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Demographics and ecology of an isolated population of the desert pocket mouse, Chaetodipus penicillatus sobrinus, in the Las Vegas Valley, Nevada

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DEMOGRAPHICS AND ECOLOGY OF AN ISOLATED POPULATION OF THE
DESERT POCKET MOUSE, CHAETODIPUS PENICILLATUS SOBRINUS,
IN THE LAS VEGAS VALLEY, NEVADA

by

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Bachelor of Science
University of Nevada, Reno
1997

Bachelor of Arts
University of Nevada, Reno
1997

A thesis submitted in partial fulfillment
of the requirements for the

Master of Science Degree
Department of Biological Sciences
College of Sciences

Graduate College
University of Nevada, Las Vegas
December 2002

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Thesis Approval
The Graduate College
University of Nevada, Las Vegas

August 16, 2002

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Entitled

Demographics and Ecology of an Isolated Population of the

Desert Pocket Mouse, Chaetodipus penicillatus sobrinus,

in the Las Vegas Valley, Nevada

is approved in partial fulfillment of the requirements for the degree of

Master of Science

Examination Committee Chair

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ABSTRACT

Demographics and Ecology of an Isolated Population of the Desert Pocket Mouse, *Chaetodipus penicillatus sobrinus*, in the Las Vegas Valley, Nevada
by

Kerstan Micone

Dr. Brett Riddle, Examination Committee Chair
Professor of Biology
University of Nevada, Las Vegas

A two-year mark recapture study was conducted on the desert pocket mouse, *Chaetodipus penicillatus sobrinus* on a relic population within the city of Las Vegas, NV. Demographic information and movement patterns were documented and microhabitat selection analyzed. *Chaetodipus. p. sobrinus* activity correlated with ambient temperatures, during colder months (Ta = 15 °C) *C. p. sobrinus* became dormant. Sex ratio was 1:1 except during the early spring in which males were favored. Reproduction occurred between March and September each year. Male *C. p. sobrinus* has significantly larger home range estimates compared to females. The maximum dispersal distance was 133 meters and sex-biased dispersal was not observed. Home range overlap varied between sexes. Female intrasexual overlap was significantly greater when compared to intersexual and male intrasexual overlap. Plant physiognomy (canopy cover and height), soil particle size (> 2.0 mm), soil bulk density and distance to the nearest food resource (mesquite and acacia) significantly contributed to microhabitat selection within this study population.
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CHAPTER ONE

POPULATION DEMOGRAPHICS

Introduction

Coarse-haired pocket mice in the genus *Chaetodipus* and family Heteromyidae include about 15 species distributed primarily in warm deserts in western North America (Hall 1981). One such species, the desert pocket mouse (*Chaetodipus penicillatus*), occurs throughout the Sonoran and Mojave deserts of the United States and Mexico and consists of six subspecies (Hall 1981; subsequently modified by Lee et al. 1996) that vary primarily in size and pelage. *Chaetodipus p. sobrinus* Goldman is a large-size subspecies that is associated with sandy soils and typically found in arid riparian washes that border the Colorado, Virgin and Muddy rivers in southeastern Nevada and northwestern Arizona (Fig. 1: Hall 1946; Hoffmeister 1986). A few adjacent populations also occur in the extreme southwestern corner of Utah near the Beaver Dam Wash (Hoffmeister 1986).

Prior to 1997, the subspecies of the desert pocket mouse originally native to southern Nevada, *C. p. sobrinus*, had not been documented within the Las Vegas Valley subsequent to Vernon Bailey’s documentation of their occurrence here in March of 1891 during the U.S. Biological Survey Death Valley Expedition. Currently, *C. p. sobrinus* is included as an "Evaluation-High Priority" species under the Clark County Multiple Species Habitat Conservation Plan (MSHCP). Evaluation species are those in need of background information in order to provide informed management prescriptions. High priority species are those that are at higher risk of extinction and therefore could be listed under the Endangered Species Act (ESA) in the
foreseeable future. Due to considerable modification of the native geographic distribution of this subspecies (generally, the lower Colorado River drainage system; Hall, 1981; Hoffmeister, 1986) the population structure currently is highly fragmented and extant populations are effectively isolated from one another. Small, isolated populations are vulnerable to human disturbances, stochastic disturbance events, and loss of genetic variation, all of which tend to increase their extinction probability. The recently documented occurrence of the desert pocket mouse, *C. p. sobrinus*, within the Las Vegas Valley (O'Farrell 1998) has initiated additional research into this subspecies' geographic distribution, genetic variability within and among extant populations, and basic population trends and potential threats.

Demographic parameters (e.g., birth, death, immigration, emigration rates; survivorship; sex ratio; and age structure) contribute to the growth or decline of a population. Additional ecological attributes (e.g., home range size and long distance movement, as well as macrohabitat and microhabitat preferences) provide needed information on components of habitat distribution and composition critical to sustaining the viability of populations. As such, an understanding of both the demographics and ecology of a species of concern within the relevant portion of its geographic range provides a necessary foundation from which to establish future management prescriptions.

