

Diet of four small mammal species from Atlantic forest patches in South Brazil

Dieta de quatro espécies de pequenos mamíferos em fragmentos de floresta atlântica no sul do Brasil

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Abstract

In this study we analyse the diet composition of small mammals of western Paraná state, southern Brazil. Species studied were mostly unknown on feeding habits. Animals were sampled during the faunal survey carried out in October 1998 when implementing the Salto Caxias dam. The diet composition, based on gut contents, seems to be mostly opportunistic and generalist for the three marsupials, *Micoureus paraguayanus*, *Caluromys lanatus*, and *Monodelphis sorex*, and for the rodent, *Akodon paranaensis*, studied. Caeca of the four small mammal species had in general a small quantity of insects when compared with other digestive tract portions. However, when volume consumed was evaluated, Arthropoda was the most important item for three species of them. Inversely, fruits were important for *C. lanatus*. The estimated amount of plant material (seeds and other plant structures) had a higher importance for *C. lanatus*, mainly for caecum samples, however these items were also found in the other mammal species samples but in lower proportions. The high proportion of intact seeds on both, digestive tract and caecum, when compared with predated seeds, is noticeable, suggesting that the species are seed dispersal. *Monodelphis sorex* seems to have a more insectivorous diet, as it is a small cursorial mammal, although there was also evidence for frugivory or carnivory. *Akodon paranaensis* was insectivorous-omnivorous, although fruits and vertebrate prey were also consumed, indicating also an opportunistic diet. *Caluromys lanatus* is classified as a more frugivorous species, besides the consumption of vertebrate prey. Insectivorous habit seems to be frequent in neotropical small mammals, with consumption of vertebrates or fruits being only opportunistic. The insectivory (except for *C. lanatus*) and opportunistic habit appear to dominate among the small mammal species studied.

Key words: *Micoureus paraguayanus*, *Caluromys lanatus*, *Monodelphis sorex*, *Akodon paranaensis*, *food habits*.

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Resumo

A composição da dieta de quatro espécies de pequenos mamíferos foi estudada no oeste do Paraná, sul do Brasil. Os animais foram amostrados durante o resgate de fauna ocorrido em outubro de 1998, durante a implementação da usina hidrelétrica de Salto Caxias. Os animais foram sacrificados logo após suas capturas. As análises foram

baseadas nos tratos digestórios das espécies. As espécies *Caluromys lanatus*, *Micoureus paraguayanus*, *Monodelphis sorex* (Marsupialia) e *Akodon paranaensis* (Rodentia) se mostraram heterogêneas quanto à composição da dieta, tanto para itens animais quanto vegetais. Os cecos das quatro espécies tinham em geral uma menor proporção de insetos quando comparados às demais partes do trato digestório. No entanto, quando avaliado o volume consumido de cada item alimentar, os artrópodes foram mais importantes na dieta de três espécies de pequenos mamíferos do que frutos. Estes foram mais importantes para *C. lanatus*. A quantidade estimada de vegetais (sementes e estruturas vegetativas) foi muito mais importante para *C. lanatus*, principalmente no material retirado do ceco. Ressalta-se ainda a grande proporção de sementes inteiras tanto no trato digestório como nos cecos em todas as espécies estudadas, em comparação com a proporção de sementes predadas, evidenciando estas espécies como dispersoras de sementes. *Monodelphis sorex* parece ter uma dieta mais insetívora, por ser um pequeno mamífero cursorial, contudo há a evidência de frugivoria ou carnivoria para a espécie. *Akodon paranaensis* mostrou-se como insetívoro-onívoro, contudo frutos e presas vertebradas também foram consumidos, indicando também uma dieta oportunista. *Caluromys lanatus* foi classificado como a espécie mais frugívora, embora tenha consumido vertebrados. O hábito em geral insetívoro observado é freqüente em pequenos mamíferos neotropicais, com o consumo de vertebrados ou frutos de forma oportunista. A insetivoria, exceto para *C. lanatus*, e hábito alimentar oportunista parecem dominar entre os pequenos mamíferos estudados.

Palavras-chave: *Micoureus paraguayanus*, *Caluromys lanatus*, *Monodelphis sorex*, *Akodon paranaensis*, hábitos alimentares.

