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SMALL MAMMAL SELECTION BY THE WHITE-TAILED HAWK IN SOUTHEASTERN BRAZIL

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ABSTRACT.—We analyzed diet and prey selection of the relatively unknown *albicaudatus* subspecies of the White-tailed Hawk (*Buteo albicaudatus*). Our study was based on an analysis of 259 pellets collected from September 2000 to September 2001 in the municipality of Juiz de Fora in southeastern Brazil. We also assessed the abundance of small mammals with pitfall traps (2,160 trap-nights). Small mammals composed 52.5% of the estimated biomass consumed by the hawks, and selection appeared to be mediated by abundance. The Bonferroni confidence intervals procedure revealed that when abundance of small mammals was higher, the hawks were selective, preying on *Calomys tener* more than would be expected by chance ($P < 0.05$); other rodents were consumed less than expected. *Oligoryzomys nigripes*, *Oxymycterus* sp., and *Gracilinanus* spp. were taken in the same proportion as they were found in the field. During reduced prey abundance (October–March), White-tailed Hawks preyed opportunistically on small mammals. Differences in habits and vulnerability of small mammals may explain prey selectivity in the White-tailed Hawk. *Received 5 October 2004, accepted 3 October 2005.*

The White-tailed Hawk (*Buteo albicaudatus*) is a poorly known species ranging from southern Texas to northern Argentinean Patagonia (Farquhar 1992, Thiollay 1994). Information on its ecology is scarce and largely descriptive or anecdotal, with most studies having been conducted in North America (Stevenson and Meitzen 1946, Kopeny 1988, Farquhar 1992). Data on type and number of prey have received some attention in Texas (see Farquhar 1992), but prey selection relative to prey abundance remains unknown. Only three studies report on the diet of this raptor in the Neotropics. Schubart et al. (1965) examined contents of two stomachs containing mainly insects; Brasileiro et al. (2003) reported predation on a snake, and Motta-Junior and Granzinolli (2004) observed consumption of a Ringed Kingfisher (*Megaceryle torquata*). The species is thought to be an opportunistic predator (Stevenson and Meitzen 1946, Kopeny 1988), and in Texas, half of the prey biomass comprises mammals (Farquhar 1986).

Opportunistic predators generally take prey in accordance with their abundance in the field, whereas selective predators consume prey in proportions that differ from those available (Jaksic 1989). This selectivity or opportunism may be explained in relation to the energy costs and benefits involved in the capture and handling of prey. Predators may consume the most profitable, but not necessarily the most abundant, prey (Schoener 1971, Korpimäki 1985, Stephens and Krebs 1986, Iriarte et al. 1989, Jaksic 1989). According to optimal foraging theory, predators behave to maximize their fitness, which is done by maximizing their net rate of energy intake (Emlen 1966, 1968; Schoener 1971; Stephens and Krebs 1986). Thus, prey selection by a predator not only depends on prey energy content, but also on the predator's success in three basic stages: finding, handling, and consuming prey. Selectivity can be assessed by observing differences among the prey species at any of these steps. Prey selectivity may be a result of both prey and predator morphology and behavior (Corley et al. 1995). Emlen (1966, 1968) hypothesized that predators will exhibit a greater degree of dietary selection when their prey are abundant, but will be more opportunistic when food is scarce. Additionally, a predator may eat more abundant prey at greater frequencies than expected in relation to abundance (Emlen 1966). Here, we analyze prey selection by the White-tailed Hawk relative to prey abundance, evaluating previous assertions about the opportunistic feeding behavior of this species (Stevenson and Meitzen 1946, Farquhar 1986, Kopeny 1988).

METHODS

Study site.—We conducted fieldwork on private farmlands in northern Juiz de Fora (21° 41′ S, 43° 27′ W), in the state of Minas Gerais

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in southeastern Brazil (Fig. 1). The elevation of our study area (17,537 ha) ranged from 670 to 800 m; the topography is mountainous. The climate is Humid Subtropical, winters are dry, and annual rainfall averages 1,536 mm. The wet season extends from October to April (192 mm rainfall, mean temperature = 20.2° C), and the dry season occurs from May to September (37 mm rainfall, mean temperature = 16.8° C). Originally, the dominant vegetation was semi-deciduous forest; now the area is primarily farmland, pastures, patches of second-growth vegetation, and plantations of exotics (e.g., *Eucalyptus* spp. and *Pinus* spp.; Juiz de Fora 1996).

