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Coyote food habits and the relative abundance of rodents in San Mateo County

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COYOTE FOOD HABITS AND THE RELATIVE ABUNDANCE OF RODENTS IN SAN MATEO COUNTY

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ABSTRACT

COYOTE FOOD HABITS AND THE RELATIVE ABUNDANCE OF RODENTS IN SAN MATEO COUNTY

By Stephanie Ann Trewhitt MacDonald

From November 2000 through October 2001, data were collected on the food habits of coyotes (*Canis latrans*) and the relative abundance of rodents at a study area located in San Mateo County, northern California. During this 12-month period, a total of 373 coyote scats were collected as the basis for determining food habits. In addition, 7103 trap-nights produced 1055 rodents used to estimate relative abundance. Results from a canonical correlation supported the hypothesis that the food habits of coyotes directly correlated with the seasonal abundance of rodent species. The results indicated that coyotes were feeding more on species, such as *Thomomys bottae, Reithrodontomys megalotis,* and *Microtus californicus* when their relative abundance was high. It was also evident that *Neotoma fuscipes* and *Sylvilagus bachmani* are staples in the coyote's diet throughout the year, as seen by the high abundance of these species in the scats across all months.

ACKNOWLEDGEMENTS

To Dr. John Matson, whose infectious passion for the study of all mammals, and endless inspiration and creativity, inspired me to become the mammalogist I am today.

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Most important, my husband, Jaime, who spent 15 months in the field with me, collecting the data for this study, keeping me laughing, giving up sleep, and enjoying all the diversity of animals one sees in the darkness. Without his hard work, patience, love, and understanding this study would have never been completed.

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INTRODUCTION

Coyotes (*Canis latrans*) are important predators and scavengers. In the northern parts of the coyote's range, which includes the area in northern California studied in this investigation, there are marked seasonal variations in coyote diets (Sheldon 1992). "Because they require large amounts of food and area for survival, coyotes are potentially sensitive indicators of the ecological health and will respond to changes in prey abundance and habitat" (Howell and Sauvajot 1998:3). Coyotes prey or scavenge on a variety of species, including rodents and ungulates. They also compete for food with other carnivores, such as foxes and bobcats (Howell and Sauvajot 1998).

Sperry (1941) supplied basic information on food habits of the average coyote. His study was based on the contents of a large number (8339) of coyote stomachs, collected throughout the year and across the animal's range. Sperry found that animal food made up 98.25% of the coyote's diet. It consisted of rabbits (33.25%), carrion (25.17%), rodents (17.52%), domestic livestock (13.59%), big-game mammals (mostly deer 3.63%), miscellaneous mammals (1.01%), birds (2.92%), and other animal material (1.16%).

Scat analysis is another effective technique for studying food habits of many carnivores. Diebello et al. (1990) analyzed the scat from *C. latrans* (coyotes), *Vulpes vulpes* (red foxes), and *Lynx rufus* (bobcats) to determine the food habits of each species in Maine. The major food item for all three predators was *Lepus americanus* (snowshoe hare). This prevalence for snowshoe hares suggests that inter-specific competition between coyotes, red foxes, and bobcats occurs. Smith (1990) conducted a study within the Sierra National Forest in Fresno County, California, in which he also analyzed scats to determine the food habits of coyotes in the North Kings deer herd range. As in many other studies, Smith (1990) found that small mammals were the most important coyote food source, while deer were minimally represented in the scats.

Several studies of scat and stomach contents have led to the categorization of coyotes as opportunistic feeders (Bowyer et al. 1983; Ferrel et al. 1953; Johnson and Hansen 1979). Yet other researchers have suggested that coyote feeding behavior is highly selective (Clark 1972; Johnson and Hansen 1979; Springer and Smith 1981). It is possible that coyotes are highly selective when preferred species are abundant. It is also possible that the coyote's overall feeding behavior is opportunistic, with items altering in its diet according to seasonal changes in the environment, as different food resources become available (Bowen 1981; Bowyer et al. 1983; Craig 1986). To better understand predator-prey relationships, the food habits of coyotes and the relative abundance of potential prey species (rodents) were studied in San Mateo County, northern California.

