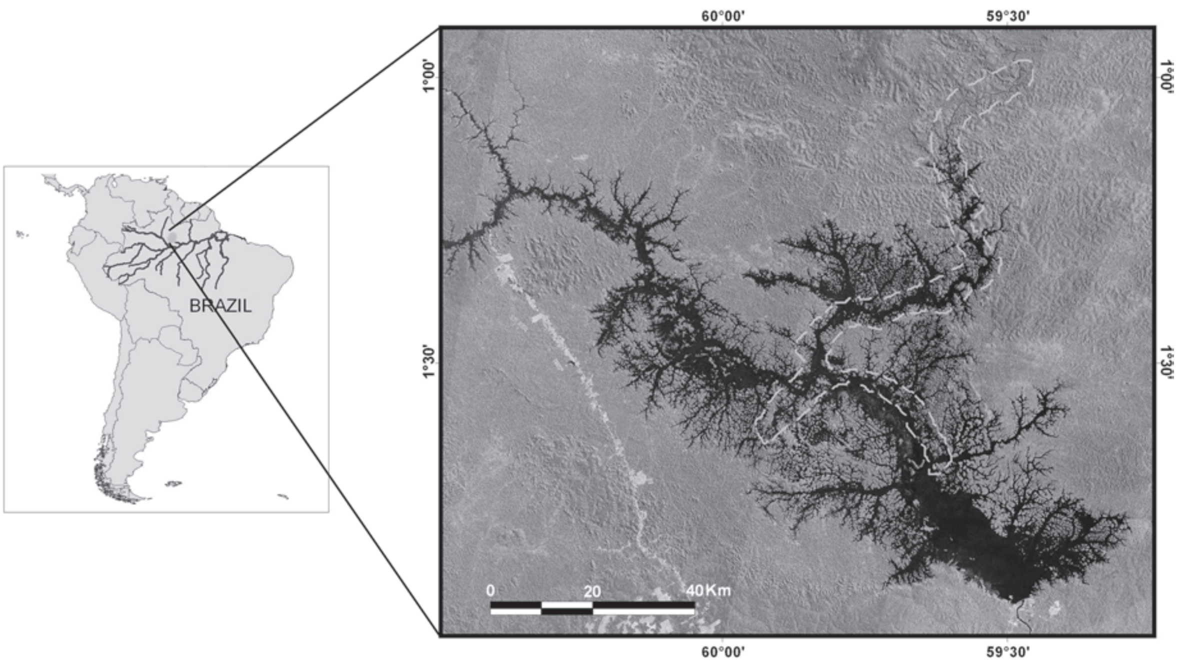

Figure 1. Map of the study area, Balbina reservoir (01°55'S, 59°29'W), municipality of Presidente Figueiredo, Amazon, Brazil. The area surveyed is delimited by the dotted line.

RESULTS

Among the 254 giant otter fecal samples analyzed, 100% contained fish remains (Tab. I) and only 0.78% (n = 2) also contained mammal fur (monkey and sloth). All fish present in the giant otter feces from Balbina were bony fish (Teleostei) distributed into three orders (Characiformes, Siluriformes and Perciformes), ten families (Anostomidae, Erythrinidae, Prochilodontidae, Characidae, Auchenipteridae, Doradidae, Loricariidae, Pimelodidae, Cichlidae, and Sciaenidae), and nine genera: *Laemolyta* (Cope, 1872), *Leporinus* (Spix & Agassiz, 1829), *Schizodon* (Spix & Agassiz, 1829), *Hoplias* (Gill, 1903), *Prochilodus* (Spix & Agassix, 1929), *Serrasalmus* (La Cepède, 1803), *Chalceus* (Cuvier, 1816), *Crenicichla* (Heckel, 1840) and *Plagioscion* (Gill, 1861) (Tab. I).

The order Perciformes showed the highest frequency of occurrence (92.9%, n = 236), followed by Characiformes (77.5%, n = 197) and Siluriformes (6.3%, n = 16). Among the families identified, Cichlidae, Characidae and Erythrinidade presented the highest frequencies, 92.5%, 60.6%, and 39.0%, respectively. Among the fish genera identified in the feces of the giant otters from Balbina, *Serrasalmus* sp. (40.9%) and *Hoplias* sp. (39.0%) were the most frequent (Tab. I).

