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Trophic Ecology of the Burrowing Owl in Southeast Brazil

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ABSTRACT

The Burrowing Owl *Athene cunicularia* is widely distributed in open habitats from south-west Canada to southern Chile and Argentina. Despite being a relatively well-known species, virtually no study was published on its feeding ecology in Brazil. The aim of this research was a comprehensive analysis of the diet of this raptor in six Sao Paulo State localities, south-east Brazil. The collection and analysis of 1,044 pellets and 54 pellet debris yielded 11,633 prey individuals distributed in approximately 77 food items. Invertebrates were numerically the main prey (66.4-96.7%), mostly represented by termites, orthoptera and beetles. On the other hand, by estimated biomass consumption vertebrates (mainly small rodents such as *Calomys tener*) formed the bulk of the diet, yielding 46.3-91.5% of total biomass consumed in each locality. The standardized Levins´s Food Niche Breadth measures among owl populations showed a rather specialized diet. In general, termites were more consumed in the dry season (April to September), whereas beetles were more preyed on in the rainy season (October to March). The greater predation on these prey may be understood by their higher temporal abundance in the environment. Therefore, this result showed temporal opportunism by the owls. The UPGMA clustering pattern of different Burrowing Owl population diets seemed to be related to the degree of environmental disturbance. Even though the data were from only six areas this result suggested opportunistic food habits of the Burrowing Owl.

INTRODUCTION

The Burrowing Owl *Athene cunicularia* is widely distributed from south-west Canada through western North America to southern Chile and Argentina, with isolated populations in the Caribbean Islands and Florida (Burton 1984; del Hoyo *et al.* 1999; König *et al.* 1999). This small owl species (120-250g) inhabits open areas, such as grasslands, savannahs, pastures and disturbed fields (Sick 1993; del Hoyo *et al.* 1999; König *et al.* 1999). Its long legs appear to be an adaptation to a terrestrial life, since its foraging activities take place mostly on the ground. This owl is nocturnal-diurnal, though hunting seems to take place mainly in the crepuscular period (Thomsen 1971; Haug *et al.* 1993). Abandoned burrows excavated by other animals, such as prairie dogs in North America and armadillos in South America, are used as nests.

The feeding ecology of the Burrowing Owl has received considerable attention, mainly in North America (see reviews in Clark *et al.* 1978; Johnsgard 1988; Haug *et al.* 1993). On the other hand, few quantitative studies on its diet have been published in the Neotropical region, mainly in Argentina (e.g. Bellocq 1987; Bellocq & Kravetz 1994; Kittlein *et al.* 2001) and Chile (e.g. Jaksic & Marti 1981; Silva *et al.* 1995). Despite being a relatively common species all over Brazil (Sick 1993), virtually no study was published on its feeding ecology in that country, with the exception of some local publications (e.g. Soares *et al.* 1992; Motta-Junior & Alho 2000).

The aim of this research was a comprehensive analysis of the diet of the subspecies *A. cunicularia grallaria* in six localities under the influence of the biome of Cerrado in south-east Brazil. We analysed the diets quantitatively by number of prey, estimated biomass consumed, seasonality and food niche breadth measures.

STUDY AREAS

Collection of pellets was conducted in six different areas in São Paulo State, south-east Brazil. Each of them showed distinct levels of disturbance, from a heavily altered area to a preserved Ecological Station:

The Ecological Station of Itirapina (ESIT, 22°15' S; 47°49' W) is located in the municipalities of Itirapina and Brotas. The vegetation cover is essentially natural, ranging from grasslands to savannahs. Contrary to the other study areas, there are no human buildings and night-lights. ESIT is one of the last remnants of savannah in São Paulo State. We collected pellets from eight to 18 owls between 2001 and 2002.

The campus of the Universidade Federal de São Carlos (UFSC, 21° 58′S; 47° 52′W) is in São Carlos municipality. Besides some urban and altered areas, there are savannah and secondary grassland savannah. We collected material from eight to 26 owls during 1992-1993.

