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Food Habits and Seed Dispersal by the White-Eared Opossum *Didelphis Albiventris* in Southern Brazil

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Abstract

The food habits and seed dispersal promoted by the marsupial *Didelphis albiventris* (Marsupialia: Didelphidae) were investigated in two forest fragments of Curitiba, southern Brazil, between February 1995 and February 1997. Forty live traps were set uniformly in the fragments for opossum captures and collection of their scats. Diet was determined by fecal analysis and seed dispersal was tested through seed germination experiments. With a total of 1842 traps set, 71 scats of the white-eared opossum were collected, and 51 contained seeds. The opossum is omnivorous, consuming invertebrates (100% of occurrence in scats), fruits (76%) and vertebrates (58%). Common animal food items were those found in the litter. Diversities of food items were similar among opossums of different age classes. Seeds of several plant species passed undamaged through the guts and remained viable. Fruits from pioneer plants were the main ones consumed. Based on these results, this omnivorous opossum must be an effective seed disperser in southern Brazil.

Keywords: Mammalia, juvenile diet, prey diversity, pioneer plants, seed germination, dormancy.

Introduction

South American opossums were commonly reported as omnivorous mammals (Cabrera & Yepes, 1960; Walker, 1964) but up to date few detailed data exist about their specific diet for most regions of their range. However, more recently diets of marsupials from northern South America (e.g., Venezuela and French Guyana) have been determined and these allowed identification of more frugivorous species such as the arboreal opossum, *Caluromys philander* (Julien-Laferrière, 1999), or more omnivorous ones such as *Didelphis* spp. (Charles-Dominique et al., 1981; Cordero & Nicolas, 1987, 1992; Atramentowicz, 1988; Julien-Laferrière & Atramentowicz, 1990), approximately half of whose diet comprises arthropods. In contrast, there is a broad absence of records on diet of marsupials in the Amazon Basin.

Records of feeding habits from eastern South America have been focused on marsupials living in disturbed and non-disturbed Atlantic dense forests or Restinga (shrubland) areas (Monteiro-Filho & Dias, 1990; Leite et al., 1994; Santori et al., 1995, 1997). These marsupials have been revealed as mostly omnivorous but again with a greater degree of frugivory for *C. philander* and, in contrast, with greater insectivory for the brown four-eyed opossum, *Metachirus nudicaudatus*.

Another phenomenon strictly related to feeding habit is seed dispersal which depends, but not solely, on the degree of frugivory of a species. Some aspects of seed dispersal by marsupials have been studied in the northern Neotropics (Charles-Dominique et al., 1981; Atramentowicz, 1988; Medellín, 1994), such as the presence of intact seeds in stomachs, viable seeds in scats and plant species eaten.

The white-eared opossum, *Didelphis albiventris* (Lund, 1840) is a common marsupial of mixed ombrophilous (= forests with *Araucaria*) and open forests (Cerrado and Caatinga) for which few data on food habits are available. It occurs from Colombia and French Guyana to central Argentina, except for the Amazon Basin (Emmons & Feer, 1990), and is commonly found in urban areas (Cabrera & Yepes, 1960; Fonseca et al., 1982). The role of the white-eared opossum on seed dispersal has not been investigated although other marsupials have been studied (Monteiro-Filho & Dias, 1990; Leite et al., 1994; Cáceres et al., 1999; Cáceres

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& Monteiro-Filho, 2000; Cáceres et al., in press), such as the southern black-eared opossum, *D. aurita*, and the lutrine opossum, *Lutreolina crassicaudata*. Considering the richness of marsupial species and their diverse life styles in the Neotropics (Emmons & Feer, 1990), their role in seed dispersal should be analyzed, including their role in forest regeneration. Therefore, a study on the feeding habits and viability of seeds ingested by the white-eared opossum, *D. albiventris*, was carried out in southern Brazil, specifically in the eastern Paraná State, to add information on the ecology of this didelphid marsupial in a region of *Araucaria* highlands.

