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Diet of the San Joaquin Antelope Squirrel in the Southern Portion of its Range

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***Abstract*.—During studies of distribution and population density of the San Joaquin Antelope Squirrel (*Ammospermophilus nelsoni*), I collected fecal samples from two sites in the core of the current distribution of the species: The Paine Preserve of The Nature Conservancy on the floor of the San Joaquin Valley, and the Elkhorn Plain, an upland site on the southwestern edge of the range of the species. A commercial analysis of these samples showed that the San Joaquin Antelope Squirrel was omnivorous, consuming a wide variety of foods including leaves, fungi, seeds, arthropods and occasionally other animal matter. The breadth of food types here was greater than that previously documented, though not unusual for a sciurid. Plant material consumed included the foliage, stems and seeds of grasses, herbs, and shrubs. Non-native plants, such as the grasses *Bromus* sp. and Arabian Grass (*Schismus arabicus*), and the herb Storksbill (*Erodium cicutarium*), were a significant proportion of the diet.**

Key Words.—Ammospermophilus nelsoni; forbs; grasses; San Joaquin Desert; shrubs

Introduction

The San Joaquin Antelope Squirrel (*Ammospermophilus nelsoni*) is a 140-180 g diurnal rodent (Fig. 1) found in the San Joaquin Desert (Germano et al. 2011) of the southern San Joaquin Valley of California (Best et al. 1990; Williams 1981). The species is listed as Threatened by the California Fish and Game Commission (California Department of Fish and Game 1980). Its elevational distribution spans from about 50 to 1,100 m and it may be found on open terrain and gently sloping hills (Best et al. 1990). Habitats occupied are open perennial bunchgrass, non-native annual grasslands, Saltbush (*Atriplex*) scrub, Jointfir (*Ephedra*) scrub, and other open shrublands on sandy loam and alluvial soils. Cultivated croplands are avoided (Grinnell and Dixon 1918; Hawbecker 1953; Williams 1981). Although shrubs may provide significant thermal cover (Hawbecker 1953; Heller and Henderson 1976), San Joaquin Antelope Squirrels are also found in areas devoid of shrubs (Best et al. 1990; Harris and Stearns 1991).

Little is known concerning the diet of this species and the relation of diet to habitat use. The only prior study of diet is that of Hawbecker (1947). That study was conducted in the Panoche Hills, San Benito County, California, near the northern range limit of the species. The study area was dominated by non-native annual grassland, with few to no shrubs. During studies of distribution and population density (Harris and Stearns 1991), I collected fecal samples from two sites in the southern portion of the geographic range of the species. In this article, I describe the results of fecal analysis from the two study areas and relate the results to the characteristics of the occupied habitats. The two sites are compared to each other and to the results of Hawbecker (1947).

Methods

Study sites.—I collected fecal samples at two locations: a 13-ha live-trapping study plot located on the Elkhorn Plain, San Luis Obispo County, and at the Paine Preserve in Kern County. The Elkhorn Plain is situated between the Carrizo Plain and the Temblor Range. The topography of the study area is rolling terrain gently sloping upward to the east. Vegetation at the site was dominated by grasses and widely spaced shrubs, primarily California Jointfir (*Ephedra californica*), with a few Anderson's Boxthorn (*Lycium andersonii*). Smaller Yellow Aster (*Eastwoodia elegans*) and buckwheat (*Eriogonum* spp.) were common. Herbaceous cover was dominated by the introduced annual grass Arabian Grass (*Schismus arabicus*) although a number of other grasses and herbs were present.

Figure 1. San Joaquin Antelope Squirrel (*Ammospermophilus nelsoni*) from the Panoche Hills, San Benito County, California. (Photographed by John H. Harris).

The second location was a 5.6-ha live-trapping study plot located at the Paine Preserve of The Nature Conservancy. This site, on the floor of the San Joaquin Valley, was a low-lying area dominated by Spinescale Saltbush (*Atriplex spinifera*) and Shrubby Seablight (*Sueda fruticosa*). Low hummocks were separated by seasonally flooded alkali flats. Most squirrel captures and all burrowing activity were located on these low mounds or on road banks. I collected fecal samples at various times from the end of May through mid-July, so any annual vegetation was dry as one would expect (Germano et al. 2011). Rainfall at the Bakersfield Airport weather station was 141 mm (86% of normal) for 1987–1988 and 95 mm (58% of normal) for 1988–1989; these were the two rainfall years preceding sampling (https://www.weather.gov/hnx/bflmain).