Chacara Mattos (CMAT, 21° 59′S; 47° 56′W) is located in the São Carlos municipality. Vegetation cover is formed by plantations of *Pinus* spp. and disturbed grassland savannahs with dominance of exotic grasses (*Melinis* and *Brachiaria*). The pellets were obtained from six to 14 individuals in 1992-1993.

The Experimental Station of Luiz Antonio (ESLA, 21° 33′S; 47° 51′W) is in the municipality of Luiz Antonio. Pellets collected in 1992-1993 from 12 to 28 owls were in pastures surrounded by *Pinus* spp. and *Eucalyptus* spp. plantations and dense savannah ("cerradao").

The Centro de Ciências Agrárias (CCAG, 22° 30′S; 47° 33′W) is located in Araras municipality. Sugar cane plantations and disturbed fields outline this disturbed landscape. We collected pellets from six to eight owls in the dry season of 1992.

São Carlos downtown (DSCA, 22° 02´S; 47° 54´W) is the most disturbed study site, where burrows of owls were located in a grass field, surrounded by several buildings and exotic trees. Four to six individuals provided the basis for pellet collection between 1992-1994.

The macro region where the six populations of the Burrowing Owl were studied is in the Cerrado biome, characterized by grasslands and savannahs. The climate is a transition between Cwa and Aw according to Köppen's classification, or rainy tropical, with marked dry (April to September) and wet or rainy (October to March) seasons. More detailed descriptions of Cerrado biome and its conservation are in Eiten (1972) and Silva & Bates (2002).

METHODS

Pellet samples were collected monthly near nests and roost sites. This material was oven-dried (50° C) for 24hrs for storage and analysis. Prey remains were identified by comparison with a reference collection from the study site. Prey individuals were quantified by pairing mandibles, except for anura, beetles and scorpions. In these groups, pairs of pelvic girdles, number of heads and stings were used, respectively. Complete ingestion of vertebrate prey was assumed, since crania and other body bones were commonly found in pellets. Prey biomass consumption in the owls' diet was estimated from mean prey body weights found in the reference collection or in the literature (Motta-Junior 1996; Marini *et al.* 1997). Both analysed pellets and the reference collection are deposited in the Departamento de Ecologia, Universidade de São Paulo, Brazil.

Mean body weight of small mammal prey (MWSM), i.e. rodents, opossums and bats, was calculated according to Jaksic & Marti (1981). The Kruskal-Wallis test (Zar 1999) was employed to compare MWSM in the six localities using the statistical package BIOESTAT v. 2 (Ayres *et al.* 2000).

Seasonality in the diet was assessed by contingency tables using chi-square test (Zar 1999). We estimated food-niche breadth (FNB) with standardized Levins's measure (Marti 1988; Krebs 1999), because pellet samples between localities had different sample sizes and/or numbers of available prey types. We considered both major taxonomic groups as Class and Order (FNBmg) and finer taxonomic levels like genus and species (FNBsp) for calculations of the Levins's index. The former is useful for an indication of the versatility of the predator in capturing and handling different prey types, whereas the latter provides possibly improved discrimination between diets (Greene & Jaksic 1983). In most cases, invertebrates were generally identified by order or family, whereas vertebrates were frequently recognized by genus and species.

Diet similarities among populations of the Burrowing Owl were calculated using Percent Similarity index, one of the most recommended by Wolda (1981) and Krebs (1999). Since data for number of prey and estimated biomass showed high amplitudes, prior to the analysis these were transformed to natural logarithms. The statistical package MVSP v. 3.0 (Kovach 1998) was used for the UPGMA cluster analysis of the diets in six localities.

RESULTS AND DISCUSSION

The analysis of 1,044 pellets and 54 pellet debris yielded 11,633 prey individuals distributed in approximately 77 food items (see Appendix). Invertebrates were numerically the main prey (66.4-96.7%), mostly represented by termites, orthoptera and beetles (Table 1). Numerical prevalence of invertebrates in the diet was also reported in different areas, as in Argentina (Bellocq 1987), North America (Haug *et al.* 1993) and Mediterranean habitats of Chile, Spain and California (Jaksic & Marti 1981). Conversely, the high consumption of termites reported here in at least two localities (Table 1) was not observed in other studies. Arachnids, in particular spiders and scorpions, were preyed on at most localities (see Appendix), a trend previously emphasized by Lourenço & Dekeiser (1976). By number of prey individuals, most of the owl populations were essentially insectivorous.

