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Rodent species diversity along an elevational transect in the Warner Mountains

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RODENT SPECIES DIVERSITY
ALONG AN ELEVATIONAL TRANSECT IN THE WARNER MOUNTAINS

A Thesis
Presented to
The Faculty of the Department of Biological Sciences
San Jose State University

In Fulfillment
of the Requirements for the Degree
Master of Science

by
Christine Schelin

May 2003

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ABSTRACT

RODENT SPECIES DIVERSITY ALONG AN ELEVATIONAL TRANSECT IN THE WARNER MOUNTAINS

by Christine Schelin

The aim of this study was to address whether rodent species diversity changes in relation to elevation and other habitat characteristics along a transect crossing the Warner Mountain range. During the summer of 2002 rodents were trapped along a west-to-east transect that spanned a section of the Warner Mountains in Modoc County, California. Neither species diversity nor species richness linearly correlated with elevation; rather, a curvilinear pattern seems evident. However, species diversity and species richness did significantly correlate with habitat variables including percent grass/forb and percent litter cover. These results indicate that in the Warner Mountains, physiognomic features may play a more important role than elevation in determining rodent species diversity. In addition, patterns of species diversity, whether influenced by elevation or physiognomic features, may be unique to individual geographic regions.

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INTRODUCTION

Patterns of species diversity and distribution have been of particular interest to biologists for many years (Brooks and McLennan 2002; Brown and Lomolino 1998; MacArthur and Wilson 1967; Rosenzweig 1995). Small mammal distribution patterns along elevational gradients from a number of regions around the globe have been the topic of several recent studies (Brown 2001; Clausnitzer and Kityo 2001; Happold and Happold 1992; Patterson et al. 1989; Rahbek 1995; Rickart 2001; Rickart et al. 1991; Sanchez-Cordero 2001, and others). The importance of elevation on species diversity was emphasized by Rahbek (1995:200), "The decline in species richness with increasing elevation is widely accepted as a general pattern". Recently, however, this pattern has come into question as several studies show that middle elevations support greater species diversity (Brown 2001; Rahbek 1995; Rickart 2001).

The Warner Mountains of Modoc County, California, represent the western-most range in the Basin and Range Province of the Great Basin (Schoenherr 1992). Patterns of elevational diversity were studied in various Great Basin mountain ranges by Brown (1971, 1978), Johnson (1975), Lawlor (1998), Rickart (2001), and others (see Wood 1978).

A study of species diversity in yet another Great Basin mountain range would be worthwhile. A search of pertinent literature indicates that while there have been several records of mammals from the Warner Mountains (Grinnell 1913; Hall 1981; Mailliard 1927; Williams 1984), no comprehensive survey has been conducted. In fact, the only extensive vertebrate study is that of the avifauna by Johnson (1970).

Due to this lack of information on the fauna of the Warner Mountains, this study examines patterns of rodent diversity along an elevational transect across the Warner Mountains of Modoc County. In addition to elevation, habitat structure can affect small mammal diversity and distribution (Corn and Bury 1991; Fellers 1994; Hanchey and Wilkins 1998; Rickard 1960). Specifically, microhabitat variables such as grass, shrub, rock, and bare ground cover, rather than general habitat features, may play a more important role in determining species diversity (Fellers 1994). The hypothesis tested was: rodent species diversity and distribution are correlated with elevation and/or other habitat characteristics along a transect across the Warner Mountains.

MATERIALS AND METHODS

Study Area.—The Warner Mountains are a part of the Modoc National Forest, located in Modoc County in northeastern California (Fig. 1). Oriented in a north-south direction, this mountain range lies within the volcanic Modoc Plateau (Hickman 1993; Schoenherr 1992). The Modoc Plateau defines the western edge of the Great Basin Province (Hickman 1993). The elevation in the Warner Mountains ranges from a low of approximately 1433–1524 m (4700–5000 ft) (Russell 1928) to a high of 2963 m (9722 ft) at Eagle Peak (Schoenherr 1992). Two valleys border the Warner Mountains, Surprise Valley on the east and Pit River Valley on the west (Russell 1928). The eastern slope of the range drops at a relatively steep angle into Surprise Valley, which is comprised of several alkali lakes. The western slope of the Warner Mountains gradually descends into Pit River Valley and Goose Lake to the north.