Sample collection.—Characterization of the diet based on fecal samples has been shown to be comparable to stomach samples for several species of ground squirrels, including the Columbian Ground Squirrel (*Urocitellus columbianus*; Harestad 1986), Black-tailed Prairie Dog (*Cynomys ludovicianus*; Wydeven and Dahlgren 1982), and Townsend's Ground Squirrel (*Urocitellus townsendii*; Van Horne et al. 1998), making this an appropriate method for a protected species that should not be sacrificed for gastro-intestinal contents. I collected fecal samples at the Elkhorn Plain site at three times: 31 May to 1 June 1988 (24 samples), 7–8 July 1988 (18 samples), and 27–28 May 1989 (50 samples). At the Paine Preserve study site, I collected fecal samples 9–10 June 1988 (13 samples) and 13–14 July 1988 (five samples). I collected fecal samples from Sherman XLK live-traps that were baited with commercially available mixed bird seed and peanut butter. I emptied traps after each capture to avoid mixing of feces from different animals. I stored fecal samples in plastic bags with no residual bait from traps. Later, I transferred the dried samples to labeled paper envelopes and I kept them in dry conditions thereafter.

Sample analysis.—I selected three random fecal pellets from the first capture of each individual to standardize the overall amount of fecal material between samples. Using the three fecal pellets, a slide was prepared by Composition Analysis Laboratory, Inc., Fort Collins, Colorado, in the following manner (Hansen et al. (1973): the feces were crushed or ground and then cleared with a bleach solution. The resulting fragments were washed through a 200 mesh Tyler standard screen (0.074 mm openings), which removes solubles and extremely small, unidentifiable particles. The washed material was then transferred to a microscope slide, making an effort to ensure that roughly equal amounts of material were on each slide.

Plant materials in the fecal samples were identified by experienced technicians using the characteristics of leaf epidermis or seed coats. I provided the Composition Analysis Lab with a plant list for each site and a list of the species in the bait seed mix. The importance of various items in the diet was quantified in two ways. For each sample slide, 20 microscope fields of view were examined. The occurrence of individual food types was recorded for each field. The percentage frequency among microscope fields was then calculated. This frequency can be converted to density if certain assumptions are made (Hansen et al. 1973; Sparks and Malechek 1968), including equal fragment size and the random distribution of plant fragments over the slide. Once the density of fragments was estimated, the percentage relative density was calculated by dividing the density of fragments of a particular species by the density of fragments of all species. The results provided by the commercial laboratory included the percentage relative density of each food type in each sample. I report the means of these relative densities for each location and sampling date, which provides an estimate of the proportion of the diet made up by a particular food type. I also calculated the percentage frequency of occurrence: the percentage of samples from a given site and time period in which a food type occurred for each food type for each site and time period.

Results

Composite and grass seeds were found in nearly every sample (Table 1). The results for the Paine Preserve site for 9–10 June 1988 indicate that seeds made up the largest proportion (58.8%) of the diet (Table 2). Even at this date, when the site was very dry, leaves made up an appreciable proportion (16.2%) of the diet. The only leaves that were found in a high proportion of the samples were *Atriplex* leaves. Fungal fragments made up a similar proportion (17.2%) of the diet and arthropods composed the remaining 7.5%. The Paine Preserve samples I collected about one month later (13–14 July 1988) revealed a somewhat different pattern. Arthropods made up the largest proportion (41.2%) of the diet and were found in all samples. Seeds had decreased in the proportion (39.1%) of the diet. The category denoted as seed includes unknown seeds, possibly including bait. If this category is eliminated, the proportions of arthropods and green vegetation would be slightly increased. Leaves continued to make up a significant fraction of the diet during this later sampling period (19.9%) but fungi were absent (Table 2).