On the other hand, by estimated biomass consumption, vertebrates (mainly small rodents) formed the bulk of the diet, yielding 36.0-87.2% of total biomass consumed in each locality (Table 1). Among vertebrates, the terrestrial rodents *Calomys tener* and *Bolomys lasiurus*, common grassland savannah species in Central and South-east Brazil (Alho *et al.* 1986; Motta-Junior 1996), were responsible for large proportions of biomass in almost all study sites. The high biomass consumption of rodents is in agreement with findings in Johnsgard (1988), Jaksic & Marti (1981) and Marti (1974). In our study three populations can be considered mostly carnivorous (DSCA, CMAT and CCGA), whereas the remainder can be classified as insectivorous/carnivorous.

Contrary to findings in North America (*e.g.*, Thomsen 1971; Haug *et al.* 1993), in which the foraging activity of the Burrowing Owl is largely diurnal, at least in south-east Brazil most prey are nocturnal in their activities (see Appendix). This suggests that Brazilian Burrowing Owls probably forage mainly at night.

Despite variation among localities (Figure 1A), numerically the most consumed prey size was between 0.1 and 1.0g, as orthoptera, spiders and some beetles. In contrast, by biomass prey weighing between 1.1 and 100.0g yielded the bulk of the diet (Figure 1B), represented by larger insects and mainly small vertebrates.

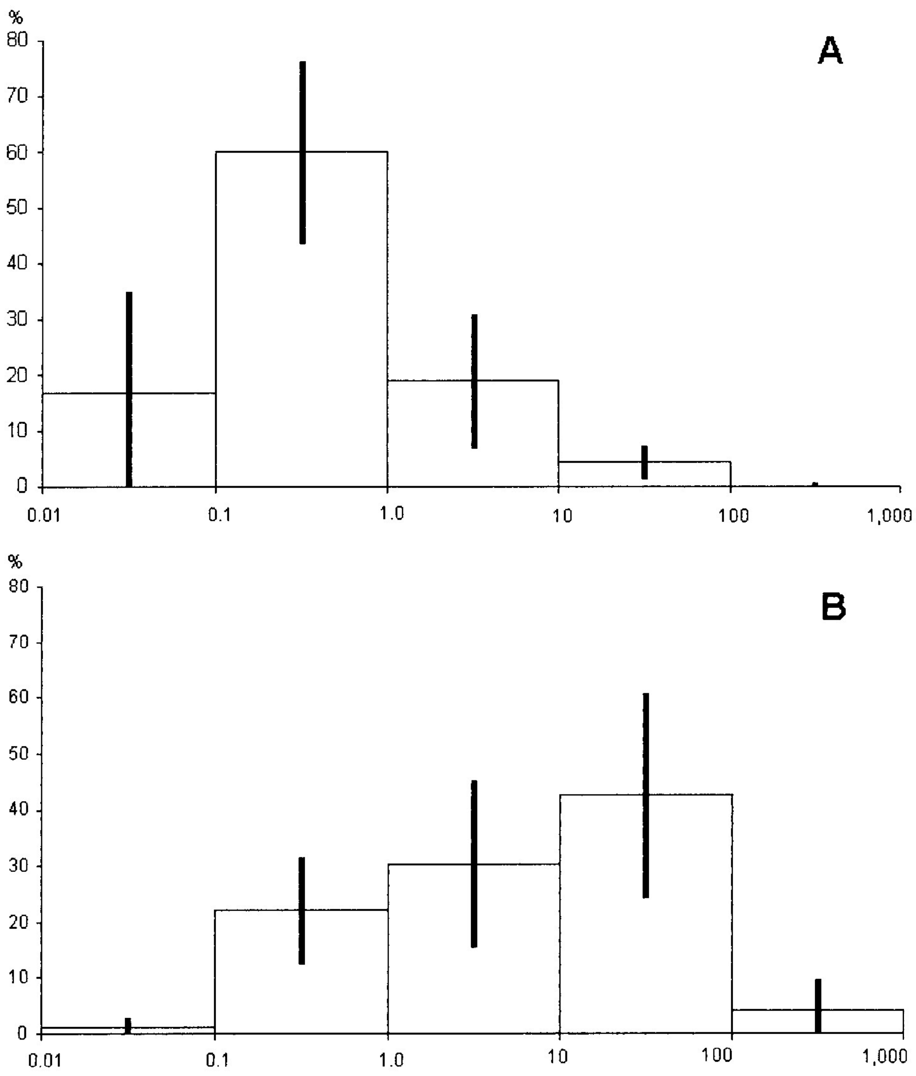
The mean body weight of small mammals consumed by the Burrowing Owl ranged from 13.2 to 18.1g in the six study sites (Table 1). A Kruskal-Wallis test showed that the MWSM was significantly different among owl populations ($H = 22.3$; d.f. = 5; $p = 0.0005$). Differences between ESIT-UFSC ($p = 0.003$), ESIT-DSCA ($p = 0.007$), UFSC-CMAT ($p = 0.001$) and CMAT-DSCA ($p = 0.016$) were significant. In spite of these differences among populations, small mammals preyed on in south-east Brazil were always smaller than in the Mediterranean habitats of Chile, California and Spain, where the MWSM varied from 55.2 to 66.3g (Jaksic & Marti 1981). Most Brazilian small mammals weighed less than 50g, except for only one species, *Clyomys bishopi* (140g) (see Appendix), whereas many Mediterranean small mammals were heavier than 100g (Jaksic & Marti 1981). Contrary to the Mediterranean habitats, lagomorphs were not found