General diet.—The analysis of the White-tailed Hawk's diet was based on 259 pellets, which we collected from seven nesting and six roosting sites of approximately seven pairs. We collected and identified (by size and shape) all pellets from perches used exclusively by White-tailed Hawks. We oven-dried the collected material and treated it with a 10% NaOH aqueous solution (Marti 1987). Prior to chemical treatment, we removed remains of scales, fur, and feathers, and later added them to other remains, such as mandibles, teeth, and invertebrate exoskeletons. We identified remains by comparing them to a reference collection from the study area. Invertebrates were generally identified to family and order, whereas vertebrates were identified mostly to genus or species. Prey biomass was estimated by counting the minimum number of individuals in pellets and then multiplying this number by the mean body mass of each species at the study site (Marti 1987).

Prey selection.—We estimated the relative abundance of small mammals in the field by monitoring five sets of drift-fence pitfall traps (Friend et al. 1989). Traps were distributed systematically around most of the hawks' hunting sites (Fig. 1), determined before and during the study period through observations of foraging individuals. We collected pellets during small mammal trapping. Each set of pitfall traps consisted of 12 buckets (36 l each), totaling 60 traps. From September 2000 to September 2001, we operated traps monthly for 3 consecutive days, totaling 2,160 trap-nights. Captured mammals were identified, weighed, sexed, earmarked, and released. An index of small mammal abundance for each month was based on the total number of individual first captures (recaptures were not counted).

Indices of prey abundance are assumed to reflect prey availability, but this may not necessarily be true (Jaksic 1989). Traps should be efficient, nonselective, and catch the entire range of small mammal prey. Moreover, traps should be placed in patches where and when the predator hunts. Our procedures fulfilled these assumptions, in terms of both time and place of foraging. Our traps were open 24 hr per day, so that both diurnal and crepuscular activities of White-tailed Hawks were accounted for by the trapping procedures. Pitfall traps appear to be less selective and more efficient, capturing larger numbers of species, individuals, and age classes compared with traditional live traps (Williams and Braun 1983; MAMG unpubl. data).

Analyses.—We conducted a *G*-test to test the goodness-of-fit of the frequency distributions of prey in the diet and in the field (Zar 1984). We interpreted nonsignificant results to mean that White-tailed Hawks exploited prey in proportion to their abundance in the field; significant differences suggested that the hawks ''preferred'' or ''avoided'' some small mammal species, hence apparently selecting or avoiding prey. To confirm selection or avoidance of prey, we used the Bonferroni confidence intervals procedure for each prey species (Neu et al. 1974, Byers et al. 1984, Plumpton and Lutz 1993, Martinez and Jaksic 1997, McLoughlin et al. 2002). If the expected proportion of consumption was not included in the confidence interval, then the observed and expected consumption differed significantly. If the confidence interval included the expected proportion of consumption, then the hypothesis that prey species were preferred or avoided was rejected. All tests were considered significant at $P < 0.05$.

RESULTS AND DISCUSSION

General diet.—Numerically, the main prey were insects, followed by small mammals, reptiles, and birds (Fig. 2). Small mammals composed the bulk of biomass, followed by insects, reptiles, and birds. Our results are similar to those of Stevenson and Meitzen (1946), Farquhar (1986), and Kopeny (1988).