Since there are several studies that suggest opportunistic feeding behavior and others suggesting selective feeding behavior, I asked the question, do coyotes in the study area demonstrate opportunistic feeding behavior? Specifically, I tested the hypothesis that the food habits of coyotes fluctuate seasonally with the availability of prey (in this case, relative abundance of rodent species).

MATERIALS AND METHODS

This study was conducted from November 2000 through October 2001. Coyote scats were collected for 12 months and sorted and identified for species content. Small mammal trapping was conducted during the same period to determine the availability of potential prey species in the same locality. Data from these two procedures were used to correlate relative abundance and diversity of small mammals trapped with those species found in the scats.

Study Area. This study was conducted on San Francisco Water Department property in a portion of the San Francisco State Fish and Game Refuge, San Mateo County, California. The area studied included approximately 56 hectares in the San Francisco Watershed (Figure 1). The landscape includes steep slopes, rolling hills, and reservoirs. The region's prominent geologic feature is the San Andreas Rift Zone. The area consists of a variety of habitats, including chaparral, oak woodland, mixed evergreen forest, riparian woodland, grassland, and freshwater marsh. The elevation of the study area ranges from 91 to 356 m above sea level. Annual temperatures range from average lows of 9.4°C to average highs of 18.4°C, although many winter mornings drop to between 0°C and 4°C. From November 2000 through October 2001, rainfall totaled 54.25 cm (San Francisco Water Department records).

Scat Collection and Processing. Coyote scat surveys in the field were conducted on 2 arbitrarily selected days.

Scats were collected in brown paper bags, with the time, date, location, and a unique identification number on each bag, from along 10 km of dirt roads and trails that dissected the 56-hectare study area. The location of each scat was determined by a Garmin II plus Global Positioning System (GPS). Scats were identified by their characteristic morphology, size, location in the study area, and placement on the trails (Craig 1986; Howell and Sauvajot 1998; MacDonald 2000; Murie 1974).

The scats were dried in a Thermolyne Dry Sterilizer Type 9500 (Thermolyne Corporation, Dubuque, Iowa) at 170°C for 1-2 h to kill parasites. They were then placed in nylon sacks and hydrated in warm water for a period of 1-3 h. While soaking, they were manually separated. The scats, each contained in its own nylon sack, were placed in a Homz 15″ x 18″ lingerie bag, washed twice in an electric GE washing machine with 1 cup Arm and Hammer laundry detergent on a normal cycle, and rinsed in a 10% Clorox bleach solution (Bowyer et al. 1983; Craig 1986; MacDonald 2000; Spaulding et al. 1998). Macro-fragments (bone, teeth, and hair) were air dried before identification. Each scat was examined to identify different food items.

Macro-fragments were identified using a stereomicroscope, with identification keys (Cavallini and Volpi 1996; Craig 1986; Mayer 1952), and the reference collection from the Museum of Birds and Mammals at San Jose State University. If more than one like skeletal element (such as 2 left dentary bones or 2 right humeri) of a species was present, it was counted as 2 separate individuals. Other food items, such as vegetation and other animals (insects, arachnids, reptiles, birds, and unidentified mammals), were recorded.

For ease of analyzing, monthly scat data were combined into 3-month seasons: winter (Jan-Mar); spring (Apr-Jun); summer (Jul-Sep); and autumn (Oct-Dec). For comparison of food items, the relative abundance for each food item found in the scats for each month was calculated as the total number of each food item occurring in each month, divided by the total number of scats collected during that month, multiplied by 100 equaling the percentage of scats that contain that food item for that month.

Trapping. A capture-recapture method was used to determine the relative abundance of each species within a specific habitat (Nichols and Conroy 1996). Two trapping sites were randomly chosen from 86 possible sites in the study area. To determine the two sites, a topographic map of the study area was divided into a grid consisting of 100 consecutively numbered (from the northwest to the southeast corners of the grid) 100 m x 100 m squares (sites). Sites located in reservoirs or other unavailable trapping areas (roads, pipelines, dams, or outbuildings) were eliminated from the grid, which resulted in 86 possible sites. The two randomly selected trapping sites were located in very different habitats. The grassland site consisted of grasses and forbs, fringed on the western and northeastern corners by oak woodland. The mixed habitat site consisted of chaparral, oak woodland, riparian woodland, and grassland.