From a total of 23 direct observations of giant otters feeding in Balbina reservoir, it was possible to identify the genus of fish consumed on only five occasions (21.7%). Giant otters were observed consuming species of *Leporinus* on two occasions, and preying upon individuals of *Prochilodus*, *Crenicichla* and *Hoplias* once. The latter four genera were present in feces in the following frequencies: 2.4%, 0.4%, 0.4% and 39.0%, respectively.

When fish orders were compared, their relative frequencies in samples from the Balbina Lake did not differ significantly ($p > 0.05$) from the frequencies found in samples from the Xixuaú creek (Rosas *et al.* 1999) (Fig. 2). By contrast, when prey comparisons were carried out at the family level (Fig. 3), the Erythrinidae (represented here exclusively by the genus *Hoplias*) had a significantly lower frequency in the Balbina reservoir ($p < 0.05$) with respect to the Xixuaú creek, while the Characidae occurred more frequently ($p < 0.05$) in the feces of giant otters from the Balbina reservoir.

Among the fish genera present in our samples, *Hoplias* (trahiras) was one of the most frequent (39.0% of the samples), which was also very common (67.6% of the samples) in giant otter feces from the Xixuaú creek (Rosas *et al.* 1999). However, despite being common in samples from both localities, differences in the relative frequencies of trahiras between the two areas were statistically significant ($p < 0.05$) (Fig. 4).

Table I. Frequency of occurrence (FO) of the fish groups identified in a total of 254 feces samples of giant otters from Balbina hydroelectric reservoir.

Prey items	N	FO (%)
Characiformes	197	77.5
Anostomidae	58	22.8
Laemolyta sp.	2	0.8
Leporinus sp.	6	2.4
Schizodon sp.	4	1.6
Others	46	18.1
Erythrinidae	99	39.0
Hoplias sp.	99	39.0
Prochilodontidae	4	1.6
Prochilodus sp.	1	0.4
Others	3	1.2
Characidae	154	60.6
Serrasalminae	137	53.9
Serrasalmus sp.	104	40.9
Characinae	9	3.5
Chalceus sp.	4	1.6
Others	25	9.8
Siluriformes	16	6.3
Auchenipteridae	2	0.8
Doradidae	1	0.4
Loricariidae	7	2.7
Loricarinae	7	2.7
Pimelodidae	2	0.8
Others	8	3.1
Perciformes	236	92.9
Cichlidae	235	92.5
Crenicichla sp.	1	0.4
Sciaenidae	1	0.4
Plagioscion sp.	1	0.4

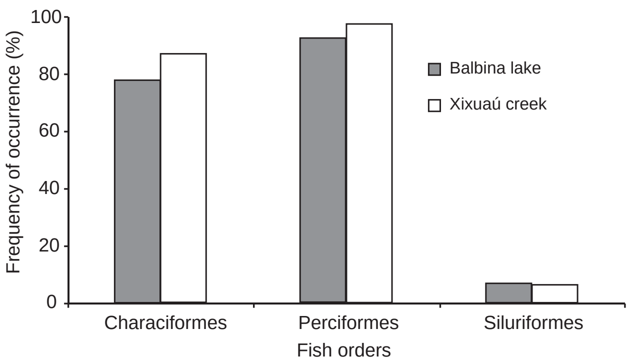

Figure 2. Frequency of occurrence of fish orders found in feces samples of giant otters from Balbina hydroelectric reservoir (N = 254 samples) (present study), and in an area without hydroelectric plant influence, Xixuaú creek, N = 37 samples (Rosas *et al.* 1999).

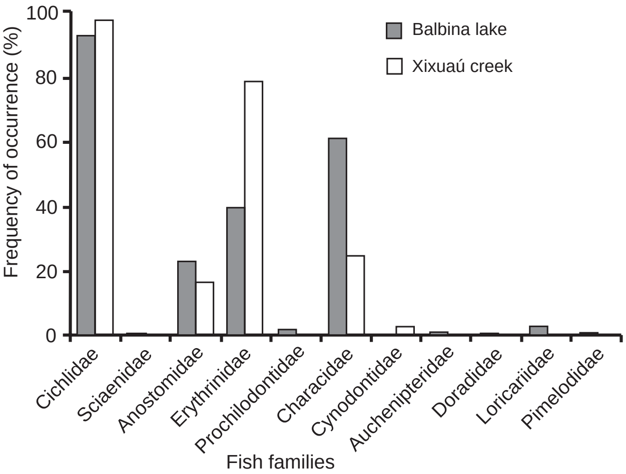

Figure 3. Frequency of occurrence of fish families found in feces samples of giant otters from Balbina hydroelectric reservoir (N = 254 samples) (present study), and in an area without hydroelectric plant influence, Xixuaú creek, N = 37 samples (Rosas *et al.* 1999).