At the Elkhorn Plain site, seeds were the largest diet category during all three sampling periods, but this category was dominated by the unknown seed category, leaving considerable uncertainty regarding the true importance of seeds at this site. Identified seeds which I found in the diet included grass seeds, chenopod seeds, and seeds of *Lycium andersonii*. Leaves were important during the 31 May to 1 June 1988 sampling period (22.4%). The most important plant foods eaten at this time included the leaves of grasses (*Bromus* sp. and

Table 1. Percentage frequency of occurrence of food types in the diet of the San Joaquin Antelope Squirrel (*Ammospermophilus nelsoni*). The percentage of samples in which a given food type was found is given for each study site and season. The abbreviation n is the number of individual squirrels from which fecal samples were collected. The locations of study areas and time of sample collection are given in the text.

	Paine Spring 1988 n = 13	Paine Summer 1988 n = 5	Elkhorn Spring 1988 n = 24	Elkhorn Summer 1988 n = 18	Elkhorn Spring 1989 n = 50
Seeds					
Grass	92.3	60.0	12.5	44.4	32.0
Chenopod	15.4	60.0	4.2	0	0
Composite	84.6	80.0	0	5.6	2.0
Lycium spp.	0	0	50.0	22.2	18.0
Unknown seed	0	40.0	100.0	89.9	100.0
Unknown pod	0	0	0	16.7	0
Leaf Tissue					
Allenrolfea	7.7	0	0	0	0
Atriplex	76.9	40.0	8.3	0	0
Baileya	0	20.0	0	0	0
Eremalche	30.8	0	12.5	0	0
Bromus	0	0	50.0	5.6	4.0
Schismus	0	0	62.5	0	10.0
Distichlis	0	0	0	0	2.0
Oryzopsis	0	0	0	0	2.0
Chrysothamnus	0	0	0	5.6	0
Trifolium	0	0	0	0	2.0
Oenothera	23.1	0	4.2	0	2.0
Medicago	0	0	4.2	0	6.0
Kochia	7.7	40.0	0	0	2.0
Ephedra	0	0	8.3	94.4	8.0
Erodium	0	0	37.5	16.7	4.0
Lycium	0	0	41.7	22.2	44.0
Gutierrezia	0	0	0	0	0
Lotus	0	0	0	5.6	0
Lupinus	0	0	0	5.6	0
Eriogonum	0	20.0	0	27.8	0
Gilia	0	0	0	0	0
Sida	0	20.0	0	0	0
Unknown flower	7.7	0	0	5.6	4.0
Fungi	76.9	0	0	0	0
Arthropods	76.9	100.0	100.0	77.8	98.0
Bone fragments	0	0	4.2	0	6.0

Schismus arabicus) and the leaves of *Lycium andersonii* and Storksbill (*Erodium cicutarium*). Arthropods were also important (18.2% of the diet) and bone fragments were found in one sample.

Samples collected five weeks later (7–8 July 1988) on the Elkhorn Plain site showed a surprisingly large proportion of leaves in the diet. By far the most important species in the diet was *Ephedra californica* (35.5% relative density, 94% of samples). I also found foliage of *Eriogonum* sp., *Erodium cicutarium*, and *Lycium andersonii* in relative densities of 1% or greater. I found arthropods in most samples, but they made up only 7.3% of the diet.

Samples collected during from 27–28 May 1989 on the Elkhorn Plain were different from those collected during the same time of year in 1988 (Table 2). Unknown seeds were again the largest category, but arthropods composed a large fraction of the diet (32.5%) and green vegetation composed a small proportion (8.3%) of the material eaten. Only the foliage of *Lycium andersonii* made up

Table 2. Mean percentage relative density (see text for explanation) of food types in the diet of the San Joaquin Antelope Squirrel (*Ammospermophilus nelsoni*) for each study site and season. The abbreviation n is the number of individual squirrels from which fecal samples were collected. The mean and standard deviation are given for each food type. The locations of study areas and dates of sample collection are given in the text.