At both sites, 100 Sherman or Tomahawk live traps were placed at 10 m intervals on a 50 m X 200 m trapping grid (1 hectare). Figure 1 depicts a 3-dimensional representation of the study area and the locations of the trapping grids. From November 2000 through October 2001, a total of 7103 trap-nights out of 7200 (Jones et al. 1996) were recorded. Since Beauvais and Buskirk (1999) suggested that the accuracy of estimates of sampling effort, and hence relative abundance of populations, could be miscalculated due to the occurrence of sprung traps, all traps sprung without capture (for this study, sprung traps equaled 97) were removed from the sampling effort to control for bias.

Airtex 100% polyester fiber was placed in all traps for insulation material. Traps were baited with rolled oats. Between each trapping session, all traps were cleaned, rinsed in a Clorox solution, dried, and supplied with clean polyester fiber. A trapping session consisted of 3 consecutive nights with inspection of each trap every morning at sunrise. All traps were closed at sunrise and opened and baited at dusk. Each individual captured was identified to species. The age (juvenile, sub-adult, or adult), weight, sex, and reproductive status were recorded. Its ear was tagged with National Brand fish and small animal tags, size 1005-1, using a size 1 applicator.

To reduce incidental mortality, warm disposable packs (Heat Factory, Carlsbad, California) were used to raise the core body temperature of any noticeably stressed animals found in the traps. This method was effective. Most of the animals found near death due to stress from being in the traps overnight were revived. Of the 1363 total captures during the 12-month period of the investigation, only 15 were lost to incidental mortality (1.1% of all captures).

All trapping was conducted in accordance with the American Society of Mammalogists protocol, the San Jose State University Institutional Animal Care and Use Committee protocol, and the California Department of Fish and Game collecting regulations.

RESULTS AND DISCUSSION

From November 2000 through October 2001, 373 coyote scats were collected from the study area. Food items identified (Table 1) included *Sylvilagus bachmani* (brush rabbit), *S. audubonii* (desert cottontail), *Sciurus griseus* (western gray squirrel), *Thomomys bottae* (Botta's pocket gopher), *Chaetodipus californicus* (California pocket mouse), *Reithrodontomys megalotis* (western harvest mouse), *Peromyscus californicus* (California mouse), *P. maniculatus* (deer mouse), *P. truei* (pinyon mouse), *Neotoma fuscipes* (dusky-footed woodrat), *Microtus californicus* (California vole), *Canis sp.* (dog species), *Felis domesticus* (domestic cat), *Lynx rufus* (bobcat), *Taxidea taxus* (American badger), *Odocoileus hemionus* (mule deer), and unidentified mammals, insects, arachnids (ticks), reptiles, birds, and vegetation. For mesocarnivores such as coyotes, scat analysis is the easiest and often the only method for determining food habits (Bowyer 1983; Craig 1986).

However, scat analyses have inherent biases and should be considered only an approximation of actual food intake. Due to differential digestibility of prey and other food materials, the number of scats produced per feeding incident of each coyote can vary (Andelt and Andelt 1984; Craig 1986; Cypher et al. 1996; Johnson and Hansen 1979). Each item or prey species a coyote eats does not necessarily result in one scat. Several scats can result from one meal or one scat can result from several meals. For this study, scats were not corrected for differential digestibility of prey species (Kelly and Garton 1997).

During this 12-month study, 7103 trap-nights (Jones et al. 1996) produced 1055 rodents, not including recaptures. This number represents an average of a 15% capture rate per 100 trap-nights (Figures 2 and 3).

Reithrodontomys megalotis was the most abundant species captured in the grassland site from November 2000 through April 2001 (Figure 2). However, from May 2001 through August 2001, *P. maniculatus* became the most abundant species captured at this site. At the grassland site, there were never more than 3 species caught during any trapping session. *Peromyscus truei* was not captured at this site during the study.

The mixed habitat site was more diverse in species composition captured than the grassland site. From November 2000 through February 2001, at the mixed habitat site, *R. megalotis* and *P. maniculatus* were generally equally abundant species (Figure 3). From March 2001 through September 2001, *P. maniculatus* became the most abundant species in this community. From February 2001 through September 2001, 6 species (*R. megalotis, P. boylii, P. californicus, P. maniculatus, P. truei, and M. californicus*) were represented in this community. During July and August 2001, however, *M. californicus* was not represented.