Introduction

Studies on diet of mammals are necessary to understand niche relationships, competitive process, coexistence, predation, and their influence on the ecosystem, as well as how resource distribution is affecting animal abundance (Galetti *et al.*, 2003). Despite the wide variety of food items available, the diet of mammals can be affected by reproductive stage, age, season, and other factors (Charles-Dominique *et al.*, 1981; Julien-Laferrrière and Atramentowicz, 1990; Carvalho *et al.*, 1999), influencing the population dynamics of prey species (e.g. Bergallo and Magnusson, 1999). Didelphid marsupials are known to be omnivorous small mammals. However, recent studies have shown that those marsupials can have divergent diets from the omnivory, as the frugivorous diet of *Caluromys philander*, carnivory for *Lutreolina crassicaudata* or insectivory for *Monodelphis* species and *Metachirus nudicaudatus* (Charles-Dominique *et al.*, 1981; Atramentowicz, 1988; Leite *et al.*, 1994; Fonseca *et al.*, 1996; Carvalho *et al.*, 1999; Cáceres, 2002; Astúa de Moraes *et al.*, 2003; Vieira and Astúa de Moraes, 2003). Nonetheless, invertebrates such as

arthropods seem to be the main food items in the diet of didelphids (e.g. Fonseca and Kierulff, 1989).

Most sigmodontinae rodents seem to be insectivorous-omnivorous (Fonseca *et al.*, 1996) but with tendencies to herbivory or frugivory (Talamoni *et al.*, 1999; Bergallo and Magnusson, 1999; Carvalho *et al.*, 1999; Vieira *et al.*, 2003). This group differs in feeding habits from the didelphid marsupials, at least in Brazil.

In nature, relationships between feeding habits and vertical use of the habitat are apparently common. Among small mammals, some species are more frugivorous and arboreal, others are more insectivorous and cursorials (Leite *et al.*, 1994; Vieira and Astúa de Moraes, 2003).

Most studies on diet of small mammals have been made by analysing faeces or stomach contents (Carvalho *et al.*, 1999; Leite *et al.*, 1994; Talamoni *et al.*, 1999; Busch and Kravetz, 1991) but little of them emphasized the role of caecum in the food digestion or even quantified the food volume in the digestive tract. The role of the caecum has been related to a more herbivorous diet (Crowe and Hume, 1997; Santori *et al.*, 2004; Cáceres, 2005). Most studies have only reported frequencies of item occurrence but not the volume

or relative importance, in the small mammal diets.

In face of the general absence of dietary studies on neotropical small mammal species, namely *Caluromys lanatus* (Olfers, 1818), *Monodelphis sorex* (Hensel, 1872), *Micoureus paraguayanus* (Tate, 1931) and *Akodon paranaensis* (Christoff *et al.*, 2000), a study on feeding habits of them was performed. Its objective was to determine qualitatively the food items on the diets of four sympatric small mammals from the area influenced by the Salto Caxias dam, low Iguaçu River, PR, Brazil. Another objective was to compare the frequency and relative importance of items in the caecum and in the rest of the digestive tract of animals.

Material and methods

Study area

The study area is located in the South of Brazil, comprising a region where semideciduous seasonal small forest patches dominate. Patches comprise mainly secondary or altered forests. The region is hilly being drained by the Iguaçu River. The central coordinates of the region are: 25° 30' S and 53 30' W. The region is in the influence of

the Salto Caxias dam, implemented in October 1998.

Animals

It was sampled 51 complete digestive tracts from four small mammal species: *Caluromys lanatus* (one male and four females), three *Micoureus paraguayanus*, 26 *Monodelphis sorex* (17 males, nine females) and 17 *Akodon paranaensis* (11 males and six females). All of them were from Salto Caxias dam, collected manually during the flooding time (October 1998) when the main habitats were flooding. All animals were sacrificed as soon as possible in the field, with guts being preserved in 70% alcohol posteriorly. Diets of the animals are thought to be little modified by the method used for sampling in the field and collection. Animals were deposited in the Capão da Imbuia Natural History Museum (MHNCI) in Curitiba, PR, Brazil.

Qualitative analyses of each digestive tract

Each digestive tract was analysed completely to verify the presence of food items, from the stomach to the hard gut. Thus, the frequency of occurrence of food items (e.g. insect Orders or seed species) in these compartments was recorded per sample (individual) and divided by the total number of samples. When present, seeds were quantified if broken or intact, to estimate seed predation level (proportion of the total number of broken seeds by the total number of seeds in the tracts).

Quantitative analyses in each digestive tract

The gut was separated in two portions of this analysis: caecum, and the other compartments (all the rest treated here as one unit), to examine if there are differences in food allocation among compartments. This separation was made to evaluate the importance of the caecum in the storage and processing

of different food items, considering that caecum is often developed in marsupials, relating with their generic omnivory (Astúa de Moraes *et al.*, 2003; Vieira e Astúa de Moraes, 2003; Cáceres, 2005). It was also measured the seed frequency in each of these two treatments.