	Paine Spring 1988 n = 13	Paine Summer 1988 n = 5	Elkhorn Spring 1988 n = 24	Elkhorn Summer 1988 n = 18	Elkhorn Spring 1989 n = 50
Seeds					
Grass	22.4 ± 30.7	3.9 ± 5.6	0.5 ± 1.5	9.3 ± 19.4	5.4 ± 12.8
Chenopod	0.8 ± 1.9	6.2 ± 10.8	1.3 ± 6.1	0	0
Composite	35.6 ± 34.6	18.7 ± 33.7	0	1.4 ± 5.9	0.1 ± 0.7
Lycium spp.	0	0	4.8 ± 6.8	22.5 ± 6.1	2.1 ± 5.4
Unknown seed	0	10.3 ± 21.2	49.1 ± 23.9	38.3 ± 32.7	51.9 ± 24.0
Unknown pod	0	0	0	10.7 ± 1.8	0
Leaf Tissue					
Allenrolfea	0.2 ± 0.8	0	0	0	0
Atriplex	6.2 ± 6.6	5.3 ± 10.6	0.6 ± 2.2	0	0
Baileya	0	0.4 ± 1.0	0	0	0
Eremalche	7.2 ± 23.3	0	0.7 ± 9	0	0
Bromus	0	0	4.7 ± 6.2	0.2 ± 0.6	0.1 ± 0.6
Schismus	0	0	10.4 ± 12.4	0	0.5 ± 1.8
Distichlis	0	0	0	0	0.1 ± 0.4
Oryzopsis	0	0	0	0	0.1 ± 0.4
Chrysothamnus	0	0	0	0.2 ± 0.9	0
Trifolium	0	0	0	0	0.1 ± 0.4
Oenothera	2.1 ± 5.7	0	0.1 ± 0.7	0	0.7 ± 0.1
Medicago	0	0	0.1 ± 0.5	0	0.2 ± 0.1
Kochia	0.2 ± 0.5	12.8 ± 8.2	0	0	0.1 ± 1.0
Ephedra	0	0	0.7 ± 2.9	35.5 ± 26.6	0.2 ± 0.9
Erodium	0	0	1.6 ± 2.3	1.0 ± 2.5	0.1 ± 0.6
Lycium	0	0	3.5 ± 5.8	1.0 ± 2.1	6.0 ± 13.9
Gutierrezia	0	0	0	0	0
Lotus	0	0	0	0.2 ± 0.9	0
Lupinus	0	0	0	0.1 ± 0.6	0
Eriogonum	0	0.6 ± 1.4	0	3.4 ± 8.8	0
Gilia	0	0	0	0	0
Sida	0	0.6 ± 1.4	0	0	0
Unknown flower	0.3 ± 1.1	0	0	0.4 ± 1.8	0.1 ± 0.7
Fungi	17.2 ± 19.9	0	0	0	0
Arthropods	7.5 ± 7.8	41.2 ± 21.5	18.2 ± 15.2	7.3 ± 7.6	32.3 ± 20.5
Bone fragments	0	0	0.3 ± 1.4	0	0.2 ± 0.8

more than 1% of the diet, and I found bone fragments in three samples.

Discussion

Hawbecker (1947) studied the diet of San Joaquin Antelope Squirrels at three sites in the Panoche Hills, San Benito County, California, during 1940–1946. Unfortunately, Hawbecker did not present quantitative results (i.e., the number of samples, etc.), the method of sample collection (observation, stomach, or fecal samples) or the method of analysis, but presented qualitative and descriptive results of his sampling, summarized in a figure showing the percentage of various food types in the diet over an annual cycle. He found that the species was omnivorous, eating a variety of plant foods (including leaves, stems, and seeds) as well as arthropods and occasional carrion. The overall seasonal pattern was one in which green vegetation was most important from December through early May. From early May to December, insects were most important. Seeds were never more than 20% of the relative density of food types but were most important from March to May and from December to January. In 1946, insects were less abundant, and seeds had a higher importance than insects in the summer. Although many plant species were consumed, by far the majority of leaves consumed was Red Brome (*Bromus rubens*) and *Erodium cicutarium*. Both of these plant species are not native to California. A wide variety of arthropods was consumed, including beetles, Jerusalem crickets, June beetles, grasshoppers, and camel crickets. Grasshoppers were the most important summer arthropods, Jerusalem and camel crickets were most important in winter and spring. Seeds important in the diet included *Erodium cicutarium*, *Bromus rubens*, and *Ephedra californica*.