Materials and methods

Study areas

The study was conducted in two forest fragments (5 ha and 2.5 ha) in Curitiba, State of Paraná, southern Brazil, located at 25°25′S, 49°18′W, 940 m a.s.l. The two fragments were 8 km distant from one another in peri-urban environment and covered with disturbed mixed ombrophilous forest (= Araucarian forest). The mean annual temperature is 17°C and the annual rainfall ranges from 1600 to 2000 mm concentrated mainly in the wetter season (September–March), although some rain may occur during the drier season (Maack, 1981).

Sampling of scats

Opossums were captured weekly in 30 live traps (40 × 20 × 20 cm) that were uniformly placed in the 5 ha study area between February 1995 and January 1996. Another 10 live traps were used twice per month in the 2.5 ha area between November 1996 and February 1997. All traps were baited with a mixture of banana, peanut butter and codfish liver oil during the afternoon and checked for captures of opossums during the following morning. All animals were aged (Gilmore, 1943; Tyndale-Biscoe & Mackenzie, 1976) and released. Their scats were collected on the ground of each trap after their release.

Analysis of scats

The diet of white-eared opossums was determined through fecal analysis. Scats collected were washed and filtered using a 1 mm mesh. Food items were determined with the help of a reference collection of seeds and invertebrates from the study areas. Diet differences between the dry and the wet season and among age classes were tested through the nonparametric Mann–Whitney *U*-test. Age classes were also compared using the standardized Levins' measure of diversity that gives more weight to abundant food items in the diet (Krebs, 1989). This measure ranges from 0 to 1, with 0 meaning no diversity and 1 meaning the maximum diversity.

Germination tests

Seeds found in scats were counted and placed in closed Petri dishes (9 cm in diameter), containing a moist microenvironment promoted by humid paper. Dishes were placed in a natural environment with diffuse light, simulating a gap in the canopy. They were monitored at least once a week for seed germination and watered frequently to maintain the humidity. A powdered fungicide was placed in each dish during these observations to avoid fungus attacking the seeds.

Plant habitat

Occurrence of plants species represented by seeds in the scats was recorded in the study area. Species commonly found growing in gaps or in forest edges were classified as pioneers, which are important during forest succession (Gorchov et al., 1993).

Results

Diet

Seventy one scats from 37 individuals of *D. albiventris* were collected in the study areas, 54 scats from the 5 ha area and 17 from the 2.5 ha area. Opossums fed mainly on invertebrates (100% of occurrence in scats) and, secondarily, on fruits (76%) and vertebrates (58%) (Table 1). There was a significant increase in the rate of consumption of most fruits and some animal prey (e.g., reptiles and coleopterans) during the wetter season ($U = 451$, $N = 36$ items, $P < 0.03$). Similarly, some other animal prey (e.g., birds and diplopods) and some other fruits were important in the drier season (Table 1).

No significant differences among the diet of young, juvenile and adult opossums were observed when age classes with at least 10 faecal samples were tested through the Mann–Whitney *U*-test ($U > 488$, $N = 33$ food items, $P > 0.45$) (Table 2, Fig. 1). However, younger individuals fed mostly on snakes (mainly fossorial species) resulting in a lower diversity index, Fig. 1) and older individuals preyed mainly on birds and mammals (Table 2). Some fruits were also consumed at higher frequencies than others (Table 2), resulting in lower diversities among age classes (range: 0.15 to 0.21, Fig. 1). However, invertebrates mostly of the litter fauna such as scarabaeoid coleopterans and diplopods were uniformly eaten (index of diversity ranging from 0.51 to 0.56 for samples greater than 10 scats) (Fig. 1).

Fruits of *Morus nigra*, *Vassobia breviflora*, *Rubus rosifolius*, *Solanum sanctaecatharinae* and *Passiflora actinia* were consumed in high numbers indicated by the number of seeds in scats (Table 3). These five species, together with *Piper gaudichaudianum* whose total number of seeds in scats was estimated at around 2,000 seeds, were responsible for more than 95% of all seeds dropped.

Table 1. Frequencies of occurrence (in %) of food items found in scats of white-eared opossums, *Didelphis albiventris*, from two forest fragments of Curitiba, southern Brazil, during 1995 to 1997. (*N* = total number of scats analysed.)