The relative importance of items was thus measured by counting how many times a kind of food item appeared in each gut part (caecum and the rest of digestive tract), as follows. Gut samples were washed in a 1 mm mesh and preserved in tubes with 70% alcohol for posterior analyses under a stereoscopy. For gut samples weighting more than 1 g, one equivalent portion was randomly taken from tubes with a forceps and placed in Petri dish, to quantify food items. This procedure was done twice, but with the replacement of the first sample taken, to better randomize the sampling of food items in each tube.

To quantify the frequency of food items in each sample, five squared grids (each one comprising a 14 x 14 mm area) were delimited regularly on the Petri dish bottom (with one central and four laterals, following an X). Each grid (7x7 format) was divided in 49 small squares (each one with 2 x 2 mm). Samples were homogenised manually in Petri dishes and, after that, they were counting for food items under a stereoscopy by considering their presence and absence in the 2x2 mm squares. With this, it was possible to estimate the mean frequency (or the relative importance) of a food item in each digestive tract compartment (caecum or the rest of the digestive tract).

The vertebrate and invertebrate items found were identified at the Order level based on feathers, bones, hairs, teeth and identifiable peaces of arthropods and mollusks (legs, elytra, heads, wings, antennas, etc.). Vegetable items were separate in: seeds and other plant structures (including leaf and tissues like fruit pulp).

To compare the frequencies of consumed items in the caecum versus the rest of digestive tract (stomach and guts), the G test was used. The same

test was used to compare the rate of intact seeds and damaged seeds in digestive tracts.

Results

Arthropods were the item more consumed by the mammals studied. Coleopterans occurred in 100 % of *C. lanatus* samples, in 33% of *M. paraguayanus*, in 54 % of *M. sorex* and in 77% of *Akodon paranaensis*. Overall, arthropods occurred in 94 % of all samples (N = 48), considering all species pooled.

All analysed small mammal species seem to be near generalist in relation to diet compositions, containing both animal and plant materials. Birds were the most frequent vertebrate item for *M. paraguayanus*, and mammals were the most frequent item for *C. lanatus* and the other species. The rodent *A. paranaensis* consumed mammalian prey at a lower rate than the other small mammal species (Table 1).

Invertebrates such as coleopterans, lepidopterans and hymenopterans were the most frequent items for *C. lanatus*; coleopterans for *M. sorex* and *A. paranaensis*, and blattarians and hymenopterans for *M. paraguayanus* (Table I). In caeca, animal items were usually less frequent when compared with other portions of the digestive tract. This difference was significant for *M. sorex* (G test = 19.7, df = 10, $P = 0.03$). Regarding estimated amounts consumed, arthropods were more important in the diet of all small mammal species, but fruits were important for *C. lanatus* as well (Table 2).

Despite the appearance in guts of all small mammal species, plant material was more important in the diet of *C. lanatus*, mainly on samples seen in the caecum (Table 1). For *C. lanatus*, digestive tracts revealed nine seed species such as those of *Piper*, *Cyphomandra*, *Cecropia* and *Ficus*. For *A. paranaensis*, *Rubus*, *Ficus*, *Cyphomandra* and another unidentified Solanaceae species were recorded. For *M. sorex* it was found *Cecropia* and

Rubus species (Table 1). *Cecropia pachystachia* and a solanaceous species were found for *M. paraguayanus*. All seeds had small dimensions (less than 5 mm).

The proportion of intact seeds for all mammal species was very high

when compared to predated seeds. The percentage of predated *Ficus luschnatiana* seeds for *C. lanatus* was 0.9% only (n = 1284); *C. pachystachia*, 5.6% (n = 57) for *M. sorex*, and *R. rosifolius*, 4.1% (n = 511) for *A. paranaensis* (Table 3).

These differences were significant for all mammal species studied except one, when the seeds were pooled (*C. lanatus*, $G = 17.1$, $df = 8$, $P = 0.03$; *M. paraguayanus*, $G = 14.4$, $df = 4$, $P = 0.006$; and *A. paranaensis*, $G = 10.2$, $df = 4$, $P = 0.04$).

Table 1. Frequency of occurrence of food items in the diet of four sympatric small mammals species from a secondary semideciduous Atlantic forest in southern Brazil during the spring of 1998. Frequencies in % are in parenthesis.