My results differ in some respects from those of Hawbecker (1947), perhaps because of the different habitats at the study sites and study methods. Results of the Hawbecker study came from a population occupying an upland, annual grassland that had been grazed by livestock with virtually no shrub cover. My samples were collected from an *Atriplex*-dominated alkali sink on the floor of the San Joaquin Valley (Paine Preserve) and from an upland, grazed *Ephedra* scrub community (Elkhorn Plain). At the Paine Preserve, seeds were important in both sampling periods, and were at least twice as prevalent as the 20% reported by Hawbecker. I found that fungi were an important spring food, which no author has previously reported being used by this species (Hawbecker 1947; Best et al. 1990); however, the consumption of fungi is widespread among sciurids (Landry 1970). Perhaps winter flooding of the site provides sufficient moisture for spring fungal growth. Leaves remained an important food source into mid-summer, in contrast to the pattern seen by Hawbecker. This probably stems from the availability of perennial shrubs such as *Atriplex*, Iodine bush (*Allenrolfea occidentalis*), and Kochia (*Kochia scoparia*) in combination with a few summer annuals, which did not occur at the Panoche Hills site. Arthropod consumption increased in summer but did not dominate the diet to the extent reported by Hawbecker (1947).

On the Elkhorn Plain, seeds were also important, although the large proportion of unknown seed material makes interpretation of this result difficult. It is possible that seeds were no more important at this site than they were in the study by Hawbecker (1947). Leaves were consumed during all three sample periods on the Elkhorn Plain, and included the foliage of grasses and shrubs, with a few annual herbs represented in smaller quantities. The foliage of perennial shrubs, particularly *Ephedra*, *Lycium*, and *Eriogonum* was an important source of green vegetation not available on the study area of Hawbecker in any significant quantity. The heavy consumption of *Ephedra* foliage during the sampling period in summer 1988 sampling period was a striking deviation from the pattern described by Hawbecker. The small proportion of arthropod material in the same sample is also quite different from the heavy preponderance of arthropods in the summer samples of Hawbecker.

The results of my study demonstrate a broader array of food types used, both generally and specifically, in comparison with the results from the Panoche Hills. This is not surprising, given that both of my study areas had more complex and diverse vegetation than the shrubless annual grassland sites of Hawbecker. The ecologically similar White-tailed Antelope Squirrel (*Ammospermophilus leucurus*) has been studied more extensively and has been shown to be omnivorous, consuming leaves, seeds, arthropods, and other materials (Belk and Smith 1991). Green vegetation is the primary food from December through May, seeds are consumed at all times of year, and arthropods are eaten primarily in late summer and autumn (Belk and Smith 1991).

There are significant limitations to interpretation of the data presented here. I collected samples incidental to other work, and as a result, the time period in which samples were collected was limited for the most part to early and mid-summer (late May to mid-July). In addition, the two years of study took place after relatively low winter rainfall. It is likely that earlier sampling at these sites would reveal more use of herbaceous green vegetation. Further diet studies should include a broader range of seasons and annual conditions and should include estimates of the availability of food types. Studies that compare food availability to reproduction would be especially useful.

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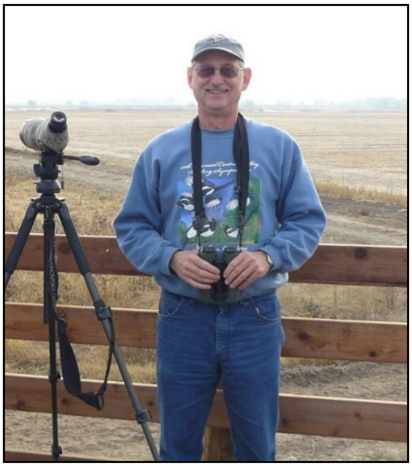

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