Food items	Dry season (*N* = 20)	Wet season (*N* = 51)	Total (*N* = 71)
Vertebrates	*65*	*55*	*58*
Birds	50	18	28
Mammals	25	8	15
Reptiles*	–	35	19
Fishes	–	2	1
Unidentified bones	–	4	3
Invertebrates	*100*	*100*	*100*
Isopoda	15	12	13
Decapoda	15	6	8
Blattariae	50	41	44
Coleoptera	55	84	76
Hemiptera	–	2	1
Hymenoptera**	15	37	31
Lepidoptera (larvae)	–	14	10
Orthoptera	–	6	4
Opiliones	70	57	60
Diplopoda	70	29	41
Pulmonata	20	49	41
Fruits	*45*	*88*	*76*
ARECACEAE			
Syagrus romanzoffiana (Cham.) Glassm.	–	4	3
CUCURBITACEAE			
Cucumis sp.	20	–	6
Melothria cucumis Vell.***	10	6	7
ERYTHROXYLACEAE			
Erythroxylum deciduum A.St.-Hill.	–	2	1
RUTACEAE			
Citrus sp.	5	–	1
MELASTOMATACEAE			
Leandra australis (Cham.) Cogn.***	–	2	1
MORACEAE			
Morus nigra L.***	–	12	11
MYRTACEAE			
Psidium guajava L.	5	–	1
PASSIFLORACEAE			
Passiflora actinia Hooker	–	25	18
Passiflora sp.	–	2	1
PIPERACEAE			
Piper gaudichaudianum Kunth	–	8	6
POACEAE***	–	4	3
ROSACEAE			
Rubus erythrocladus Mart. ex Hook***	–	16	11
Rubus rosifolius Stokes***	–	6	4
SOLANACEAE			
Cyphomandra corymbiflora Sendtn.***	–	2	1
Solanum sanctaecatharinae Dun.***	5	24	18
S. cf. *maioranthum* L.B.Sm. & Downs***	5	12	9
Solanum sp.***	–	6	4
Vassobia breviflora (Sendtn.) Munz.***	–	10	7
Unidenfied seeds	20	16	17
Traces of garbage	15	6	8

* Mainly *Liotyphlops beui* (Serpentes). ** Mainly ants. *** Pioneer plants.

Table 2. Frequencies of occurrence (in %) of food items in feces of different age classes of the white-eared opossum, *Didelphis albiventris*, in two mixed ombrophilous forest fragments of Curitiba, southern Brazil.

	Age Classes					
Items	2 ($N = 13$)	3 ($N = 26$)	4 ($N = 7$)	5 ($N = 16$)	6 ($N = 6$)	7 ($N = 3$)
Vertebrates						
Birds	9	15	43	50	17	33
Mammals	–	–	29	31	17	33
Reptiles	45	38	–	6	–	–
Fishes	–	4	–	–	–	–
Unidentified bones	–	4	–	6	–	–
Invertebrates						
Isopoda	9	15	–	13	33	–
Decapoda	–	8	–	19	17	–
Coleoptera	73	85	57	56	83	100
Blattariae	9	58	86	25	50	–
Hemiptera	–	–	–	6	–	–
Hymenoptera	36	38	14	25	33	33
Lepidoptera (larvae)	36	4	–	–	–	–
Orthoptera	–	12	–	–	–	–
Diplopoda	27	27	71	69	17	67
Opiliones	55	58	14	81	33	–
Gastropoda	27	46	43	38	83	33
Fruits						
Citrus sp.	–	–	–	6	–	–
Cucumis sp.	–	–	29	13	–	–
Cyphomandra corymbiflora	–	4	–	–	–	–
Erythroxylum deciduum	–	–	–	–	17	–
Melothria cucumis	–	4	–	6	33	33
Morus nigra	9	–	–	31	17	–
Passiflora actinia	–	31	14	–	17	33
Passiflora sp.	–	–	14	–	–	–
Piper gaudichaudianum	–	12	–	–	–	33
Psidium guajava	–	–	–	–	17	–
Rubus erythrocladus	64	4	–	–	–	–
R. rosifolius	–	4	–	13	–	–
Solanum cf. *maioranthum*	9	12	29	–	–	33
S. sanctaecatharinae	–	46	14	–	–	–
Solanum sp.	27	–	–	–	–	–
Syagrus romanzoffiana	18	–	–	–	–	–
Vassobia breviflora	9	8	14	–	–	33
Unidentified seeds	18	16	–	19	–	67
Traces of garbage	–	–	–	19	–	33