Table 1. Diet of the Burrowing Owl at six localities in Southeast Brazil by number of individuals and estimated biomass. Figures are percentages. FNBmg – standardized Levins's food niche breadth for major groups of prey; FNBsp - standardized Levins's food niche breadth for finer taxonomic levels; MWSM – mean body weight of small mammals (g).

Major prey groups	*ESIT*		*UFSC*		*CMAT*		*ESLA*		*CCAG*		*DSCA*	
	Number	*Biomass*	*Number*	*Biomass*	*Number*	*Biomass*	*Number*	*Biomass*	*Number*	*Biomass*	*Number*	*Biomass*
Mammals	2.3	34.3	2.1	40.0	6.4	67.8	2.3	27.8	6.9	60.4	5.1	24.3
Birds			0.2	4.8	0.3	2.0	0.3	4.9	0.3	1.7	1.8	22.1
Lizards & Snakes	0.8	7.1	1.5	8.4		0.3	0.1	1.2	0.3	1.7	23.3	36.2
Frogs & Toads	1.2	3.8	0.5	2.1	0.2	0.4	0.5	2.1			3.2	4.6
Arachnids	20.0	5.8	10.5	5.3	7.3	2.1	9.2	3.8	5.4	1.7	3.2	0.6
Orthoptera	24.6	13.5	20.1	13.4	30.7	14.0	33.2	19.3	63.3	21.5	20.5	3.9
Cockroaches	12.8	11.1	0.4	0.3	1.1	0.8	2.7	4.4	0.9	0.7	4.1	1.5
Termites	2.3	0.1	41.3	3.1	37.1	1.8	8.9	0.6			7.1	0.2
Beetles	25.2	21.5	15.9	16.6	13.0	7.8	38.8	34.1	14.0	6.6	15.4	5.1
Other insects	9.9	1.6	4.4	1.1	1.5	0.5	3.1	0.9	0.9	0.1	13.1	0.6
Other	0.9	1.2	3.2	5.0	2.4	2.5	0.8	1.0	8.1	5.6	3.0	1.0
Totals	1,093	1,242.0	3,998	3,757.7	4,279	6,039.6	1,494	1,608.5	335	586.3	434	1,395.9
FNBmg	0.469	0.432	0.298	0.353	0.286	0.105	0.258	0.322	0.163	0.173	0.567	0.308
FNBsp	0.434	0.312	0.083	0.214	0.100	0.094	0.242	0.242	0.168	0.237	0.264	0.144
MWSM ± SD (N)	17.0 ± 25.9 (18)		18.1 ± 9.2 (83)		15.0 ± 7.6 (273)		13.2 ± 4.9(34)		15.4 ± 7.9 (23)		15.4 ± 11.6(22)	