Only 5 of 12 genera of small mammals

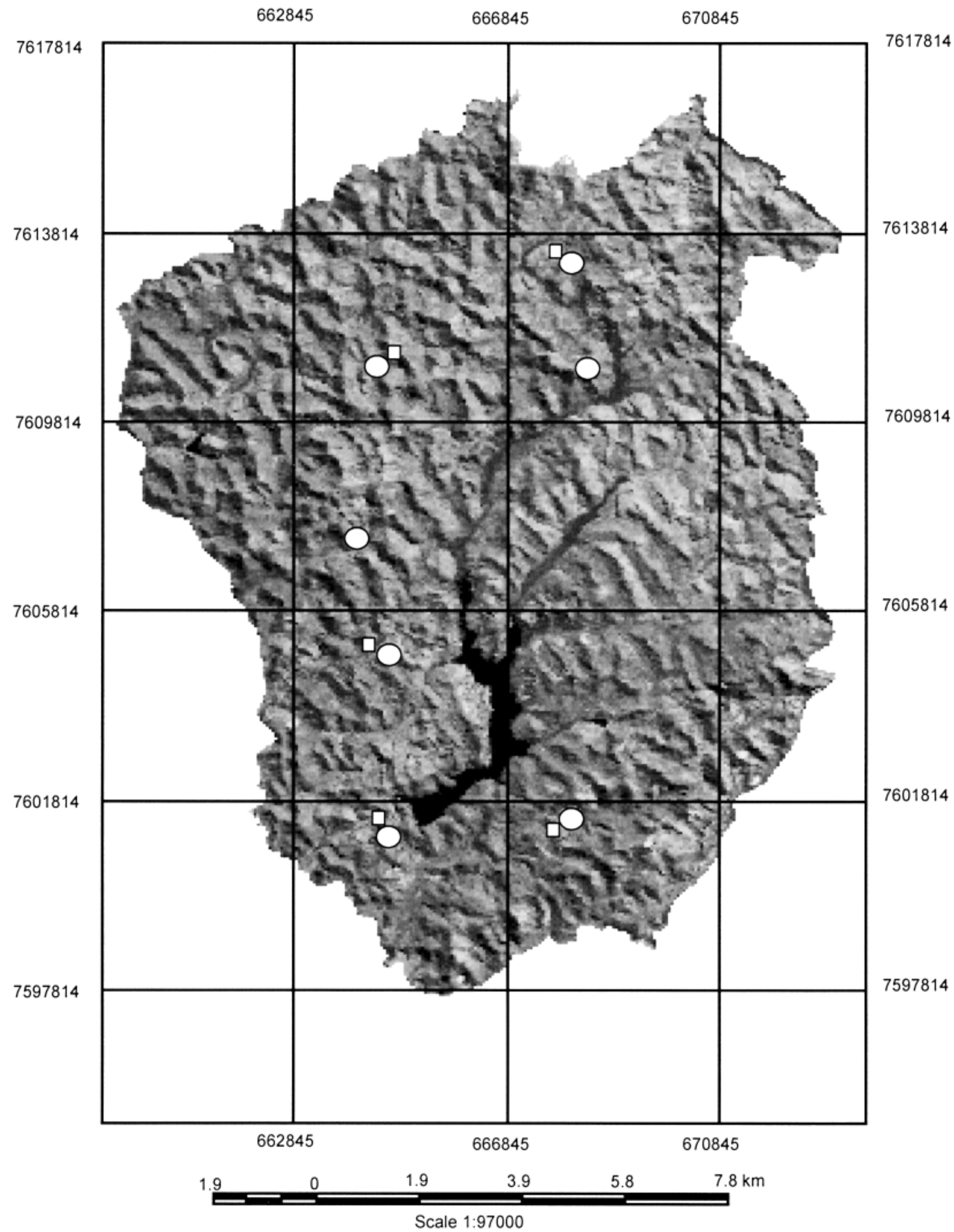

FIG. 1. Satellite image (LANDSAT 7/ETM, 27 June 2000) of study area in Juiz de Fora municipality, Minas Gerais, southeastern Brazil. Coordinate grid system is UTM (Zone 22, Corrego Alegre). White squares are sites of pitfall traps; white circles are nest and perch sites of White-tailed Hawks.