Age classes following Gilmore (1943) and Tyndale-Biscoe & Mackenzie (1976).

Seed-Germination

Germination experiments revealed that most seeds were viable after passage through the digestive tract of opossums (Table 3). All seeds that appeared undamaged were less than 1 cm long. The largest intact seed belonged to *Passiflora* sp. (0.8 cm) and the smallest seeds were from *Leandra australis*, *Piper gaudichaudianum* and *Solanum* cf. *maioranthum* fruits (all ~1 mm long). The maximum size of seeds dropped undamaged by the smallest opossums (age class 2) was 0.4 mm (*Rubus erythrocladus*) but juvenile opossums (age class 3) also dropped intact *Passiflora actinia* seeds (0.5 mm). Seeds greater than 1 cm were destroyed (e.g., *Erythroxylum deciduum*) or probably rejected (*Syagrus romanzoffiana*) near the parent plant because only their fibrous pulp appeared in feces.

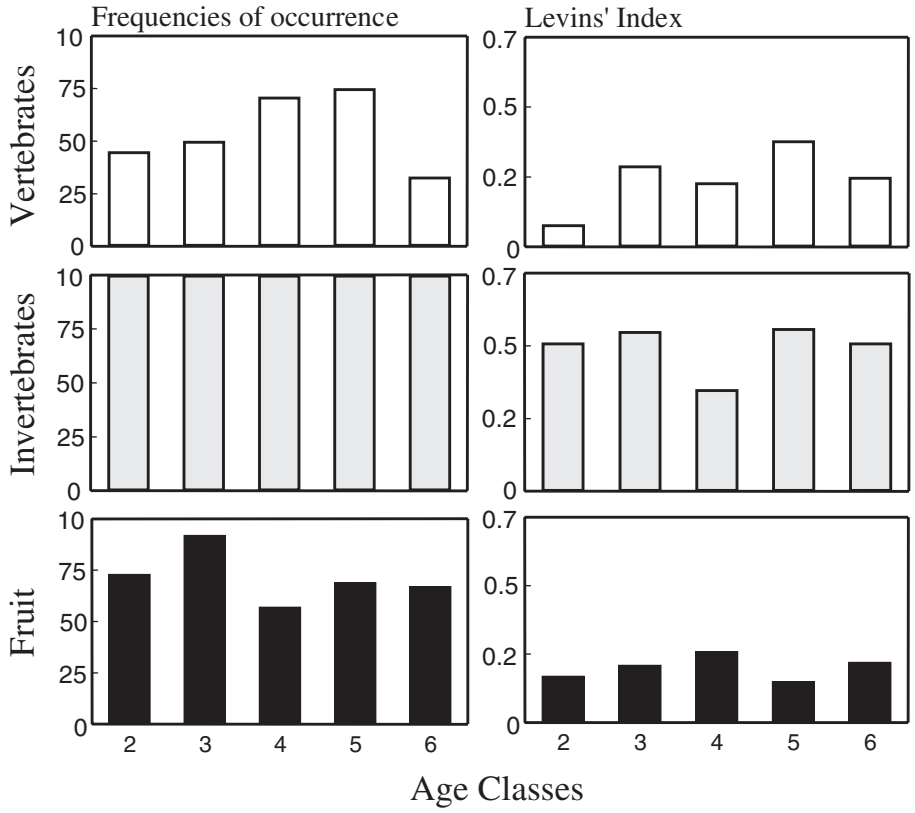

Fig. 1. Frequencies of occurrence (in %) and diversity of food items based on 71 scats of different age classes of the white-eared opossum, *Didelphis albiventris*. Age classes are (2) infant, (3) juvenile, (4) subadult, (5) adult, (6) older adult. Levins' index of diversity (Krebs, 1989) ranged from 0 (no diversity) to 1 (maximum diversity).