as a prey item in Brazilian Burrowing Owls' diet, even though they were present in the environment (pers. obs.). Another explanation for the lower MWSM found in the present study may have been the use of mean body weights including juveniles, sub-adults and adults of small mammals. This was justified by the observation that owls also preyed on some sub-adults and juveniles, as revealed by analysis of worn out teeth.

Figure 1. Prey size distribution in six populations of the Burrowing Owl. Mean percentages (n=6) and associated standard deviations (black bars) of number of prey (A) and biomass (B) as a function of prey body mass class.



Irrespective of the level of analysis, the standardized FNB among owl populations ranged from intermediate to very low values (Table 1) showing a rather specialized diet. This apparently is contrary to the findings in which sit-and-wait foragers (like the Burrowing Owl, Jaksic & Carothers 1985) have broader diets (*e.g.*, Schoener 1969). Nevertheless, this narrower food niche breadth can partially be understood by the fact that the Burrowing Owl can also forage secondarily as an active searcher (Jaksic & Carothers 1985, pers. obs.). Higher consumption of termites resulted in narrower diet breadths in CMAT and UFSC concerning number of prey, by both taxonomic levels (Table 1). In these areas termite mounds were common (pers. obs.) suggesting opportunistic consumption by the owls. In terms of biomass consumption, low values in the CMAT may be explained by the great importance of mammals (Table 1). In comparison to UFSC, the availability of small mammals in CMAT was three times higher (*cf.* Motta-Junior 1996), explaining their heavier consumption by owls. In general, the higher FNB values were in the ESIT population (Table 1). According to Marti (1988), this may probably be a consequence of a richer prey assemblage available in the area and richer patchiness of vegetation, since ESIT is covered with large proportions of natural physiognomies of savannah. Conversely, in terms of number of individuals, DSCA showed the wider food niche breadth among the studied populations. Although this is the most disturbed site with low prey richness, food items such as the exotic *Passer domesticus, Mus musculus* and *Hemidactylus mabuya* were abundant and consumed to some extent evenly by DSCA owls.

Table 2. Seasonality in the diet of the Burrowing Owl at five localities in Southeast Brazil. Figures are percentages.