The differences in rodent relative abundance between the two trapping sites suggest that availability of prey species is not uniform across habitats. However, it does appear that some species are high in the environment across all habitats during certain months and low during other months. For example the increasing relative abundance of *R. megalotis* at both the grassland and mixed habitat sites from November 2000 through January 2001, and its decreasing relative abundance from February 2001 through May 2001, at both sites (Figures 2 and 3).

A canonical correlation was performed between a set of trap variables (relative abundance of each rodent species found in the traps each month) and a set of scat variables (relative abundance of each rodent species found in the scats each month, which were also found in the traps) using SYSTAT version 10.0 for Windows. Data were combined from both the grassland and the mixed habitat sites for the trap variables. The trap variables included the species captured in the traps (*R. megalotis, P. maniculatus, P. californicus, P. truei, P. bolyii,* and *M. californicus)* during each of the 12 months. The scat variables included the same species found in the scats that were also captured in the traps during each of the 12 months. Because *P. boylii* was not found in any month in the scats, it was omitted from the set of scat variables. A canonical correlation does not accept data unless it varies across replicates i.e., each month (in the scats, *P. boylii* had a value of zero for each of the 12 months) (Tabachnick and Fidell 1996).

The first canonical correlation between the species trapped (trap composition score) and the species found in the scats (scat composition score) was 0.999. The correlation was statistically significant with all five canonical correlations included, X^2 (30) = 53.976, p = 0.005. With the first canonical correlation removed, the remaining four canonical correlations were not statistically significant, X^2 (20) = 22.665, p = 0.306. Therefore, the first canonical correlation accounted for the significant relationship between the set of trap variables (relative abundance of each rodent species found in the traps each month) and the set of scat variables (relative abundance of each rodent species found in the scats each month). This positive correlation of 0.999 indicates that as the score for trap composition increases, so does the score for scat composition.

To interpret this canonical correlation, the loadings, or correlations between variables and score on a variate, were examined. Variables with loadings less than 0.3 were excluded because they indicated small correlations of the variable with a variate. The loadings for the trap composition score indicate that when the trap composition score was high the relative abundance of *R. megalotis* and *P. boylii* in the traps was high (loadings of 0.828 and 0.608, respectively) and that of *P. truei* was low (loading of - 0.902). The loadings for scat composition score indicate that when the scat composition score was high, the relative abundance of *R. megalotis, P. californicus, P. maniculatus,* and *P. truei* in the scats were also high (loadings of 0.520, 0.383, 0.524, and 0.599, respectively). Since the canonical correlation between scat composition score and trap composition score was positive (0.999), high trap composition scores accompanied high scat composition scores. This positive correlation of 0.999 along with the loadings indicate that as the relative abundance of *R. megalotis* and *P. boylii* in the traps increased, and the relative abundance of *P. truei* in the traps decreased (high trap composition score), the relative abundance of *R. megalotis, P. californicus, P. maniculatus,* and *P. truei* increased in the scats (high scat composition score) (Figure 4).

The results from the canonical correlation support the hypothesis that coyote food habits in this area fluctuate seasonally with the relative abundance of rodents. For most of the trappable rodent species, the coyotes fed opportunistically, preying on them in direct proportion to available numbers in the area. However, *P. truei* does not fit this model. As the relative abundance of *P. truei* decreased in the traps its relative abundance increased in the scats. These results also indicate that coyotes were selectively feeding on *P. truei*, as seen by the high relative abundance of this species in the scats when its relative abundance in the environment was low.

However, the trapping data did not incorporate the complete diet of coyotes in this study area. They were not only eating species from the trappable rodent population, they were also eating a variety of other foods. Coyotes also appear to have been selective in their feeding behavior on the non-trappable species, as indicated by the high relative abundance of *S. bachmani*, and *N. fuscipes* in the scats. *Neotoma fuscipes* and *S. bachmani* were the most important food sources for coyotes throughout the year as indicated by the high relative abundance of these food items during all seasons (Table 1). While *N. fuscipes* was potentially a trappable species and their houses were seen in or within 20 m of the trapping grids, none were trapped.