The plant associations of the Warner Mountains are partly influenced by the surrounding Modoc Plateau. This plateau mainly supports western juniper (*Juniperus occidentalis*) savanna and sagebrush (*Artemisia* spp.) scrub (Hickman 1993). With a rise in elevation, western juniper begins to

mix with jeffrey pine (*Pinus jeffreyi*) and ponderosa pine (*Pinus ponderosa*) communities. Mountain mahogany (*Cercocarpus ledifolius*) is mostly found along rocky slopes on the eastern half of the study transect. Typical in a range adjacent to a desert, jeffrey pine is found at mid-elevations, below ponderosa pine (Schoenherr 1992). White fir (*Abies concolor*) and lodgepole pine (*Pinus contorta* ssp. *murrayana*) communities characterize some of the higher elevations along the transect.

In general, the Warner Mountain range is considered part of California's Mediterranean highland climate (Holland and Keil 1995). Specifically, the Warner Mountains are associated with California Zone 1 where winters are extremely frigid, freezing temperatures may occur throughout the year, and the growing season is relatively short with 100 growing days on average (Hickman and Roberts 1993). To generally characterize the region, average temperature, precipitation, humidity, and wind speeds were calculated from data collected by two weather stations located immediately on either side of the mountain range in the towns of Alturas (California Department of Water Resources 2002) and Cedarville (U.S. Bureau of Reclamation 2002). Temperatures during 1 June and 3 August 2002 ranged

from a low of 1.48 °C (35 °F) to a high of 38.34 °C (101 °F). Precipitation during this same period ranged from a low of 0.00 cm (0.00 in) to a high of 0.18 cm (0.07 in). Average humidity was 53% and the average wind speed was 8 km/h (5 mph).

Transect.—The transect was located on National Forest Service (NFS) Route 31 (Fig. 1). The U.S. Forest Service categorizes NFS Route 31 as an improved gravel road. It is located approximately in the middle of the Warner Mountains south of California Highway 299 and north of the South Warner Wilderness Area. The entire length of the transect was within the Modoc National Forest and spanned a distance of approximately 27 km (17 mi) covering the west- and east-facing slopes, as well as a portion of the ridge. The western third of the transect started at an elevation of 1585 m (5200 ft) and ended on a ridge at an elevation of 2027 m (6650 ft), covering a distance of approximately 9.6 km (6 mi). The eastern third of the transect started at an elevation of 1487 m (4880 ft) and ended on the same ridge at an elevation of 2195 m (7200 ft), covering a distance of approximately 8 km (5 mi). The ridge portion makes up the final third of the transect and includes the crest of the

Warner Mountains. It ran south-north for approximately 9.6 km from an elevation of 2027 m (6650 ft) to Payne Peak at 2347 m (7700 ft).

This transect was chosen for several reasons. First, it is in a relatively remote part of the Warner Mountains. The transect's remoteness would limit the possible vandalization of materials and equipment at the trap-sites. Second, while relatively remote, it was easily accessible. Third, NFS Route 31 was within a narrow north-south band (less than six minutes of latitude, approximately 10 km [6.2 mi]) that encompassed both the western and eastern slopes of the Warner Mountains. Fourth, the transect covered similar elevational changes on each slope. These characteristics provided an appropriate framework from which to study species diversity along an elevational transect across the mountain range.

Sampling of small mammals took place at 11 trap-site localities (Fig. 1) selected as follows. Since the western and eastern slopes spanned approximately similar elevation ranges, each was divided into four equal segments. The ridge was divided into only three equal segments since its elevation range was not as pronounced as on the western or eastern slopes.

Each of the 11 segments were further divided into 0.16 km (0.10 mi) intervals. Within each segment, one of the 0.16 km intervals was randomly selected as the interval in which to place a trap-site. Finally, trap-site locations were selected based upon physical accessibility within the interval (i.e., no sheer cliffs, bodies of water, etc.).

Upon determining a trap-site's primary direction of slope, each was then categorized as either belonging to the western slope, ridge, or eastern slope of the Warner Mountain range. Since one segment of the ridge drained primarily to the west, it was included in the western slope. Another segment of the ridge drained to the east and was included in the eastern slope. Trap-sites 1-5 were located on the western slope, trap-site PP was located on the ridge, and trap-sites 7-11 were located on the eastern slope of the range.

Trap-site 1 (TS 1) had an average elevation of 1660 m, an elevation range of 141 m, and was situated along a generally north-facing slope. Parker Creek ran along the northern edge of TS 1. TS 1 was characterized by rock outcroppings and a ponderosa pine-western juniper-jeffrey pine forest community.

Trap-site 2 (TS 2) had an average elevation of 1702 m, an elevation range of 124 m, and was also located along a north-facing slope. TS 2 was characterized by rock outcroppings and a western juniper-ponderosa pine-white fir forest community.

