Papéis Avulsos de Zoologia

MUSEU DE ZOOLOGIA DA UNIVERSIDADE DE SÃO PAULO

ISSN 0031-1049

PAPÉIS AVULSOS ZOOL., S. PAULO 39(19): 351-364 10.X.1996

USE OF CAVES BY *PHILANDER OPOSSUM* (MAMMALIA: DIDELPHIDAE) IN SOUTHEASTERN BRAZIL

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ABSTRACT

The four-eyed opossum Philander opossum *(Marsupialia, Didelphidae) ranges from Mexico to southern Brazil and northeastern Argentina. Some individuals are trogloxenes in caves from the Ribeira Valley, southeastern Brazil. They use caves for shelter, feeding (mainly on harvestmen) and breeding (at least for rearing the young). This relationship varies seasonally, being highest during the breeding season and during the dry season, when low availability of epigean food forces the animals to forage inside the caves.*

Keywords: *Philander opossum*; Didelphidae, cave habitat, ecology, food items, Brazil.

INTRODUCTION

The four-eyed opossum *Philander opossum* (Marsupialia, Didelphidae) ranges from Mexico to southern Brazil and northeastern Argentina, living in forested regions, usually near rivers and wet areas (Nowak & Paradiso, 1983). They are terrestrial, nocturnal and solitary animals. They feed mainly on invertebrates, small vertebrates, and fruits (with much pulp rich in water and sugars - Emmons, 1990); approximately 50% animal vs. 50% vegetal matter (Julien-Laferrière & Atramentowicz, 1990).

Other than bats, only a few small mammals have been recorded in caves: *Proechimys* sp. in Venezuela (Ojasti, 1961), *Nectomys squamipes* in Venezu-

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Trabalho recebido para publicação em 05.IV.95 e aceito em 08.IV.96.

ela (Linares, 1969), *Neotoma floridana* in the USA (Clark et al., 1994), and *Neotoma cinerea* and *Peromyscus maniculatus* in the USA (Nelson & Smith, 1976). In the Ribeira Valley (southeastern Brazil), Trajano & Gnaspini-Netto (1991) reported *Agouti paca* (Rodentia: Agoutidae), *Lutra longicaudis* (Carnivora: Mustelidae) and *Philander opossum* from several caves. The last named was especially common in caves at Fazenda Intervales - an Atlantic rainforest reserve. Because mammals are homeothermic, they need a large amount of food (Pough, Heiser & McFarland, 1989); when they occur in caves, they are classified as trogloxenes (animals which regularly frequent caves, but which need to leave the subterranean habitat in the search for food or reproductive sites).

The few works focusing on the biology of *P. opossum* were conducted in a humid tropical forest in Panama (Fleming, 1972, 1973) and in a seasonally humid tropical forest in French Guiana (Atramentowicz, 1986a, 1986b, 1988; Julien-Laferrière & Atramentowicz, 1990).

The aims of the present paper are to document the relationship between *P. opossum* and the cave environment, based on cavernicolous populations from Fazenda Intervales, southeastern Brazil, especially on their feeding and movements in the cave habitat.

Methodology

This study was conducted at the Fazenda Intervales, Ribeira Valley, state of São Paulo, during six field trips: 01-04/July, 06-08/August, 04-11/September, 09-17/December/1993, 26/March-03/April, and 08-13/July/1994. The study focused on the population in the area of the Barra Bonita cave, but some collections were also made at Colorida cave, to add data on diet, development and movements.

The Ribeira Valley reserve is one of the last remnants of Atlantic Forest in the states of São Paulo and Paraná. It is humid subtropical forest, evergreen, located at the transition between the Tropical Atlantic Domain and the Araucaria Domain (Ab'Saber, 1977; Hueck, 1972). The climate is humid subtropical, with 1500mm total rainfall and yearly average temperature between 18°C and 19°C (Monteiro, 1973; Setzer, 1966). The altitude ranges from 100m to 1100m. Limestone outcrops form discontinuous NE-SW strips; there is great density of caves, often more than one kilometer long (Karmann & Sánchez, 1979; Sánchez, 1984). The Fazenda Intervales is located at the highest elevations and its 25000 ha include more than 50 known caves (see Gnaspini-Netto & Trajano, 1992).