In the winter, *T. bottae* was very important, appearing in the diet more frequently than *S. bachmani* but less than *N. fuscipes*. *Thomomys bottae* was not considered a trappable species because of its fossorial habits. However, its burrow mounds were evident year round, especially during the winter and spring when the soil was wettest. In these seasons, the wet ground would make it easier for the coyotes to see, hear, and dig up the burrowing pocket gophers. During the winter and spring burrows appeared more numerous, as well, *T. bottae* was found to be more abundant in coyote scats.

Even though *C. californicus* occurred in the scats (Table 1), none were caught in the 12 months of trapping. Marten (1972) indicated that although tracks of *Perognathus* (silky pocket mice), a species closely related to *Chaetodipus* (coarse-haired pocket mice), were common in his study area, very few had been captured in 5 consecutive years of regular trapping.

It is not surprising that the abundance of mule deer in coyote diets was greatest in the spring and summer (Table 1), when many fawns were available as prey. The study site was in a protected area where hunting is not allowed, and food and water are in ample supply. Therefore, the mule deer population is large and stable from year to year. *Puma concolor* (puma) inhabit the area and are probably the major predator of mule deer. However, it was reported on one occasion that *L. rufus* took a mule deer (John Adza, Watershed Keeper, personal communication).

It is interesting to note the presence of *F. domesticus* in the scats. Coyotes have shown a strong affinity for pets, including this species, in urban areas (Baker and Timm 1998). Here however, the presence of domestic cats in these scats was unusual, because the study area is a relatively pristine and protected wildlife refuge.

In summary, this study shows that coyotes opportunistically tracked the more abundant rodent species in the area. They fed more on species such as *T. bottae, R. megalotis,* and *M. californicus* when the relative abundance of these species was high. Coyotes also fed more on mule deer at times when they were not only more abundant, but also during the spring and summer when fawns were present. It was also evident that coyotes preferred a staple diet of *N. fuscipes* and *S. bachmani*, as indicated by the high relative abundance of these species in the scats throughout the year. Therefore, the coyotes were selective, feeding mainly on two species throughout the year. However, they were also feeding opportunistically, altering the items in their diets according to the seasonal changes in prey abundance.

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Table 1.-Summary of food items identified in 373 coyote scats collected in the San Francisco Watershed, San Mateo Co., California, from November 2000 through October 2001. Numbers represent percent of (N) scats containing each food item (see text for explanation).

	Percent of Scats Containing a Food Item				
	Year Total	Winter (Jan-Mar)	Spring (Apr-Jun)	Summer (Jul-Sep)	Autumn (Oct-Dec)
Food Item	(N = 373)	(N = 104)	(N = 99)	(N = 78)	(N = 92)
Sylvilagus bachmanii	29.5	24.0	36.4	33.3	25.0
S. auduboni	1.6	1.0	0.0	3.8	2.2
Sciurus griseus	2.4	1.0	3.0	3.8	2.2
Thomomys bottae	16.1	28.8	23.2	3.8	4.3
Chaetodipus californicus	0.5	0.0	1.0	0.0	1.1
Reithrodontomys megalotis	6.2	8.7	7.1	0.0	7.6
Peromyscus californicus	0.8	2.9	0.0	0.0	0.0

Table 1.-Continued.

	Percent of Scats Containing a Food Item				
Food Item	Year Total (N = 373)	Winter (Jan-Mar) (N = 104)	Spring (Apr-Jun) (N = 99)	Summer (Jul-Sep) (N = 78)	Autumn (Oct-Dec) (N = 92)
P. maniculatus	2.9	1.9	1.0	2.6	6.5
P. truei	3.8	7.7	2.0	1.3	3.3
Neotoma fuscipes	34.3	45.2	31.3	21.8	35.9
Microtus californicus	20.9	27.9	27.3	15.4	10.9
Canis sp.	0.3	0.0	0.0	1.3	0.0
Felis domesticus	0.8	0.0	1.0	1.3	1.1
Lynx rufus	0.3	0.0	1.0	0.0	0.0
Taxidea taxus	0.3	0.0	0.0	0.0	1.1

Table 1.-Continued.