Trap-site 3 (TS 3) had an average elevation of 1825 m, an elevation range of 65 m, and was located along east- and south-facing slopes. TS 3 was characterized by logged areas with many downed trees, meadows, rock outcroppings, and a ponderosa pine-western juniper-white fir forest community.

Trap-site 4 (TS 4) had an average elevation of 1974 m, an elevation range of 64 m, and was located along a northwest-facing slope. TS 4 was characterized by a white fir-ponderosa pine-jeffrey pine forest community.

Trap-site 5 (TS 5) was located near the ridge, but on a primarily west-facing slope. TS 5 had an average elevation of 2078 m and an elevation range of 31 m. It was characterized by sagebrush scrub and western juniper-white fir-mountain mahogany forest communities.

Trap-site PP (TS PP) was located on the ridge near Payne Peak along a slightly south-facing slope. TS PP had an average elevation of 2220 m and an elevation range of 31 m.

It was characterized by logged areas, sagebrush scrub, and white fir-ponderosa pine-lodgepole pine forest communities.

Trap-site 7 (TS 7) was located near the ridge on the east side of the range along a south-facing slope. TS 7 had an average elevation of 2234 m and an elevation range of 67 m. It was characterized by logged areas and a white fir-ponderosa pine-lodgepole pine forest community.

Trap-site 8 (TS 8) had an average elevation of 2172 m, an elevation range of 78 m, and ran along south- and east-facing slopes. Springs, from which Deep Creek originates, were located on the south-facing slope. Deep Creek then ran through the middle of TS 8. TS 8 was characterized by logged areas with many downed trees and a white fir-ponderosa pine forest community.

Trap-site 9 (TS 9) had an average elevation of 1905 m, an elevation range of 112 m, and south- and north-facing slopes. The center of TS 9 was located next to Deep Creek. It was characterized by sagebrush scrub and white fir-western juniper forest communities with many downed trees.

Trap-site 10 (TS 10) had an average elevation of 1688 m, an elevation range of 73 m, and south- and north-facing slopes. The center of TS 10 was located next to Deep

Creek. It was characterized by sagebrush scrub and western juniper-mountain mahogany-white fir forest communities.

Trap-site 11 (TS 11) had an average elevation of 1591 m, an elevation range of 113 m, and south- and north-facing slopes. The center of TS 11 was also located along Deep Creek. It was characterized by rock out-croppings, and sagebrush scrub and western juniper-mountain mahogany-white fir forest communities.

Trapping.—Each trap-site was composed of four 250 meter-long trap-lines radiating away and beginning 50 m from a center point located on NFS Route 31. The compass bearing for each trap-line was randomly chosen and based from the center point, having one trap-line in each of the four quadrants (Fig. 2). Random bearings were altered only when unexpected obstacles (e.g., roads, private land, cliffs, etc.) were encountered. In addition, the order (i.e., the date, from June through August 2002) in which the trap-sites were trapped was random with the provision that trapping would not begin until a trap-site was free of snow.

Each trap-line was composed of 25 Sherman live-traps placed at 10 m intervals. Thus, there were 100 traps

placed at each trap-site, set for three consecutive nights. For each trap-site a total of 300 trap-nights (as defined by Jones et al., 1996) were utilized to sample rodents. With 11 trap-sites there were a total of 3300 trap-nights.

Traps were baited with crimped oats and set at dusk, and checked, emptied, and closed at dawn. Polyester fiber was placed in each trap to provide insulation and bedding. Upon checking traps, the species identification and the sex of each captured individual was recorded. Voucher specimens were kept and prepared as conventional museum study specimens. These are deposited in the Bird and Mammal Museum at San Jose State University. The California Department of Fish and Game (CDFG) and the U.S. Forest Service (USFS) issued collection permits (CDFG permit #803025-04; USFS authorization #WAR0026). The San Jose State University Institutional Animal Care and Use Committee approved this study (protocol #793).

Habitat Sampling.—The habitat at each trap-site was characterized by recording information along each of the four trap-lines. A 2 meter-long transect was placed at the 100 m and 200 m marks on each trap-line and habitat variables were measured. These habitat variables included

grass height and cover, forb height and cover, shrub height and cover, litter depth and cover, bare ground cover, rock cover, tree canopy cover, tree density, and degree slope/aspect. Forest communities were also identified at the 100 m and 200 m marks on each trap-line. Forest communities were named with tree species listed in order of dominance, from most to least dominant. The elevation and latitude/longitude of each trap-site center and trap-line were recorded using a Geo Explorer III (Trimble Navigation) global positioning system.