Table 3. Frequencies of germination and length of dormancy of different seed species found in scats of the white-eared opossum in two forest fragments of Curitiba, southern Brazil.

Species	Rate of germination (%)	No. of seeds in test	Total of seeds in scats	Length of dormancy (in days) $\bar{x} \pm$ SD	Mean time of germination (1995–1996)
Cyphomandra corymbiflora[S]	98	41	48	159 ± 62	18/06
Leandra australis[S]	100	13	32	58 ± 23	19/02
Melothria cucumis[L]	13	8	193	129	13/08
Morus nigra[S]	36	215	970	47 ± 16	24/10
Passiflora actinia[L]	15	41	460	361 ± 326	18/01
Psidium guajava[T]	100	4	4	129 ± 00	13/08
Rubus erythrocladus[S]	25	4	4	650	21/08
R. rosifolius[S]	67	55	485	269 ± 137	06/10
S. cf. *maioranthum*[S]*	71	7	16	228 ± 38	15/08 20/08
Solanum sanctaecatharinae[T]	31	118	306	182 ± 03	01/10
Vassobia breviflora[S]*	81	26	656	30 ± 04	23/01 09/02

T: tree, S: shrub, L: liana. * The two values for mean time of germination are due to fecal samples collected during the same season but in successive years.

Time of germination

Dormancy was found among most seed species and germination was delayed several months (Table 3). The maximum dormancy was found for *R. erythrocladus* seeds and, secondarily, for *P. actinia* seeds but these seed species germinated at low rates (Table 3). Among species that attained high germination rates, *R. rosifolius* reached the greater mean time of dormancy (9 months). In most species germination was synchronized to the early wetter season (August–October). The two species for which the germination experiment was repeated in successive years germinated at the same period in both years (Table 3).

Pioneer-Plants

In general, fruits of pioneer trees or shrubs were consumed by opossums (Tables 1, 3). More than half of the species identified were pioneer plants. Fruits of pioneer plants such as *Vassobia breviflora*, *Solanum sanctaecatharinae*, *Rubus rosifolius* and *Morus nigra* were among the most frequently consumed (Table 3).

Discussion

The omnivorous diet of opossums

Based on the frequency of occurrence of prey in feces, white-eared opossums feed mainly on invertebrates and secondarily on fruits and vertebrates in southern Brazil. This is in accordance with other studies of South American *Didelphis* (Cajal, 1981; Atramentowicz, 1988; Cordero & Nicolas, 1987, 1992; Leite et al., 1994; Santori et al., 1995). A preliminary analysis of animal prey consumed revealed a diet composed mainly of animals from the litter stratum, such as coleopterans, diplopods, opiliones, and fossorial snakes like *Liotyphlops beui* (J.C. Moura-Leite, pers. comm.). Data for the congeneric marsupial, the black-eared opossum *D. aurita* corroborate this (Freitas et al., 1997). However, the method regarding the frequency of occurrence of diet components does not take into account different nutritional qualities of the food items, so that the importance of large and protein-rich mammalian prey as dietary items of opossums may be underestimated (see Cordero & Nicolas, 1987; Dickman & Huang, 1988; Robinson & Stebbins, 1993).