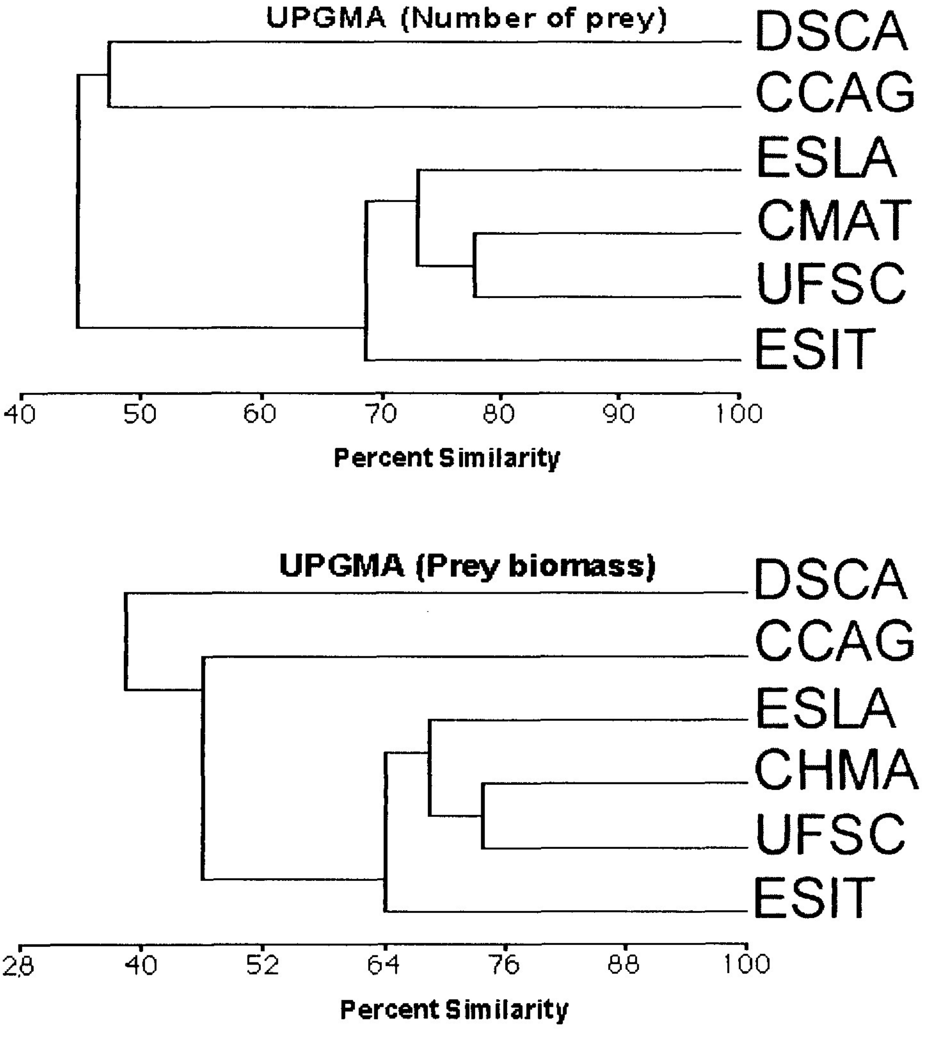
Major prey groups	*ESIT*		*UFSC*		*CMAT*		*ESLA*		*DSCA*	
	Dry	*Wet*	*Dry*	*Wet*	*Dry*	*Wet*	*Dry*	*Wet*	*Dry*	*Wet*
Mammals	2.5	2.0	2.0	2.2	7.1	4.4	1.8	3.5	5.2	4.7
Birds			0.1	0.3	0.3	0.3	0.3	0.2	2.0	1.6
Snakes & Lizards	1.2	0.4	1.1	2.4	0.1	0.1	0.1	0.2	12.3	50.0
Frogs & Toads		2.6	0.2	1.2	0.1	0.6	0.2	1.4	4.2	0.8
Arachnids	31.2	6.8	10.6	10.0	6.7	8.8	10.5	5.8	4.2	0.8
Orthoptera	27.3	23.0	19.8	21.1	25.3	44.4	36.0	26.5	25.0	9.6
Cockroaches	16.4	8.6	0.3	0.7	0.9	1.6	2.2	4.2	3.6	5.6
Termites	3.2	1.0	53.0	16.3	49.3	6.5	12.2	0.7	10.4	
Beetles	13.5	37.2	7.9	31.1	6.7	28.4	32.5	54.3	18.2	7.9
Other insects	3.7	17.6	1.5	10.7	1.1	2.5	3.4	2.3	10.7	19.0
Other invertebrates	1.0	0.8	3.5	4.0	2.4	2.5	0.8	0.9	4.2	
No. of individuals	593	500	2,731	1,267	3,029	1,250	1,063	431	308	126
FNBmg	0.443	0.361	0.194	0.421	0.211	0.242	0.280	0.169	0.601	0.282
χ^2; *P*	233.88;	<0.001	786.33;	<0.001	905.73;	<0.001	117.83	<0.001	101.71	<0.001

Note: degree of freedom is 10 for all areas, except for EEIT (df = 9).