The Barra Bonita cave (SP-271, 2416'S 4827'W), located at an altitude of 855m, is a 135m long gallery, with varying width (0.4m to 2.5m) and height (1m to 10m); there are two opposite entrances (Figure 1). The Colorida cave (SP-129, 2416'S 4825'W), located at 825m altitude, at approximately 3.5km from the former, is a complex network of connected galleries (the lower gallery crossed by a river) totalling 1000m of development.

At Barra Bonita cave, on the first two trips, 20 traps for small mammals were set, 8 inside and 12 outside the cave, along the trail that leads to it. From the third trip on, a rectangular "grid" of traps was placed, as shown in Figure 1. The grid had 60 traps placed in three parallel lines (A, B, C - line B passes through the interior of the cave) with 20 traps each. Each trap was positioned 10m from the nearest neighbour; 3800m² is the total area covered by the grid.

For Colorida cave, 7 traps were placed inside the cave, up to 160m from the main entrance, in September and December 1993 and July 1994.

The traps were baited with guava candy (which, during former trips to the region, was found to be a good bait for these animals) in July, August and September 1993. In order to detect preferences, in December 1993 and July 1994, some of the traps were baited with guava candy and some with bologna; guava candy or pineapple was used as bait in March/April 1994.

The animals collected were weigthed, measured (body, tail, left hind foot and ear lengths, following Emmons, 1990), from September 1993 on, and marked (by fur-clipping, in different positions). Some of the animals had a spool of thread attached to their backs, to detect their movements inside and outside the cave.

All faeces released inside the traps or during handling were collected in order to determine diet. The faeces were fixed in 70% ethyl alcohol in the field, and studied under a stereomicroscope in laboratory. Vegetal and animal matters were identified to the lowest possible taxonomic level.

Results and Discussion

Captures and movements

The results of the mark-recapture study are shown on Table 1. Several animals were captured on the same date, and were captured more than once during each field trip. This agrees with Atramentowicz's statement (1986b) that these didelphids are "easy-to-capture animals". This applies especially to individual n° 5, which was captured during all trips but the last one, because it was found dead in April/94. This animal was followed for several months, and clearly used the area to forage and breed (as discussed later in this paper). According to Atramentowicz (1986b), these didelphids are solitary animals which do not defend their territories and may have large home ranges, and show variable individual degrees of philopatry (some are captured only once at each trap, and some might be captured always at the same place). Our results showed the same variation.

The density of the animals varied from more than 100 individuals per hectare during July-August/93 to less than 5 individuals per hectare during September/93-April/94. These results are intermediate between the higher densities from French Guiana (850 to 1800 - Atramentowicz, 1986b) and the lower ones from Panama (0.55 to 0.65 - Fleming, 1972). The differences in our results may be explained by (1) migration and/or mortality of the animals; (2) the area covered by the traps during the first two trips (185m^2) was much smaller and was comprehended in the area covered by the grid of traps during the next trips (3800m^2), which could result in larger density (for instance, if the same number of individuals was captured in both trips, the density would have been different only because the sampled areas were different); (3) the lower availability of food during the dry season forced the animals to look for food more intensively, increasing the chance of capture with baited traps; and the contrary occurred during the rainy season, when the animals tend to visit the traps at a lower frequency because of the higher availability of food in nature (as suggested by Fleming, 1972).

The captures in the hypogean habitat occurred both near and far from the cave entrances (in the aphotic region). Some trails were visible on the ground and were found crossing the Barra Bonita cave from one entrance to the other, being interrupted only when crossing the river. This suggests a regular usage of the hypogean environment by this species, at least in the studied area.