Items	<i>Caluromys lanatus</i> (n=5)	<i>Monodelphis sorex</i> (n=26)	<i>Micoureus paraguayanus</i> (n=3)	<i>Akodon paranaensis</i> (n=17)
Vertebrates				
Birds	2(40)	1(4)	2(67)	
Mammalia	3(60)	8(31)		4(24)
Invertebrates				
Chelicerata				
Acarina		2(8)		2(12)
Arachnida				1(6)
Opiliones		4(15)		3(18)
Crustacea		2(8)		6(35)
Decapoda		4(15)		4(24)
Isopoda				4(24)
Myriapoda		1(4)		5(29)
Chilopoda				2(12)
Insecta				
Blattariae		8(31)	2(67)	9(53)
Coleoptera	5(100)	24(92)		17(100)
Scarabaeidae		3(12)		
<i>Curculione</i> sp.		1(4)		
Diptera				1(6)
Hymenoptera	5(100)	16(80)	2(67)	13(77)
"Homoptera"				2(12)
Insect larvae		1(4)		5(30)
Isoptera				3(18)
Orthoptera		6(30)	1(33)	6(35)
Plants				
Unidentified parts	2(40)	6(30)	1(33)	3(18)
Seeds	5(100)	2(8)	2(67)	5(30)
<i>Cecropia pachystachia</i>	1(20)	1(4)	1(33)	
<i>Cyphomandra</i> sp.	1(20)			2(12)
<i>Ficus luschnatiana</i>	1(20)			1(6)
<i>Piper</i> sp.	2(40)			
<i>Rubus rosifolius</i>		1(4)		1(6)
Solanaceae sp.	1(20)		1(33)	3(18)
Unidentified seeds	4 spp.		2 spp.	1 sp.

Table 2. Mean estimated amount of food (in %) in digestive tracts of four species of small mammals from a semideciduous Atlantic forest in southern Brazil, during the spring of 1998. (<) indicates samples with less than 0.05%, and (-), the absence of the item. Standard deviation of each item is in parentheses. Main values are in bold, and the (*) indicates $P < 0.01$ between caecum and stomach-guts (G test).

Items	Caluromys lanatus (N=5)		Monodelphis sorex (N=26)		Micoureus paraguayanus (N=3)		Akodon paranaensis (N=17)	
	Stomach and guts	Caecum	Stomach and guts	Caecum	Stomach and guts	Caecum	Stomach and guts	Caecum
ANIMALS	1.0 (1.7)	-						
Mammalia			0.1 (0.2)	-	-	-	- (0.05)	-
Birds	6.4 (10.5)	0.3 (0.7)	-	-	2.4 (4.2)	-	-	-
Bones	< (0.1)	-	< (0.2)	-	-	-	-	-
Arthropoda	8.4 (2.7)*	1.7 (1.2)	4.5 (4.6)*	0.2 (0.7)	7.1 (9.8)*	0.7 (0.7)	9.8 (7.3)*	6.6 (4.5)
Coleoptera	0.9 (0.6)	0.1 (0.2)	0.6 (1.1)	-	0.7(1.2)	-	1.0 (1.2)*	0.5 (0.8)
Hymenoptera	1.0 (1.0)	0.1 (0.2)	0.1 (0.3)	-	-	-	0.3 (1.1)	< (0.1)
Lepidoptera	3.0 (2.3)	-	0.3 (0.7)	-	0.1 (0.1)	-	0.8 (0.9)	-
PLANTS								
Seeds	1.0 (1.3)	5.4 (9.6)*	0.2 (0.8)	-	0.1 (2.0)	-	0.1 (0.2)	-
Other plant parts	0.8 (1.1)	6.8 (15.0)*	0.2 (0.4)	-	0.1 (0.2)	-	0.1 (0.2)	-
Unidentified	1.7 (2.0)*	0.7 (1.3)	1.6 (1.6)*	0.5 (1.0)	1.3 (2.2)*	0.5 (0.4)	1.3 (2.2)*	0.5 (0.4)

Table 3. Proportion of intact seeds (at left) compared with predated seeds (at right) in digestive tracts of four sympatric small mammals of a secondary semideciduous Atlantic forest of Southern Brazil, during the spring of 1998. Trace indicates no predation sign.

Species	<i>Caluromys lanatus</i>	<i>Monodelphis sorex</i>	<i>Micoureus paraguayanus</i>	<i>Akodon paranaensis</i>
<i>Ficus luschnatiana</i>	1272 / 12			1 / -
<i>Piper</i> sp.	3 / -			
<i>Cyphomandra</i> sp.	3 / -			13 / -
<i>Cecropia pachystachia</i>	12 / -	54 / 3	1 / -	
<i>Solanaceae</i> sp.	1 / -		1 / -	131 / -
<i>Rubus rosifolius</i>		2 / -		491 / 20
Sp. 1	75 / 3			
Sp. 2	144 / 8			
Sp. 3	28 / -			
Sp. 4			4 / -	
Sp. 5			1 / -	
Sp. 6			- / 4	
Sp. 7				1 / -
Sp. 8	13 / 1			

Discussion

The main results seen here were that small mammals at secondary semideciduous forest of Salto Caxias dam are basically omnivorous, but with trends to one feeding speciality according to species and life style, and that they are potential dispersers of seeds of small size.