Data Analysis.—The Shannon-Wiener diversity index (H') was used to calculate species diversity for each trap-line (Magurran 1988) and the diversity scores were calculated from the 349 total individuals caught. Species richness was calculated by totaling the number of different species caught per trap-line. Trap-line elevations were calculated by averaging the elevations recorded at the 0 m, 50 m, 100 m, 150 m, 200 m, and 250 m marks along each trap-line. Linear regression was used to determine correlations and significance between (a) species diversity, species richness, and average elevations and between (b) species diversity, species richness, and habitat variables.

RESULTS

A total of 349 individual rodents were caught, with a trapping success rate of 11%. The 349 trapped individuals included seven rodent species: California kangaroo rat (*Dipodomys californicus*), bushy-tailed wood rat (*Neotoma cinerea*), dusky-footed wood rat (*Neotoma fuscipes*), Great Basin pocket mouse (*Perognathus parvus*), deer mouse (*Peromyscus maniculatus*), pinyon mouse (*Peromyscus truei*), yellow pine chipmunk (*Tamias amoenus*) (Table 1). The percentage of rodents trapped, out of the total caught ($N = 349$), varied between the west, east, and ridge sections. (Table 2). On the eastern slope, 15% and 19% more rodents were trapped than on the western slope and ridge, respectively.

Neither diversity nor species richness linearly correlated with elevation (Fig. 3). Visual inspection of Figure 3 does indicate, however, that diversity and species richness may have a curvilinear relationship with elevation. Higher diversity and species richness were found at low and high elevations while lower diversity and species richness were found at mid-elevations.

Diversity and species richness were significantly correlated with some habitat variables. Both diversity and

species richness negatively correlated with the percentage of grass/forb cover while only species richness positively correlated with the percentage of litter cover (Figs. 4 and 5).

DISCUSSION

This study indicates that a linear relationship does not exist between species diversity and elevation in the Warner Mountains. Instead, the relationship appears to be curvilinear (Fig. 3). This contradicts the findings of several other studies. In the Philippines, Rickart et al. (1991) found a positive correlation between small mammal diversity and elevation (elevation range of 475–1750 m). In Chile, Patterson et al. (1989) found a negative correlation between small mammal diversity and elevation (elevation range of 425–1135 m). Rahbek (1995) analyzed 97 studies conducted primarily in the tropics and found a peak in diversity at mid-elevations between approximately 1000 m and 2000 m from a total elevation range of 0–5000 m. Most similar to the current study's findings were those of Clausnitzer and Kityo's (2001) Ugandan study. They did not find a significant correlation between diversity and elevation. Comparisons to these studies, however, must be

interpreted with caution. The studies of Rickart et al. (1991), Patterson et al. (1989), Rahbek (1995), and Clausnitzer and Kityo (2001) were conducted in different regions of the world. Thus, these study areas likely differ from each other in vegetation, climate, and small mammal species.

In addition, differences in elevation range between studies may provide inconsistent gradients from which to compare one elevational transect to another. The elevational transects used by Rickart et al. (1991) and Patterson et al. (1989) fall largely below, and Clausnitzer and Kityo (2001) falls above, this study's elevation range of approximately 1500–2200 m. Rahbek's (1995) study does include elevations covered in the current study; however, his results show an inverse relationship between diversity and elevations from 1500–2200 m. Thus, by limiting comparisons to studies with similar elevations, only Rahbek's (1995) study can be used, and the current study contradicts his findings.

Rickart (2001) studied the relationship between small mammal diversity and elevation in 17 mountain ranges of the Basin and Range Province. Although the Warner Mountain range was not included in Rickart's (2001) study, his

results provide a more relevant comparison. The Uinta Mountains of Utah and Wyoming were used in Rickart's (2001) study to represent the typical relationship between diversity and elevation found in the Basin and Range Province. In addition to a similar geographic location, Rickart (2001) provided results for an elevation range of 1500–3100 m, which overlaps the elevation range in the current study. Rickart (2001) found a positive relationship between diversity and elevation ranging from 1500–2100 m with only a slight peak in diversity at mid-elevations (1700–2100 m). Above 2100 m, and particularly above 3100 m, diversity declined (Rickart 2001). In contrast with Rickart's (2001) findings, the current study did not find a positive correlation between diversity and elevation within elevations of 1500–1900 m. However, in the 1900–2100 m elevation range, the results from both studies (Rickart 2001 and the current study) document a positive correlation between diversity and elevation. From 2100–2200 m, the current study found that diversity continued to increase. This contradicts Rickart's (2001) findings for elevations above 2100 m.