In order to detect their activity path, spools of thread were attached to the back of individuals 2, 3, 4, 5, 6 and 7, generally only at the first time they were captured. When released they either hid inside crevices inside the caves, or left the cave by one of the entrances, and not necessarily the closest one. Three of them (n° 2, 4, and 5) followed the river course inside the cave, and two (n° 6 and 7) followed the epigean river course. This suggests they might be using the rivers as a geographic reference, and might explain why no animal was captured at traps 1 to 5, which were placed far from the water courses.

Development

The measurements made are summarized on Table 2. The probable age of each individual, also shown on Table 2, was calculated based on both weight and length, using the graphics in Atramentowicz (1986b).

The data for animal 5, which was repeatedly captured throughout the study, agrees with the growth graphics in Atramentowicz (1986b), suggesting that development in the southern Brazilian population follows the same pattern as in the French Guiana population. Moreover, the fact that this animal was captured with young in the marsupium at an approximate age of 8 months also agrees with the literature, which recorded the start of sexual life at an age of 6-7 months for males and 8 months for females (Fleming, 1973; Atramentowicz, 1986b). Also the reddish colour of the marsupium of the same animal in April suggested that the young had left the marsupium only a short time before, giving an approximate time of 3 months for milk feeding, which also agrees with Atramentowicz (1986b), who recorded a period of 75-80 days.

Animals 8 and 9 were captured only during the last trip and had a calculated age of 5-6 months, which matches with the possiblity of being born from female 5.

Feeding

The main food items, summarized on Table 3, show that the animals feed on both cavernicolous (mainly harvestmen) and epigean invertebrates (mainly orthopterans and beetles). Analysis of the frequency of food items in the faeces showed that 24% contained harvestmen fragments (66.7% of the faeces collected during July/93 contained harvestmen fragments), and 55% contained Lutosa cricket fragments.

Our results agree with the literature (Hunsaker, 1977; Nowak & Paradiso, 1983; Emmons, 1990; Julien-Laferrière & Atramentowicz, 1990) that diet is variable, and is based on invertebrates, small vertebrates and plants. While Julien-Laferrière & Atramentowicz (1990) found a proportion of 50% animal matter and 50% vegetal matter, we found variable proportions, depending on the season: 80% animal and 20% vegetal matter in July, August and September/93; 50% each in December/93; 10% animal and 90% vegetal in March/April/94 and 100% animal matter (only a few *Cecropia* seeds) in July/94. This can be directly related to the seasonality of ripe fruits - during the rainy season (December), when they are most available, fruits were eaten in large amounts, whereas during the rest of the year animal matter prevailed as food items.

Among the animal matter, the main items were *Lutosa* crickets, carabid and scarabaeid beetles, diplopods, chilopods, spiders, and *Goniosoma* cave harvestmen (the latter only during the dry season).

In some cases, fragments of decaying leaves were found in the faeces. We consider these to be accidental, because they might have been eaten while the animals forraged in the litter. This is probably the same case for the ants found in the faeces. In this case, the ants were entire, meaning they were swallowed without chewing, i.e., they were not swallowed as food, but accidentally. And this is also the case for other whole items, which appeared in 67.7% of the feaces analysed, and which are probably ectoparasites, ectocomensals, phoretic animals, etc., such as ticks, fleas, *Amblyopinus* beetles, and pseudoscorpions, swallowed during grooming.

Among them, the case of the *Amblyopinus* beetles should be noted. These beetles are considered to be comensals in mammals nests (Ashe & Timm, 1988) and were occasionally collected in a few caves in the Ribeira Valley. Because they were found in several faecal pellets, we consider them to be commonly associated with *Philander opossum* in these caves. However, it is still premature to consider their relationship with other cave mammals, because studies are scarce.

In one case (individual 7), the animal probably fed on a bird carcass because, amongst the bird remains, scavengers such as cholevid beetles, mites, ants, and nematodes were found in the faecal pellets. These other animals might have been feeding on the bird carcass when this was eaten.