	Percent of Scats Containing a Food Item				
	Year Total	Winter (Jan-Mar)	Spring (Apr-Jun)	Summer (Jul-Sep)	Autumn (Oct-Dec)
Food Item	(N = 373)	(N = 104)	(N = 99)	(N = 78)	(N = 92)
Odocoieius hemionus	21.4	13.5	27.3	28.2	18.5
Unidentified mammals	10.2	10.6	7.1	17.9	6.5
Insects	18.0	24.0	18.2	10.3	17.4
Arachnids (ticks)	21.2	22.1	24.2	12.8	23.9
Reptiles	4.6	1.9	7.1	3.8	5.4
Birds	11.3	13.5	4.0	14.1	14.1
Vegetation	64.1	51.9	59.6	76.9	71.7

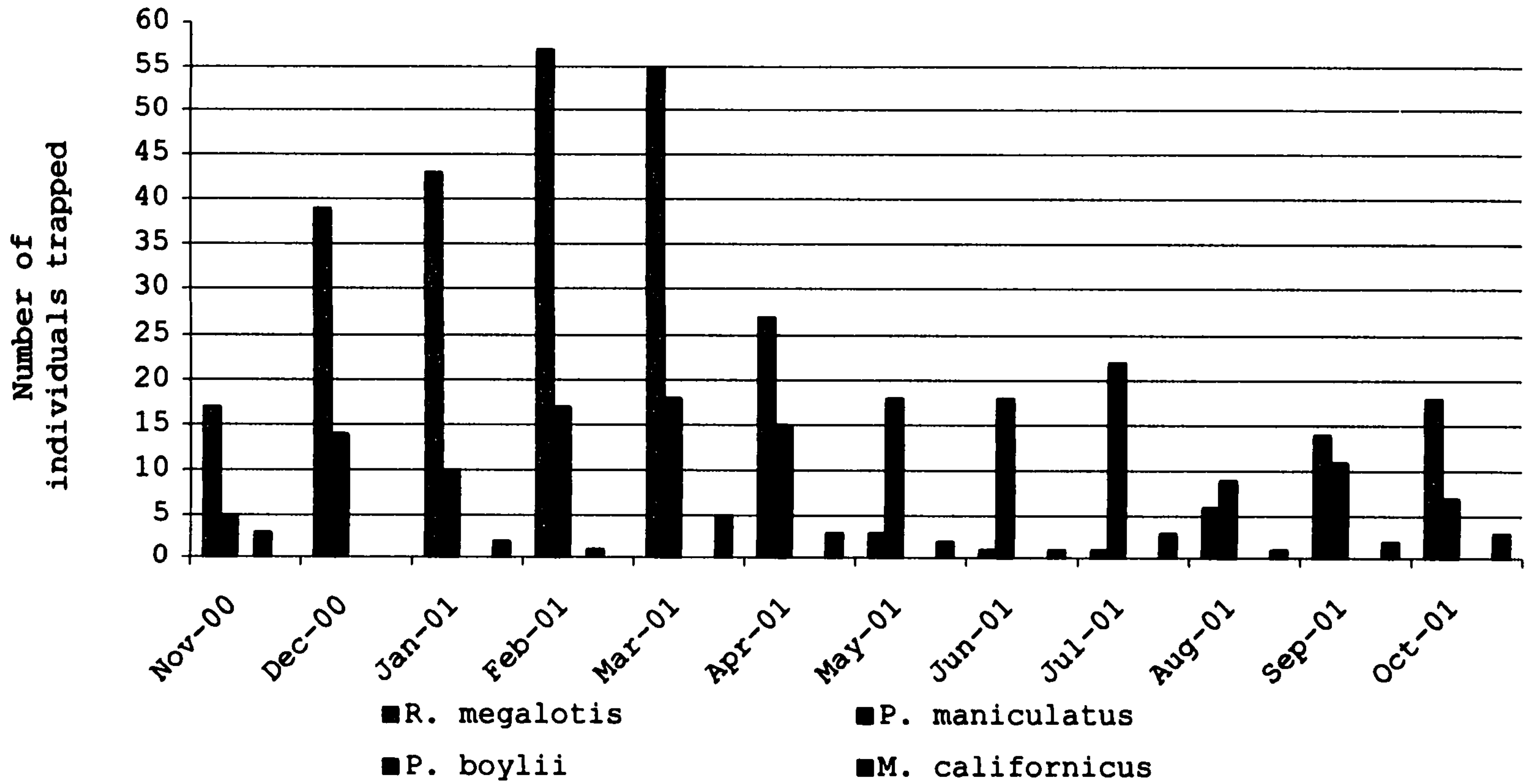

Figure 2.-Histogram of species abundance, by month, at the grassland site.