The consumption of major groups of food items was dependent on the season of the year for all six populations of Burrowing Owls (Table 2). In general, termites were more consumed in the dry season, when their abundance was higher in the environment following first rains at the end of this season.

Conversely, beetles were more captured in the rainy season (Table 2) when they were more abundant and conspicuous (*cf.* Motta-Junior 1996). Therefore, at least for these items, the owls showed temporal opportunism. The high consumption of the exotic geckos (*Hemidactylus mabuya*) at DSCA, mainly in the wet season, is possibly due to major activity of these reptiles searching for insects at this time of year (pers. obs.). Some owl populations may exhibit more generalist diets in the dry season (ESIT, ESLA and DSCA), whereas others in the wet season (UFSC and CMAT). This apparent discrepancy may reflect simply different temporal availability of prey among localities.

Figure 2. Clustering of Burrowing Owl populations in South-east Brazil according to their diets, both in terms of prey numbers and prey biomass consumed..



Irrespective of the use of number or biomass of prey, the clustering pattern (Figure 2) of different Burrowing Owl population diets may be related to the degree of environmental disturbance. Diets from highly disturbed sites (DSCA, CCAG) were clearly dissimilar to less disturbed ones. By contrast, the more preserved area (ESIT) was to some extent isolated from areas with intermediate disturbance (Figure 2). Although data were from only six areas this result suggested opportunistic food habits of the Burrowing Owl. The commonness of this owl in Brazil, including disturbed sites and the colonization of deforested areas (Sick 1993) can be at least partially explained by its flexible feeding ecology.

The existence of differences in the diet of the distinct populations of owls has been explained by environmental heterogeneity (Jaksic & Marti 1981; Marti 1988) and changes in diversity or abundance of prey species (Herrera 1974; Herrera & Hiraldo 1976; Marti 1988). Further studies assessing the availability of prey simultaneously with the diet in each locality may improve our understanding of the Burrowing Owl feeding ecology.

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APPENDIX

Prey of the Burrowing Owl in six localities in southeast Brazil. The figures are numbers of individuals counted in pellets and debris. Abbreviations of localities in STUDY AREAS. Period of activity: N – nocturnal; D – diurnal.

Prey (mean body mass; period of activity)	ESIT	UFSC	CMAT	ESLA	CCAG	DSCA
MAMMALIA						
RODENTIA						
Akodon cursor (21.4; ND)		1	3	1		
Bolomys lasiurus (29.7; ND)	1	26	55	1	5	
Calomys tener (10.8; N)	18	34	175	11	15	
Clyomys bishopi juvenile (140.0; N)	1					
Mus musculus (11.0; ND)		6	7		1	18
Oligoryzomys nigripes (11.9; N)	3	11	22	12		
Rattus rattus juvenile (44.0; ND)		1				3
Unidentified medium sp. (30.0; ?)				1		
Unidentified small spp. (10.0; ?)	1			4		
MARSUPIALIA						
Gracilinanus spp. (16.3; N)	1		10	4	2	
CHIROPTERA						
Glossophaga soricina (9.6; N)						1
Unidentified Phyllostomidae (25.0;N)		4				
Unidentified juvenile sp. (5.0; N)			1			
AVES						
COLUMBIFORMES						
Zenaida auriculata (133.0; D)		1				1
PASSERIFORMES						
Passer domesticus (25.0; D)						7
Sporophila caerulescens (10.0; D)			1			
Volatinia jacarina (9.8; D)		4	10	3		
Unidentified small spp. (10.0; D)		1	1		1	
Unidentified medium sp. (50.0; ?)				1		
REPTILES						
SAURIA						
Hemidactylus mabuya (5.0; N)		59				101
Unidentified small spp. (10.0; D)	5		2		1	
SERPENTES						
Unidentified small spp. (9.5; ?)	4	2		2		
AMPHIBIA						
ANURA						
Bufonidae spp. (2.0; N)	2	5	6	3		5
Hylidae spp. (2.5; N)	8	4	1			
Leptodactylidae (9.2; N)	2	1		1		3
Unidentified spp. (4.5; N)	1	11	2	4		6