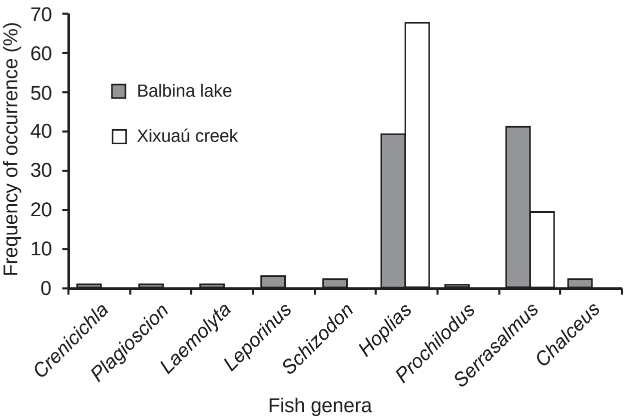

Figure 4. Comparison of the frequency of occurrence of fish genera found in feces samples of giant otters from Balbina hydroelectric reservoir (N = 254 samples) (present study), and in an area without hydroelectric plant influence, Xixuaú creek, N = 37 samples (Rosas *et al.* 1999).

The variation observed in the frequency of fish families in giant otter feces during the hydrological cycle of the Balbina hydroelectric lake is presented in figure 5. Since Balbina reservoir is a man-made lake, it has a low seasonal variation in water level when compared with other natural (unaltered) areas in the Amazon. The maximum variation of the water level in the Balbina reservoir during the study period was 3.87 m, which is not very impressive when compared with the 10-12m difference between the highest and lowest water levels in non-dammed areas in Central Amazonia (Sioli 1984). Nevertheless, the results suggest a discrete seasonality in the giant otter diet in the reservoir, and consistent with our expectations, a wider range of prey items was observed in the fecal samples during the low-water period (Fig. 5).

We recorded Cichlid fish remains with frequencies of occurrence above 85% in both seasons. However, among most of the other fish families, especially the Erythrinidae, there was an increase in the frequencies of occurrence during the low-water season (Fig. 5).

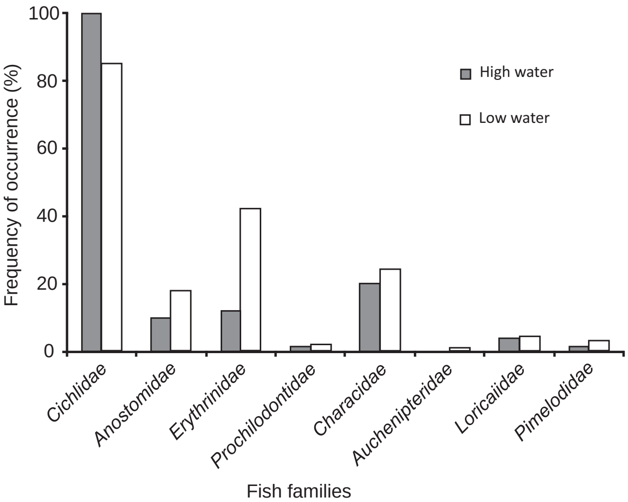

Figure 5. Seasonal analyses of the fish families (frequency of occurrence) found in fresh feces samples of giant otters from Balbina hydroelectric reservoir (N = 75 samples) during two entire hydrological cycles (2006-2007).

DISCUSSION

Even though the literature mentions the predominance of fish in the diet of giant otters throughout its distribution range, other food items, such as crustaceans, mollusks, birds, reptiles, amphibians, and small mammals have also been reported (Duplaix 1980, Emmons 1999, Rosas *et al.* 1999, Rosas 2004). Despite the presence of at least two crab families (Pseudothelphusidae and Trichodactylidae), two shrimp families (Euryrhynchidae and Palaemonidae) (Magalhães & Pereira 2007), and several species of birds, snakes, caimans and turtles in the Balbina reservoir (Cabral *et al.* 2008), none of these items were found in our samples. With the exception of a very low amount of mammalian fur (0.78% of the samples), the lack of any other food item and the massive predominance of fish in the feces of the giant otters from the reservoir clearly indicate that fish is practically the only food they consume, suggesting that their diet is somewhat more restrictive than the diet of giant otters living in other (unmodified) areas of the Amazon.