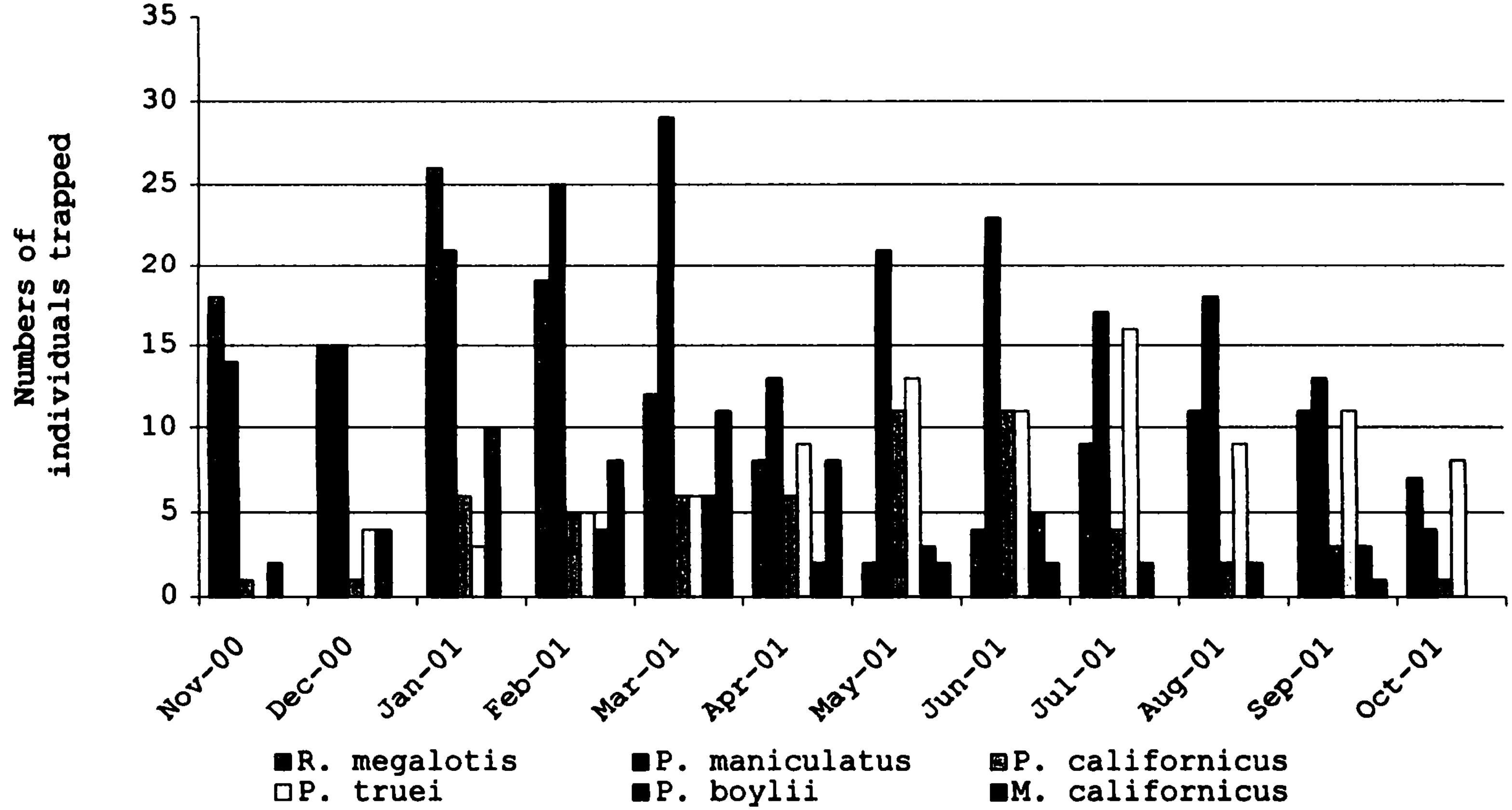

Figure 3.-Histogram of species abundance, by month, at the mixed habitat site.