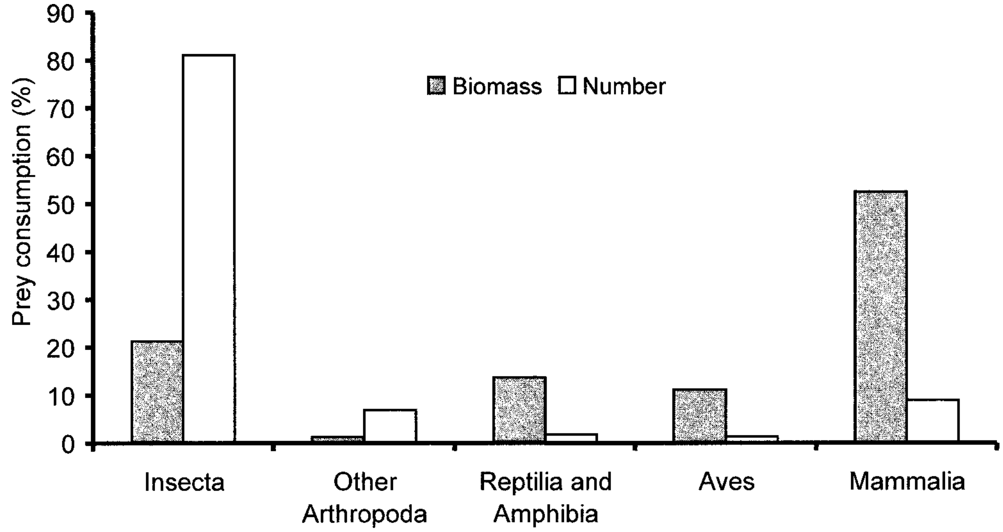

FIG. 2. Number of individuals and estimated biomass of prey groups consumed by White-tailed Hawks from September 2000 to September 2001, Juiz de Fora municipality, Minas Gerais, southeastern Brazil.

(*Calomys*, *Akodon*, *Oligoryzomys*, *Oxymycterus*, *Gracilinanus*) found in the study area (Appendix) were identified in White-tailed Hawk pellets. The genus *Akodon* was represented mostly by *A. lindberghi*, with some *A. cursor*; both were found in pellets and in pitfall traps. The seven genera whose remains were not found in pellets were uncommon: only 12 individuals (4.6% of total captures) were trapped in pitfalls (Appendix). Prey behavior or habitat choice may explain the absence of some genera in the diet of White-tailed Hawks. *Rhagomys*, *Oryzomys*, and *Juliomys* (=*Wilfredomys*) have arboreal or scansorial habits, whereas *Thaptomys*, *Bibimys*, *Bolomys*, and *Blarinomys* display subterranean or fossorial habits, and all but *Bolomys* and *A. lindberghi* inhabit mostly forests (Emmons 1990, Eisenberg and Redford 1999, Nowak 1999; JCM-J pers. obs.). Furthermore, although the genus *Oxymycterus* was as uncommon as the seven genera not recorded in White-tailed Hawk pellets, its habitat is mostly open vegetation (MAMG unpubl. data).

Prey selection.—White-tailed Hawks exhibited differential predation on small mammal species when both seasons were combined ($G = 32.54$, $P < 0.001$; Table 1). The

TABLE 1. Small mammal prey selection by White-tailed Hawks in Juiz de Fora municipality, Minas Gerais, southeastern Brazil, from September 2000 to September 2001. Observed values (Obs) are actual frequencies in the diet; expected values (Exp) are frequencies calculated from proportions obtained in the field by pitfall trapping.

	Dry season		Wet season		Total diet	
Species	Obs	Exp	Obs	Exp	Obs	Exp
Akodon spp.	11	33.5	6	7.5	17	40.8
Calomys tener	95	59.1	18	23.7	113	83.1
Oligoryzomys nigripes	24	41.3	14	6.8	38	47.9
Oxymycterus sp.[a]	2	0.7	1	—	3	0.7
Gracilinanus spp.[a]	4	1.4	1	2.0	5	3.5
Total	136	136.0	40	40.0	176	176.0
G[b]	52.07		7.68		32.54	
P	<0.001		0.054		<0.001	

[a] *Oxymycterus* sp. and *Gracilinanus* spp. were grouped for *G*-tests.
[b] *G*-test, df = 3.

same pattern was observed during the dry season (G = 52.07, P < 0.001), but not in the wet months (G = 7.68, P = 0.054; Table 1).

The Bonferroni confidence intervals procedure revealed that in the dry season, the hawks preyed more on *Calomys tener* and less on *Akodon* spp. than expected based on trapping data (Table 2). Conversely, in wet months, there were no differences in small mammal predation compared with the availability of small mammals in the study area (Table 2). *Oligoryzomys nigripes*, *Oxymycterus* sp., and *Gracilinanus* spp. were always consumed in the same proportion that they were found in the environment (Table 2). Hence, our findings are not entirely congruent with those of Stevenson and Meitzen (1946) and Kopeny (1988).