However, the fish orders consumed by the giant otters in our data were not very different from those observed in the feces of otters from unmodified areas (areas without artificial dams) in the Brazilian Amazon (Rosas *et al.* 1999) (see Fig. 2). Similar results were also presented by Staib (2005) for giant otters in Peru, where fish belonging to the orders Characiformes and Perciformes were also the most common.

In the Brazilian Pantanal, Schweizer (1992) reported a prevalence of Characiformes (*Hoplias* sp.) followed by Siluriformes in the diet of the giant otter. These results corroborate findings by Rosas *et al.* (1999), who analyzed a few giant otter fecal samples from the Aquidauana River (Brazilian Pantanal area). In their data, remains of Characiformes were present in 100% of the samples collected, followed by Siluriformes (66.6%) and Perciformes (33.3%). Although Siluriformes were not the most frequent prey in samples from the Pantanal, they were still more frequent than in samples from the Amazon region, where frequencies were lower than 7% in both dammed (present study) and non-dammed areas (Rosas *et al.* 1999). The differences in the occurrence of Siluriformes in the giant otter feces from both areas (Pantanal and Amazon) are probably related to regional differences in prey availability (abundance or suitable foraging grounds).

The three fish families most frequently found in the Balbina reservoir (Cichlidae, Characidae, and Erythrinidae, see table I), were also the most frequent in feces of giant otters from the Xixuaú creek (Rosas *et al.* 1999), where the frequencies of these fish families were 97.3, 29.7 and 78.4%, respectively (see Fig. 3). The differences observed in the frequency of occurrence of Characidae and Erythrinidae between dammed and non-dammed areas can be due to different sample sizes between these two locations (Balbina n = 254, Xixuaú creek n = 37), and/or differences in prey availability.

The high frequency of Cichlidae recorded may be related to the fact that most species of this family have sedentary habits, living generally in lakes (lentic environments) and river-edge areas (Santos *et al.* 2006). Their sedentary lifestyle makes them easy prey for giant otters along the huge extensions of the shallow margins of the reservoir. A similar set of habits and preferential habitats adopted by the erythrinid *Hoplias* sp. probably also explains the high occurrence of this genus in the diet of giant otters.

Characidae contains approximately half of the fish species of the order Characiformes. Relatively large and well-known species such as "matrinxã" (*Brycon* sp.), piranhas and "pacus" (Serrasalminae), as well as many small-sized species, such as "piabas" (Tetragonopterinae), are included in this family. The high species richness and corresponding abundance of characids may be responsible for the significant presence of this family in the feces of giant otters from the Balbina reservoir.

When comparing the fish families in fecal samples of the giant otter from Balbina reservoir with those found in the feces of otters from the Xixuaú creek (a non-dammed area) (Rosas *et al.* 1999), we noted that Sciaenidae, Prochilodontidae, Auchenipteridae, Doradidae, Loricariidae, and Pimelodidae were only recorded in the samples from Balbina (Fig. 3), though in low frequencies (3.0% or below) (Tab. I). It is possible that these differences (absence of some taxa from Xixuaú creek samples) are due to the small sample size analyzed by Rosas *et al.* (1999). However, the authors recorded the presence of remains of Cynodontidae (dogtooth characins) in the feces of giant otters from the Xixuaú creek, which were absent from the Balbina samples. This suggests a possible difference in the availability of fish families between these two areas. Nevertheless, the frequency of Cynodontidae (a surface- and mid-water-dwelling fish predator) in the Xixuaú creek samples was very low (2.7%) (Rosas *et al.* 1999), suggesting that this food item is not very important in the diet of giant otters.

The variation observed in the frequency of members of the Erythrinidae in the feces of giant otters during the hydrological cycle of the Balbina reservoir (Fig. 5) could explain the differences observed in the frequency of this family between the reservoir and the non-dammed area studied by Rosas *et al.* (1999). However, even though their study included the entire hydrological cycle of the Xixuaú creek, it did not discriminate the results by season, which precludes a more detailed comparison with our seasonal results. Notwithstanding, *Hoplias* sp. has also been reported as a frequent item in the diet of giant otters throughout their distribution range (Schweizer 1992, Schenck 1999, Staib 2005). In general, this genus is one of the most common fish in Brazilian rivers, occurring in all water bodies and in any type of environment, including polluted areas (Santos *et al.* 2006). Individuals of this genus usually live in lentic waters such as lakes and river margins, and are able to occupy environments with extremely low oxygen concentrations. Additionally, they have the ability to move out of the water, being capable of moving for short distances between water bodies through the vegetation and/or moist ground (Santos *et al.* 2006). According to Rosas *et al.* (1999), it is unknown whether fish with these behavioral characteristics are simply easier for giant otters to catch, or whether giant otters became more efficient at catching fish with these characteristics through adaptive specialization.