Overall, the current study does not fit the patterns found by others (Clausnitzer and Kityo 2001; Patterson et

al. 1989; Rahbek 1995; Rickart 2001; Rickart et al. 1991).

The results of the current study are unique in that diversity and elevation are not linearly correlated, but rather reflect a curvilinear pattern with the lowest diversity measured at mid-elevations (1750–1900 m) (Fig. 3). Other factors may explain why these results differed from Rickart's (2001) study and some of the other studies mentioned above.

Season can influence trapping results, thereby affecting the correlation between species diversity and distribution (Sanchez-Cordero 2001; Yu 1994). All of the trapping in this study was conducted between 1 June and 3 August 2002. In addition, due to snow on the east slope, the west slope segment (TS 1–5) of the transect was trapped during the first eight days of June (Table 2). This may have influenced the results, as only 30% of the total individuals trapped were caught on the west slope.

The physiognomy of an area can also affect species diversity and distribution (Fellers 1994). Actually, habitat features, rather than elevation, may play a more important role in determining small mammal diversity and distribution (Figs. 4 and 5). Fellers (1994) reported microhabitat variables such as grass, shrub, rock, and bare

ground cover affect small mammal species diversity more than general habitat features. In addition, Rickard (1960) found that the amount of vegetation cover affects rodent distribution. Likewise, the current study found that an increase in grass/forb cover decreased species diversity and species richness, while an increase in litter cover increased species richness.

It may be that patterns of small mammal species diversity and distribution, whether influenced by elevation or physiognomic features, are unique to each region. In fact, it may be that no general pattern between diversity and elevation exists. Continued research is needed to determine if there are general patterns linking small mammal diversity and elevation. In addition, comparisons between studies in different geographic regions and with different elevation ranges should be made with caution to avoid inaccurate conclusions regarding patterns of species diversity and distribution.

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Table 1.—Trapping summary for entire study period (1 June–3 August 2002) including number of individuals caught and trap-site slope.

Trap-Site	Species*							Slope	
	PM	PT	PP	TA	DC	NF	NC	Total Richness	% Total Captures
1	19	0	0	0	0	1	0	20	2 5.73
2	13	0	1	0	0	0	0	14	2 4.01
3	13	0	0	0	0	0	0	13	1 3.72
4	17	0	0	6	0	0	0	23	2 6.59
5	29	0	4	0	0	0	0	33	2 9.46
PP	66	0	5	15	3	0	0	89	4 25.50
7	18	0	0	0	0	0	0	18	1 5.16
8	32	0	0	3	0	0	0	35	2 10.03
9	29	0	0	0	0	0	0	29	1 8.31
10	14	1	1	1	1	3	1	22	8 6.30
11	39	1	0	0	2	11	0	53	4 15.19
Total	289	2	11	25	6	15	1	349	7 100.00
% Total Captures 82.81 0.57 3.15 7.16 1.72 4.30 0.29									

* PM = *Peromyscus maniculatus*; PT = *Peromyscus truei*; PP = *Perognathus parvus*;
 TA = *Tamias amoenus*; DC = *Dipodomys californicus*; NF = *Neotoma fuscipes*; NC =
Neotoma cinerea.

Table 2.—Percent of individual rodents trapped along the transect on the west slope, ridge, and east slope.

Trap-Sites	% Trapped	Slope	Dates Trapped
1, 2, 3, 4, 5	29.51	west	June 1-8
PP	25.50	ridge	August 1-3
7, 8, 9, 10, 11	44.99	east	June 25-30; July 8-13, 29-31

Figure 2.—Diagram of a typical trap-site with four quadrants. The vertical thick line represents the transect or road, NFS Route 31. The black dot represents the center of the trap-site. The trap-lines are shown radiating out from the trap-site center by dashed lines. Trap-lines were placed along randomly selected compass bearings. The dashed line circled around the trap-site center represents a radius of 50 m.

a)

b)

Figure 3.—Comparison between trap-line average elevations (m) and a) Shannon-Wiener diversity scores (H') (r [42] = 0.175; $p \geq 0.05$) and b) species richness (r [42] = 0.143; $p \geq 0.05$).

Figure 4.—Relationship between trap-line Shannon-Wiener diversity scores (H') and average percent grass/forb cover (r [42] = -0.302 ; $p < 0.05$).

a)

b)

Figure 5.—Relationship between trap-line species richness and a) average percent grass/forb cover ($r [42] = -0.323$; $p < 0.05$), and b) average percent litter cover ($r [42] = 0.309$; $p < 0.05$).