Other studies on small mammal populations in southeastern Brazil indicate peaks of abundance during the dry season (e.g., Motta-Junior 1996, Vieira 1997, Talamoni and Dias 1999). The same pattern was observed in our study (Fig. 3).

The high frequency of *C. tener* (sometimes considered a subspecies of *C. laucha*; Eisenberg and Redford 1999) in the White-tailed Hawk's diet may be due to its higher vulnerability. A similar suggestion was proposed by Corley et al. (1995) for other rodent and predator species in Patagonia. A less vulnerable species (*Eligmodontia typus*, better escape ability) was preyed upon less than expected by the culpeo fox (*Dusicyon culpaeus*), while the behaviorally and morphologically vulnerable *Akodon* spp. were consumed more frequently than expected. Other diet studies of owls (Motta-Junior 1996, Motta-Junior and Bueno 2004, Motta-Junior et al. 2004) in southeastern Brazil have revealed that *C. tener* is one of the main prey species, despite not being the most abundant in the field, suggesting higher vulnerability. *C. tener* is apparently mainly terrestrial and does not dig burrows (Eisenberg and Redford 1999, Nowak 1999); thus, it is more vulnerable because it is likely to be more conspicuous to the hawks. In contrast, species of *Akodon* travel in tunnels under the leaf litter and nest in burrows (Emmons 1990); thus, *Akodon* spp. may be able to escape White-tailed Hawk predation more efficiently than *C. tener*.

Our results suggest that prey selection by

TABLE 2. Bonferroni confidence intervals analysis for small mammal selection (usage) by White-tailed Hawks during the dry and wet seasons from September 2000 to September 2001, Juiz de Fora municipality, Minas Gerais, southeastern Brazil. If the expected proportion of usage (P_{io}) was greater than the upper confidence interval estimate, the prey species was consumed less than expected (−). Conversely, a P_{io} lower than the lower confidence interval estimate suggests that the prey species was exploited more than expected (+). If an expected proportion fell within the confidence interval, prey consumption was similar to prey availability (0).

	Dry season			*Wet season*		
Species	Actual proportion of usage (P_i)	Expected proportion of usage (P_{io})	Bonferroni intervals for P_i	Actual proportion of usage (P_i)	Expected proportion of usage (P_{io})	Bonferroni intervals for P_i
Akodon spp.	0.081	0.304	$0.020 \le p_i \le 0.141$ (−)	0.150	0.187	$0.004 \le p_i \le 0.295$ (0)
Calomys tener	0.699	0.435	$0.597 \le p_i \le 0.799$ (+)	0.450	0.593	$0.247 \le p_i \le 0.652$ (0)
Oligoryzomys nigripes	0.176	0.246	$0.092 \le p_i \le 0.260$ (0)	0.350	0.170	$0.155 \le p_i \le 0.544$ (0)
Oxymycterus sp.	0.015	0.005	$0.000 \le p_i \le 0.041$ (0)	0.025	0.000	$0.000 \le p_i \le 0.088$ (0)
Gracilinanus spp.	0.029	0.010	$0.000 \le p_i \le 0.066$ (0)	0.025	0.050	$0.000 \le p_i \le 0.088$ (0)