INSECTA						
ODONATA						
Calopterygidae (0.5; D)	1					
ORTHOPTERA						
Acrididae (0.70; D)	19	45	30	112	16	3
Tettigoniidae (0.58; N)	53	362	391	215	146	65
Stenopelmatidae (0.77; N)	42	147	360	48	2	10
Gryllidae (0.60; N)	119	229	523	105	48	8
Gryllotalpidae (0.60; N)	13	8	3	1		3
Unidentified orthopterans (0.50; N)	23	12	6	15		
MANTODEA						
Mantidae spp. (0.61; D)	11	23	27	8		
BLATTODEA						
Periplaneta sp. (1.13; N)					2	18
Parahormetica sp. (1.81; N)	53	3	21	38	1	
Unidentified Blattidae (0.48; N)	87	13	27	3		
ISOPTERA						
Termitidae spp. soldier/worker(0.07;N)	25	1654	1588	133		31
DERMAPTERA						
Unidentified sp. (0.20; N)		95	2	19		
HEMIPTERA						
Reduviidae sp. (0.45; N)			2			
HOMOPTERA						
Cicadellidae (0.12; ND)			1			
COLEOPTERA						
Hydrophylidae (1.0; ND)	3					
Carabidae spp. (0.31; N)	58	172	175	182	20	24
Silphidae sp. (0.20; N)		9				
Staphylynidae sp. (0.18; N)				1		1
Elateridae (0.34; N)		5	1	3		1
Buprestidae (0.80; N)		3				
Tenebrionidae (0.90; N)		2				
Scarabaeidae/Geotrupinae (0.21; N)	5	23	22	18		
Scarabaeidae/Rutelinae (0.50; N)	40		7			1
Scarabaeidae/Scarabaeinae (1.80; N)	79	241	76	197	1	30
Scarabaeidae/Dynastinae (1.75; N)	38	49	128	39	15	2
Unidentified Scarabaeidae (0.42; ?)	3	33	62	117	10	
Lucanidae (1.0; ND)	5					
Cerambycidae (1.45; N)			3	2		1
Prionidae (2.0; N)				4		1
Curculionidae (0.20; N)	25	53	73	14	1	2
Unidentified adult Coleoptera(0.27;?)	6	40	8	3		4
Unidentified larvae Coleoptera (0.25; ?)	13	6	2			
LEPIDOPTERA						
Unidentified adult (1.20; N)			3	1		
DIPTERA						
Unidentified adult (0.10; D)		1				
Larvae Cuterebridae (0.30; ?)		1				
HYMENOPTERA						

Mutillidae (0.18; ND)				2		
Formicidae spp. (0.15; ND)	53	55	27	6	3	55
Vespidae (0.20; D)	1					
Apidae (1.40; D)			1			
Unidentified small Hymenoptera (0.1; ?)	40			6		
Unidentified Insects (0.40; ?)	2		2	5		2
GASTROPODA						
Helix sp. (0.5; N)		1		2		
ARACHNIDA						
Scorpiones						
Bothriurus spp. (0.27; N)	65	85	139	35		
Tityius sp. (0.36; N)	50	8	20	22		
Araneae						
Lycosidae spp. (0.56; N)	37	298	148	75	18	14
Unidentified spp. (0.60; ?)		3				
Opiliones						
Gonyleptidae spp. (0.24; N)	67	25	4	5		
ISOPODA						
Oniscidae sp. (0.17; N)		2			6	4
DIPLOPODA						
Julida						
Julidae spp. (1.51; N)	10	123	99	10	21	9
Polydesmida						
Unidentified sp. (0.47; N)			2			
NUMBER OF ITEMS	43	50	48	46	21	31
NUMBER OF INDIVIDUALS	1,093	3,998	4,279	1,494	335	434
NUMBER OF PELLETS	106	246	404	172	32	84
NUMBER OF PELLET DEBRIS	3	18	23	6	1	3