Use of cave and general discussion

Recent studies in caves from the Ribeira Valley (southeastern Brazil) recorded four-eyed opossums inhabiting these caves (Trajano & Gnaspini-Netto, 1991). It is noteworthy that this species shows a very broad geographical distribution, ranging from Mexico to Argentina (Emmons, 1990). In spite of that, as far as we know, they have been recorded inhabiting caves only in the Ribeira Valley (Trajano & Gnaspini-Netto, 1991).

Especially considering the Fazenda Intervales area, we noticed that these animals use the caves regularly. Our mark-recapture studies showed that they use the caves with high frequency. All individuals (except the young n° 8 and 9) were captured at least once in the hypogean habitat, as shown on Table 1.

In order to make further considerations on the relationships between the four-eyed opossums and the studied caves, we will discuss in detail the case of female n° 5. It was captured during several months in a large number of traps regularly distributed in the grid (see Table 1). In December 1993 she was carrying young in the marsupium; and in April 1994, the young had just left. While rearing her young (April), she was submitted to attachment of a spool of thread to detect the activity path. After being released (at trap B06), she went inside a crevice near "*Philander* column". Next day, the thread showed she had left the cave through the main entrance, wandered outside and returned directly to the same crevice. And on the next day, the thread left the crevice again, and ended near the main entrance. We noticed a trail of leaves following the thread, and a large amount of leaves just at the entrance of the crevice, suggesting that the female was constructing her "nest" inside the crevice, where her young were probably hiding.

In a former trip, the same place was used by another female as nest. We could observe the construction of the nest. The female made several trips to the epigean habitat and, when coming back each time, she carried a bunch of leaves in the curl of her tail. After climbing the column, the leaves were released and arranged inside a crevice. The young were placed back inside the crevice on the leaves, and concealed behind a "wall" of leaves.

Specimen 5 showed a high degree of philopatry, which may be related to the breeding season - because she carried young in the marsupium, her sedentary behaviour could be related to the presence of a nest to rear the young. This may also explain the high rate of recaptures, especially in traps baited with bologna, on account of the need of a greater amount of protein during lactation.

If the animals make nests inside the caves, the higher rate of capture in the hypogean habitat could be explained by the fact that they would be captured by the first trap while on their way out of the cave to forage. However, if making nests inside the caves was the only explanation for the higher hypogean capture rate, the seasonal variation of captures inside the caves (i.e., higher in the dry season) should be related to a seasonal variation of nesting inside the caves (equally higher in the dry season), which was not detected during the study.

The analysis of the food items (Table 3) showed a seasonal variation of food ingested. This is explained by the seasonal availability of the different kinds of food in the epigean habitat. Ripe fruits are available only during the rainy season (summer), when the number of epigean arthropods also increases. This different availability of food during the seasons may also explain why the animals were captured in the hypogean habitat with a higher frequency during the dry season (see Table 1). The lower availability of food during the dry season forces the animals to look more intensively for food, and even to enter caves, where the availability of arthropods (especially harvestmen) is rather high throughout the year. This is also suggested by the analysis of the food items in the faeces, which showed a large amount of fragments of cave harvestmen during the dry season (see Table 3). This item became rare during the following trips in the rainy season.

Table 1. Places of capture (between parentheses) and recapture of *P. opossum* at Barra Bonita cave. Numbers of locations refer to the grid as shown in Figure 1. + = recaptures in same day; baits: G = guava candy; B = bologna; P = pineapple

Animal	Date	Location of hypogean captures	Location of epigean captures	Sex / Development
1	07/93	(B11), B13	B18	young female
2	07/93	(B11), B13, B10		adult (? sex)
3	07/93	(B13)		adult (? sex)
4	07/93	(B13)	C18	adult male
	08/93	B13+, B09, B11+	C18	
5	07/93	(B11)		young female
	08/93	B13		
	09/93	B14, B09	A09, A08, C09, A11	
	12/93	B14-B+	B19-G, A19-B, A18-B+, C06-B	adult female[1]
	03-04/94	B07-P, B06-G	B16-G, A15-G	adult female[2]
6	12/93	(B13-G), B08-B, B09-G	A16-G, A15-B	adult male
7	07/94	(B14-B)+	B20-B	adult male
8	07/94	—	(A20-G)	young female
9	07/94	—	(A11-B)	young male