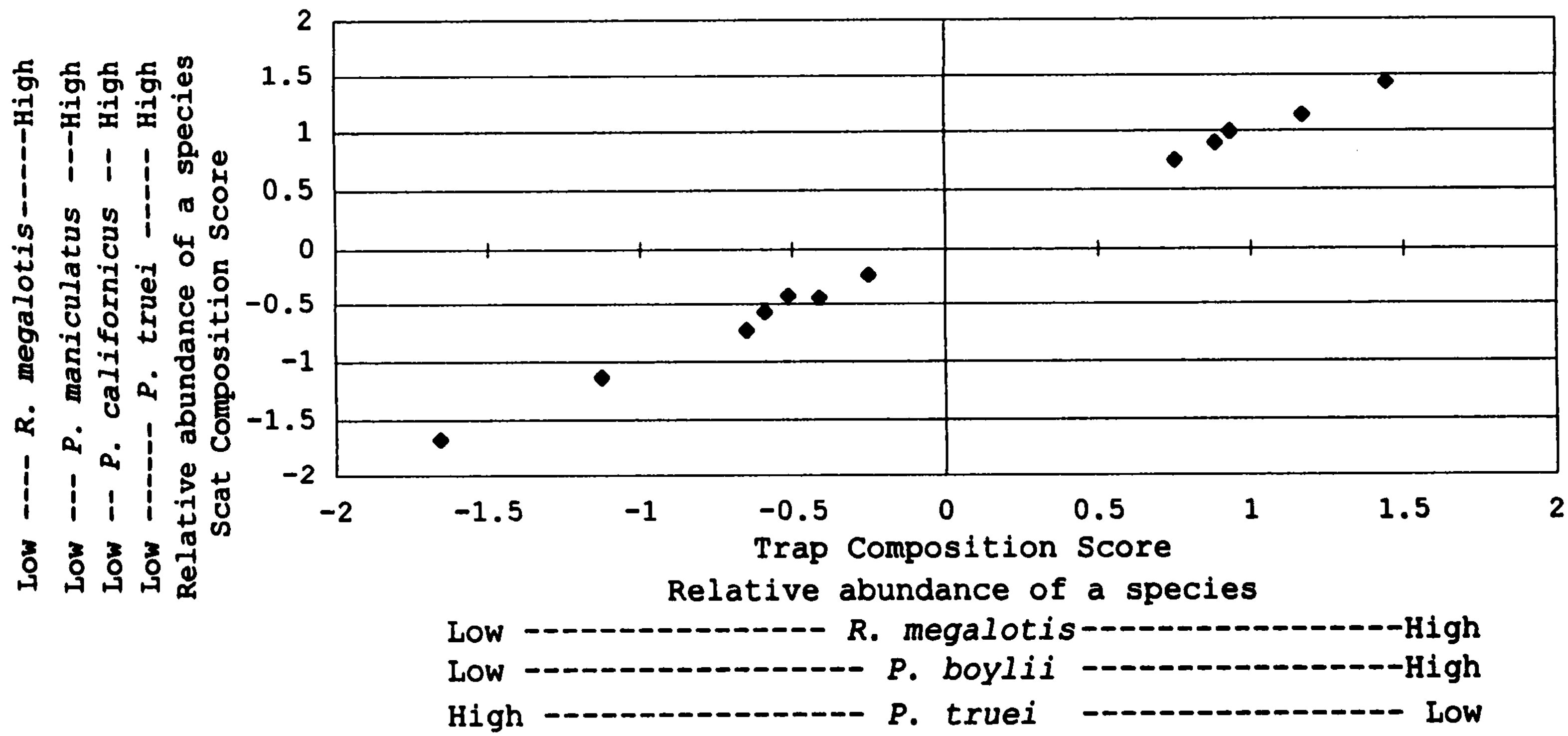

Figure 4.-Scatter plot of the canonical correlation between trap composition score and scat composition score. Scales indicate how the relative abundance of a species was related to each score. For example, when the trap composition score was low, the relative abundance of *R. megalotis* was also low in the traps.