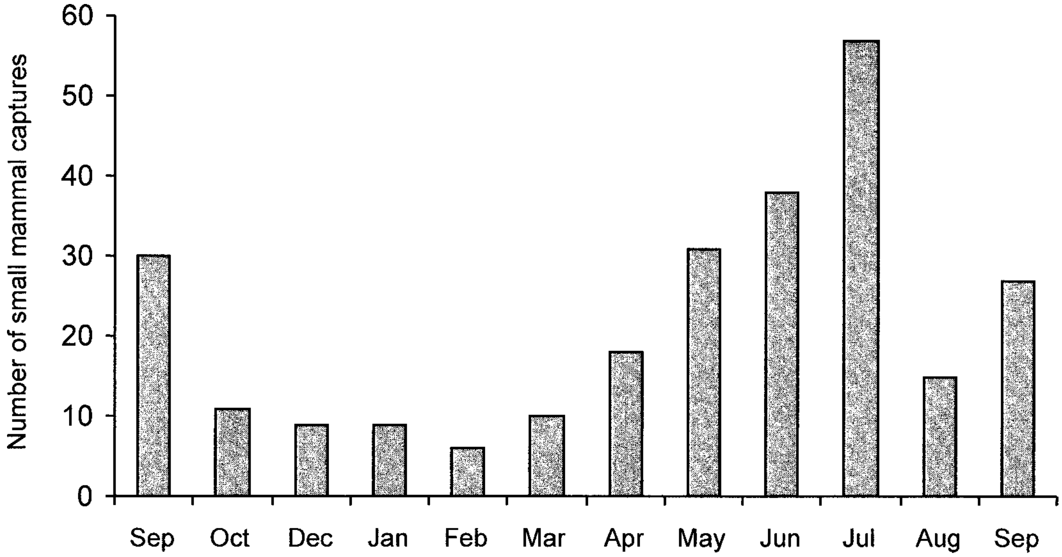

FIG. 3. Small mammal abundance from September 2000 to September 2001, Juiz de Fora municipality, Minas Gerais, southeastern Brazil. Data were not available for November 2000.

White-tailed Hawks was mediated by prey abundance. When the abundance of small mammals was higher (dry season), the hawks selected the more abundant prey, *Calomys tener* (Table 2). However, during a period of lower abundance of prey (wet season), White-tailed Hawks were opportunistic relative to small mammal species. Our results support the prediction of Emlen (1966) that predators feed selectively on very abundant prey, thus suggesting that White-tailed Hawks exploit resources depending on their availability.

In conclusion, White-tailed Hawks seem to prey selectively on a more vulnerable small mammal (*C. tener*), which has terrestrial habits and uses open habitat. The semi-fossorial *Akodon* spp. were apparently less vulnerable to the hawks. Alternatively, but not exclusively, our results support Emlen's (1966) hypothesis that predators, in times of high prey abundance, will prey selectively on species that are more abundant. Further studies of raptor diet selection in the Neotropics should stress morphological and behavioral traits of prey as a way to understand differential vulnerability to predators (e.g., Kotler 1985, Corley et al. 1995).

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APPENDIX. Rodents and opossums (*Gracilinanus* spp.) captured in pitfall traps in Juiz de Fora municipality, Minas Gerais, southeastern Brazil, from September 2000 to September 2001. For each month, we tallied only first captures. Data were not available for November 2000.

Species	Mean body weight (g)	Month												Total
		Sep	Oct	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
Akodon cursor[a]	17	1	—[b]	—	1	—	1	1	2	—	—	—	—	6
Akodon lindberghi[a]	13	—	3	2	—	—	2	1	10	7	14	4	9	52
Bibimys labiosus	19	—	—	1	—	—	—	—	1	—	—	—	—	2
Blarinomys breviceps	12	—	—	—	1	—	—	—	—	—	—	—	—	1
Bolomys lasiurus	24	—	—	1	—	—	—	—	—	—	—	—	—	1
Calomys tener[a]	12	22	6	3	5	5	5	11	12	17	24	2	6	118
Gracilinanus agilis[a]	20	1	—	1	—	—	—	—	—	1	—	—	—	3
Gracilinanus spp.[a]	19	—	1	—	1	—	—	—	—	—	—	—	—	2
Juliomys sp.	20	—	—	—	—	—	—	—	—	—	—	—	1	1
Oligoryzomys cf. *flavescens*	18	1	—	—	—	—	—	—	—	—	—	—	—	1
Oligoryzomys nigripes[a]	11	4	1	1	1	1	1	5	6	13	18	6	10	67
Oryzomys cf. *kelloggi*	29	—	—	—	—	—	—	—	—	—	—	2	1	3
Oxymycterus sp.[a]	73	1	—	—	—	—	—	—	—	—	—	—	—	1
Thaptomys nigrita	22	—	—	—	—	—	1	—	—	—	—	—	—	1
Rhagomys rufescens	27	—	—	—	—	—	—	—	—	—	1	1	—	2
Total		30	11	9	9	6	10	18	31	38	57	15	27	261

[a] Species preyed on by White-tailed Hawks.
[b] — represents no captures.