Although it was used just a few individuals, *Caluromys lanatus* seems to be more frugivorous than the other three sympatric small mammals species, which is in agreement with other studies with the congener species, *C. philander* (Julien-Laferrière, 1999; Atramentowicz, 1988; Leite *et al.*, 1994; Carvalho *et al.*, 1999). Evidence of a more frugivorous

diet of *C. lanatus* and *C. philander* was demonstrated in studies of digestive tract proportions of didelphid marsupials (Santori *et al.*, 2004; Cáceres, 2005). Therefore, caecum of *C. lanatus* is well developed (Cáceres, 2005) and must be related to the fruit processing, as we reported here a significant amount of seeds in this part. Arboreal mammals,

such as the congeneric *C. philander*, have been constantly considered as more frugivorous (e.g. Vieira e Astúa de Moraes, 2003), being the frugivory facilitated by this life style. The same trend would occur for the *C. lanatus*. Otherwise, escansorial species have an equilibrated diet with arthropods and fruits, as occurs for *Didelphis* species (Atramentowicz, 1988; Leite *et al.*, 1994; Cáceres and Monteiro-Filho, 2001).

Micoureus paraguayanus is also an arboreal species (Leite *et al.*, 1994; Vieira and Monteiro-Filho, 2003), but probably less frugivorous than *C. lanatus* (Leite *et al.*, 1994; Cáceres *et al.*, 2002). These results are in agreement with Fonseca *et al.* (1996), Leite *et al.* (1994) and Carvalho *et al.* (1999), that classified this species as insectivorous-omnivorous. However, it has been observed the consumption of vertebrate prey by this species, which is in agreement with Cáceres *et al.* (2002).

Monodelphis sorex had a more insectivorous diet, as was expected for a cursorial small mammal (Vieira e Monteiro-Filho, 2003), although fruits and vertebrate prey were seen in its diet at some level. Opiliones, blatarians, lepidopterans and coleopterans were reported in the diet of *M. sorex* in Araucarian mixed forest in Brazil (Cáceres, 2000), similarly as we see here. In Argentina, *M. dimidiata* is classified as more carnivorous because the feeding on rodents, but also on arthropods as a complement of its diet (Busch and Kravets, 1991).

Akodon paranaensis belongs to a genus of rodents usually classified as insectivorous-omnivorous (Emmons and Feer, 1997), which is in agreement with our results, although it also fed on fruits in a reasonable proportion (25%). All small mammal species studied here preyed on vertebrates but usually at lower rates. This indicates them as opportunistic animals, even the small, more insectivorous rodent species, *A. paranaensis*, or the arboreal, more frugivorous *C. lanatus*.

Also, all animals consumed fruits

at different frequencies, besides the general trend for insectivory. Seeds consumed were mainly those small ones (< 5 mm), being this possibly related to the body size, as evidenced elsewhere (Magnusson and Sanaiotti, 1987; Carvalho *et al.*, 1999; Cáceres *et al.*, 2002; Vieira *et al.*, 2003).

Insectivorous habit is thought to be dominant in neotropical forest small mammals (Fonseca e Kierulff, 1989), mainly for cursorial and/or escansorial species (Leite *et al.*, 1994; Vieira and Astúa de Moraes, 2003). Other feeding behaviour can appear occasionally in generalist and opportunist small mammals, such as herbivory, frugivory or carnivory, depending of season, sex, age, and health condition (Charles-Dominique *et al.*, 1981; Julien-Laferrrière and Atramentowicz, 1990; Santori *et al.*, 1997; Cáceres and Monteiro-Filho, 2001; Cáceres, 2004).

Seed dispersal have been noticed for small, cryptic, forest small mammals (Charles-Dominique *et al.*, 1981; Atramentowicz, 1988; Medellín, 1994; Santori *et al.*, 1997; Galetti *et al.*, 2003; Cáceres, 2002, 2004; Cáceres *et al.*, 2002; Astúa de Moraes, 2003; Vieira *et al.*, 2003), mainly by field rather than captive studies. Some species are more dependent of fruits and others are not. The habit of feeding on fruits is also widespread in neotropical small mammals, and possibly will be related to dispersal rather than predation for small sized seeds (e.g. see Vieira *et al.*, 2003). Our data on seed dispersal vs. predation corroborate this for the small mammal species studied.

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