[1] young in the marsupium
[2] marsupium still "red", indicating young had just left

Table 2. Measurements of specimens of *P. opossum* (numbers refer to specimens collected at Barra Bonita cave, and letters to those colleted at Colorida cave). The specimen 5 was collected and measured three times; 5* with young in the marsupium; 5** after young have left the marsupium

N°	Date	Weigth	Body Length	Tail Length	Hind Foot Length	Ear Length	Probable Age
5	09/93	125g	205mm	257mm	30mm	30mm	5 months
5*	12/93	310g[1]	252mm	280mm	37mm	28mm	8 months
5**	03/94	280g	265mm	280mm	37mm	32mm	11 months
6	12/93	270g	243mm	280mm	33mm	27mm	9-10 months
7	07/94	310g	295mm	300mm	35mm	28mm	13-14 months
8	07/94	140g	225mm	235mm	30mm	26mm	05-06 months
9	07/94	150g	200mm	270mm	30mm	27mm	05-06 months
A	09/93	300g	280mm	310mm	40mm	30mm	10-11 months
B	12/93	370g	314mm	310mm	39mm	33mm	11-12 months
C	07/94	260g	245mm	300mm	35mm	30mm	09-10 months

[1] total weigth, including young.

Table 3. Summary of the main food items found in faeces of *P. opossum* captured during the study, including data from both Barra Bonita and Colorida caves. Numbers between parentheses = minimum number of individuals in the same pellet; "!" = large amount; "?" = possible identification

Food Item	07/93	08/93	09/93	12/93	04/94	07/94
Cave harvestman (*Goniosoma spelaeum*)	x!			?x		?x
Epigean harvestman		x			x	
Spider	x	x	x	x	x(2)	x
Terrestrial isopod	x		x			
Amphipod				x		
Diplopod	x	x	x			x
Chilopod	x			x	x	x
Gryllacridid cricket (*Lutosa* cf. *brasiliensis*)	x		x	x	x	x
Phalangopsid cricket	x					
Cockroach				x	x	
Carabid beetle	x(2)			x		
Staphylinid beetle			x		x	
Scarabaeid beetle	x			x	x(2)	
Chrysomelid beetle				x		
Unidentified beetle		x	x	x	x(4)	
Lepidoteran larva				x		
Bird						x[2]
Rodent		x		x		
Small Mammal				x		
Pseudoscorpion [1]	x					

Tick [1]	x	x!	x		x
Flea [1]			x	x	x
Staphylinid beetle (*Amblyopinus* sp.) [1]	x	x	x		
Ant [1]	x		x	x	x
Melastomatacean seeds (*Leandra* cf. *purpuraceus*)	x		x	x!	
Rubiacean seeds (*Psychotria mapoureoides*)			x!	x!	
Leguminosean fruits (*Machaerium* sp.)				x	
Myrtacean seeds (*Psidium* cf. *cattleyanum*)				x!	
Caesalpinioidean seeds			x		
Ficus sp. infrutescense			x		

[1] these items are not considered to be food items proper, because they were entire (they were not ingested as food), and include parasites and phoretic animals (see text for discussion)

[2] because of the occurence of several saprophages together with the bird remains, it is probable that the animal ate a carcass which was already being eaten by scavengers (beetles, nematodes, etc).