Seasonal changes in the diet

Diplopods, opiliones and endothermic vertebrates were important prey items mainly for adult opossums during the drier season, as they were also for *D. aurita* in the same study area (Cáceres & Monteiro-Filho, 2001). However, most invertebrates, fruits and reptiles were mainly consumed by younger opossums (rather than adults) during the wetter season (see Julien-Laferrière & Atramentowicz, 1990; Santori et al., 1997, for seasonality data of other opossums, spp.). The fructification of many zoochoric plants in South American forests coincides with the wet season (Smithe, 1970; Charles-Dominique et al., 1981; Cáceres et al., 1999). Thus, the white-eared opossum can be considered an opportunistic frugivorous marsupial as was also emphasized by Smithe (1986) for several mammals, including neotropical marsupials (Charles-Dominique et al., 1981). Some fossorial snakes such as *L. beui* were important in the diet of infant and juvenile opossums that preyed on them foraging in the litter, but vertebrate prey such as mammals and birds were eaten mainly by adults, as reported by Santori et al. (1997) for the four-eyed opossum *Philander frenata*. In general, the diet of younger opossums was not significantly different from that of older individuals (see also Santori et al., 1997), showing that young when released from the pouch are already omnivorous. The time of recruitment of these marsupials, mainly the wetter season (Cáceres, 2000), coincides with the time of increased consumption of fruits and some ectothermic vertebrates (such as reptiles) by opossums in southern Brazil. Thus, these prey items should favour the survival of younger opossums during this time (Cordero & Nicolas, 1987).

Seed size, plant habitat and opossums as seed dispersers

Both young and old opossums are potential seed dispersers. They eat mainly fruits with small seeds, several of which remain viable after passing through the opossum's gut. Infant opossums that average 200 g should pass proportionally larger seeds than older opossums that average 1800 g (Cáceres & Monteiro-Filho, 1999). This indicates, in a certain way, the importance of fruits in the diet of young opossums. Thus, small seeds would have good chances to pass through the gut undamaged, and to be dispersed by a wide range of animals with different body sizes (Fleming et al., 1993). Based on adult individuals the maximum size of intact seeds in scats seen here is in accordance with other data for *Didelphis* (feeding mainly on fruits with small seeds: 0.1–2.0 cm) (Charles-Dominique et al., 1981; Cordero & Nicolas, 1987; Atramentowicz, 1988; Santori et al., 1995; Cáceres & Monteiro-Filho, 2000; Cáceres et al., in press). Nonetheless, Charles-Dominique et al. (1981) reported that didelphid marsupials in French Guyana usually reject large seeds near the parent plant, consuming only the pulp. This should also occur here for large seeds such as those from *Syagrus romanzoffiana* (see also Cáceres & Monteiro-Filho, 2000).

Opossums consumed mainly fruits of pioneer plants, which are usually found in forest gaps. Elsewhere, Monteiro-Filho & Dias (1990) and Medellín (1994) reported similar results for other didelphid marsupials. These results emphasize the importance of opossums as pioneer plant dispersers mainly because they may live at high densities even in disturbed forests (Monteiro-Filho & Abe, 1999; Cáceres, 2000) where this type of plant is mainly found (Foster, 1980).

Dormancy

The variable time of germination of the seeds tested showed that there are at least two strategies for germination, following Garwood (1982): 1) the syndrome of seeds dispersed and germinating quickly during the same rainy season (*V. breviflora*, *L. australis* and *M. nigra*), and 2) the syndrome of seeds dispersed during the wet season but remaining dormant during the dry season until the beginning of the next wet season (e.g., *C. corymbiflora*, *S. sanctaecatharinae* and *R. rosifolius*). Dormancy is the primary mechanism controlling the time of seed germination in this latter syndrome (see Garwood, 1982). In accordance to Vázquez-Yanes & Orozco-Segovia (1990) the condition for germination of pioneer plants here was most probably the change of the light quality that took place during the onset of the wet season. The same two syndromes of germination have been observed for seeds dispersed by a sympatric marsupial, *D. aurita* (Cáceres & Monteiro-Filho, 2000, unpublished data).

In summary, this omnivorous opossum is important in forest regeneration due to its diet based on pioneer plants' fruits. Since this marsupial lives in several types of environments (Cabrera & Yepes, 1960; Fonseca et al., 1982), it is capable of dispersing seeds in different types of habitats. Therefore, the role of *D. albiventris*, and other marsupials, for conservation and regeneration of forests should be further evaluated, emphasizing, for example, distance of seed dispersal, seed deposition site and its importance regarding other dispersers such as bats.

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