The frequency of piranhas (*Serrasalmus* sp.) in samples from the Balbina reservoir (40.9%) was twice that observed by Rosas *et al.* (1999) for the Xixuaú creek samples (18.9%, Fig. 4). It is well known that piranhas commonly occur in rivers and lakes, mainly in clear and black water, and are among the most successful fish in artificial reservoirs in the Amazon region (Santos *et al.* 2006). The high frequency of occurrence of piranhas in the feces of giant otters from Balbina suggests an opportunistic feeding habit, following the increase in the abundance of piranhas after damming the Uatumã River. However, even though piranhas seem to be an important item in the diet of giant otters in the Brazilian Amazon, they were not recorded in the diet of giant otters from the Peruvian Amazon (Schenck 1999, Staib 2005).

According to those authors, piranhas present a regular occurrence in fishing catches in Peruvian rivers, but were not observed in 60 feces samples of giant otters from that region. Based on this result, SCHENCK (1999) and STAIB (2005) suggested that giant otters are selective predators.

There are also no reports of giant otters eating piranhas (Characidae) in the Brazilian Pantanal, where Erythrinidae and Pimelodidae were the most frequent fish families recorded by SCHWEIZER (1992). His records, however, were based on direct observations of the feeding habits of giant otters, and did not include a detailed analysis of fecal samples. Direct observation is extremely sensitive to errors, because observations are usually carried out at a distance of 20 m or more from the subjects and can lead to problems with prey identification. We believe that visual records (direct observations) are valid to complement diet information, but they should not be used as the only method to study the diet of giant otters.

The most important fish species in the diet of giant otters from the Peruvian Amazon were *Prochilodus caudifasciatus* (Starks, 1906), *Crenicichla semicincta* (Steindachner, 1892), *Hoplias malabaricus* (Bloch, 1794), *Satanoperca jurupari* (Heckel, 1840), *Steindachnerina* sp. (Fowler, 1906), *Curimata* sp. (Walbaum, 1792), *Potamorhina* sp. (Cope, 1878) and *Triportheus angulatus* (Spix & Agassiz, 1829) (SCHENCK 1999, STAIB 2005). Of these, only the first three genera were recorded in the diet of giant otters from Balbina. Nevertheless, SCHENK (1999) and STAIB (2005) did not express their results in terms of frequency of occurrence, which precludes a quantitative comparison with our results.

Despite a lack of data on the availability of fish in the Balbina dam, the variations observed in the frequency of occurrence of some prey items in the diet of the giant otter throughout the hydrological cycle suggest that some fish species are substituted by others according to changes in the water level (Fig. 5). During the low-water period, fish leave the flooded forests and become restricted to perennial water bodies. On the other hand, during the flooded season, fish disperse again throughout huge extensions of flooded areas (SANTOS *et al.* 2006), becoming more difficult for giant otters to catch (ROSAS *et al.* 1999). During this time, the Balbina otters seem to opportunistically prey on fish species that are available. However, the high incidence of the families Erythrinidae and Anostomidae during the low-water period (Fig. 5) suggests some level of selectiveness when more prey options are available. Nevertheless, as the water level variation in the reservoir is not very pronounced, this hypothesis needs further verification.

The amount of fecal samples analyzed in this study (n = 254) represents one of the largest samples ever obtained for giant otters, and certainly reveals information regarding the diet of the population in the study area with great reliability. The year-round presence, group dynamics, behavior and regular reproduction of giant otters in the Balbina dam (ROSAS & MATTOS 2003, ROSAS *et al.* 2007, ROSAS *et al.* 2009), together with data on feeding habits presented herein, indicate that giant otters are well adapted to the environmental conditions created by the damming of the Uatumã River, namely the increase of accessible land by the creation of more than 3,000 islands where the otters can dig their dens and reproduce (ROSAS *et al.* 2007), and a large extension of shallow habitats where they forage for fish prey. Moreover, even though the diet of the Balbina otter population presented some differences in comparison with the diet of giant otters from other (non-dammed) areas in the Brazilian Amazon, the main fish prey consumed varied very little. However, the massive presence of fish, and the reduced number of other prey items in the feces of giant otters from Balbina, despite being available, suggests a preference for fish in the reservoir.

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