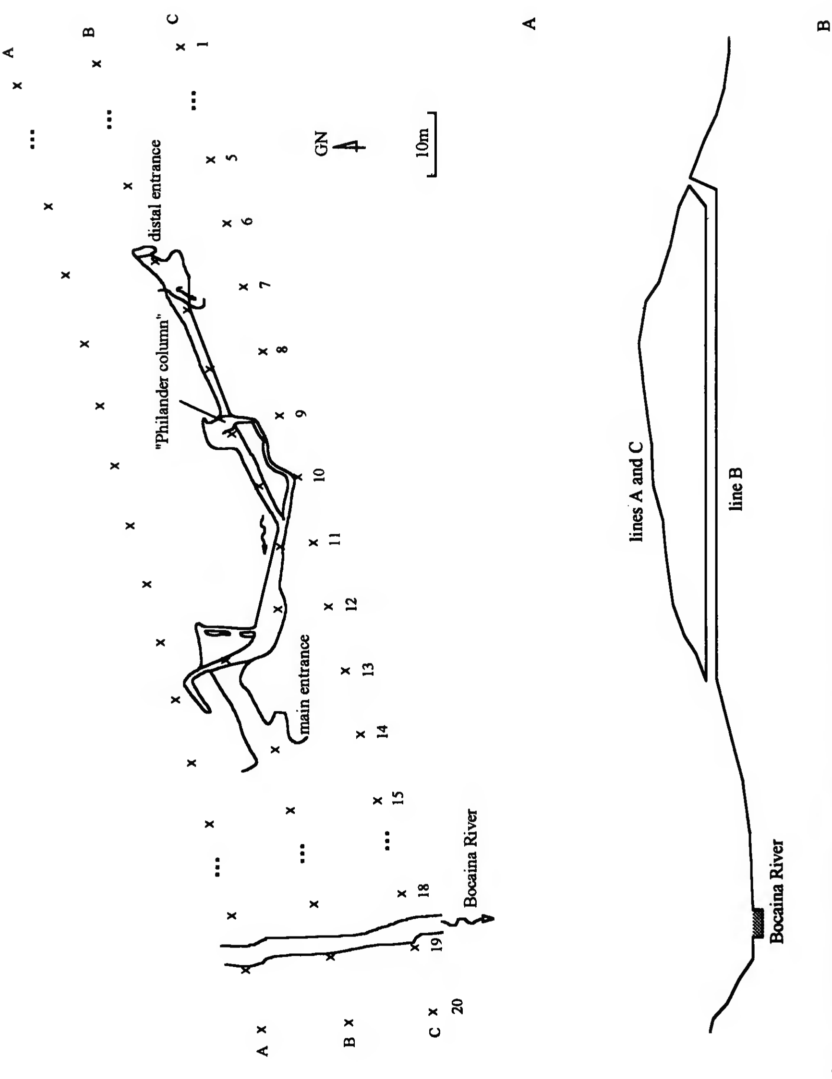

Fig. 1. A. Plan of the grid of traps at Barra Bonita cave-lines (A) and (C) are epigean and (B) passes through the cave. Each line has 20 traps. GN = Geographic North. B. Sectional profile of the grid of traps.

Conclusions

This study showed that the *Philander opossum* at Fazenda Intervales are trogloxenes, which use the caves for shelter, feeding (mainly on harvestmen) and breeding (at least for rearing the young). This relationship varies seasonally, being higher during the breeding season, and the dry season when the low availability of epigean food forces the animals to forage inside the caves. This is a rare behaviour amongst trogloxenes, which generally leave their caves to forage, and is reported only for snakes which enter caves to forage on cave bats (Ginet & Decou, 1977), and for feral house cats in Puerto Rico and Panama, that also to forage on bats (S.B. Peck, pers. comm.).

Acknowledgements

The animal matter in the faeces was identified by S.A. Vanin (USP - Arthropods in general) and F.A.G. Mello (UNESP/Botucatu - Ensifera); the vegetal matter by J.R. Pirani and W. Mantovani (USP). P.L.B. da Rocha and R. Pardini (USP) made usefull suggestions on the improvement of the methodology. S.B. Peck (Carleton University, Canada), E. Trajano (USP) and the referees made valuable improvements to the manuscript. This study was supported in part by a fellowship from CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) to one of us (FPF). Fundação Florestal do Estado de São Paulo allowed and supported the field studies at the Fazenda Intervales reserve.

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Credenciamento e Auxílio Financeiro do Programa de Apoio às Publicações Científicas Periódicas da USP. Comissão de Credenciamento.