*Ecology of C. penicillatus*

Desert pocket mice are nocturnal granivores and collect seeds by sifting through light organic litter. All have fur-lined cheek pouches that serve to transport seeds back to their burrows to be eaten in safety or stored for later use. Previous studies have found that *C. penicillatus* tend to prefer large seeds regardless of texture (Price 1983). Smigel and Rosenzweig (1974) found that *C. penicillatus* had a more specialized diet when seed densities were high and became adaptively flexible, or less selective, when seed densities were low. Thompson (1982) described pocket mouse foraging as a slow and continuous movement within and between shrub areas while simultaneously sifting sand to extract seeds. Pocket mice are known to locate seeds by tactile (Lawhon and Hafner 1981) and olfactory (Jorgenson 1981) means and are thought not to
have the sophisticated learning abilities that have been found in confamilial kangaroo rat species in the genus *Dipodomys* (Rebar 1995).

*Chaetodipus penicillatus* is fully independent of exogenous water (Grubbs 1974). This ability to exist entirely on a metabolic water supply is due to enhanced behavioral and physiological abilities to reduce water lost to the environment. One individual *C. penicillatus* was documented as having urine concentration of 7,500 mOsm/kg (Altshuler et al. 1979).

Seed caching in the family Heteromyidae and genus *Chaetodipus* is somewhat controversial. Price and Heinz (1984) found that the number of seeds harvested was positively correlated to seed and soil density in *C. penicillatus*. The number of seeds harvested was negatively correlated with larger soil particle size. Jenkins and Breck (1998) found that in laboratory arenas, larger kangaroo rat species larder hoarded (stored seeds inside the burrow system) more than the long-tailed pocket mouse, *C. formosus*. *Chaetodipus formosus* made larger scatter hoards (caches buried at shallow depths in soil) when compared to larger kangaroo rat species. *Chaetodipus formosus* also deposited multiple seed loads within each scatterhoard. However in field studies *C. formosus* larder hoarded more than Merriam’s kangaroo rat, *Dipodomys merriami* (Jenkins and Breck 1998, Price et al. 1997). *Chaetodipus penicillatus* has also been observed climbing on forbs and grasses in order to obtain seeds (Reichman and Price 1993).

Past studies have reported that *C. penicillatus* forages under shrubby canopy cover rather than out in open areas (Rosenzweig 1973, Price 1978, Wondolleck 1978). In a study conducted by Rosenzweig (1973), *C. penicillatus* shifted microhabitat use in response to cleared and augmented areas. The augmented areas were made up of plant debris that had been cut. This study demonstrated that foraging was determined to a greater extent by the physical structures of the vegetation, not the food resource associated with it. However, when microhabitat was cleared, *C. penicillatus* did forage up to four meters into open areas. In field studies, Hoover et al. (1977) found that *C. penicillatus* (now considered a separate species, the Chihuahuan desert pocket mouse, *C. eremicus*) occurred in soils with higher percent fine soil particles and with higher heat buffering capacity when compared to the rock pocket mouse, *C. intermedius*. In
laboratory settings *C. eremicus* aggressively defended sandy soil habitat against *C. intermedius* (Hoover 1977). Rosenzweig and Winakur (1969) did not detect an increase in population density related to soil depth or soil particle size for *C. eremicus*. Price et al. (1984) hypothesized that microhabitat partitioning within the Heteromyid family may be due to predation pressure. She found that moonlight had a significant effect on the frequency of capture in open versus covered traps in various Heteromyid species including *C. penicillatus*. Frequency of capture in open areas was significantly lower during periods of full moon compared to subsequent periods of partial dark and completely dark phases (new moon) of moonlight. Longland and Price (1991) found that owl velocities during attack were greater under full moon conditions when compared to attack velocities under new moon conditions, thus moonlight may be associated with higher predation rates and microhabitat partitioning in *C. penicillatus* may reflect this predation pressure.

Desert pocket mice typically reproduce during the growing season when seed abundance is high, during spring or late summer. Females have a gestation time averaging twenty-six days and will produce litters that range from 2-4 young and have a mean litter size of 1-2 (Price 1998). Female young that are born in spring may even have one litter by late summer when seed production is high (Genoways and Brown 1993). Reproduction trends may vary due to extreme climate differences across the large geographic range of this species.

Torpor is used by many heteromyids as an energy-conserving mechanism for short periods of time and as a form of hibernation during the cold season, during which individuals abandon surface activity for months at a time (MacMillen 1982). Brower (1970) found that mean length of torpor in *C. penicillatus* increased as ambient temperature decreased. Entry into torpor typically occurred slightly after dawn and ended during the latter half of the evening. *C. formosus* also used torpor as a means for conserving food stores when seed sources were limited. Seeds stored during the fall months are used as a reserve during the winter season (Price 1998). Seasonal dormancy varies over the range of *C. penicillatus*. In the lower latitudes of this species distribution *C. penicillatus* is active year round (Jameson and Peters 1988), but in other parts of its range becomes seasonally inactive during the winter (Arnold 1942, Swift et al. 1994).
The maximum lifespan of *C. penicillatus* is not known, although Porter (1994) reported high annual turnover. Only 5% of *C. p. woodhouse* individuals captured during the peak season of activity survived one year. However, mortality may be overestimated if undetected dispersal occurs (Zeng and Brown 1987). Brown and Zeng (1989) found that the maximum longevity for *C. penicillatus* was twenty-six months in a long-term field study conducted in the Chihuahua Desert.

Home range size and dispersal distance of *C. p. sobrinus* was not known prior to this study. Certain species of *Chaetodipus* (*C. formosus* and the San Diego pocket mouse, *C. fallax*) exhibit both intrasexual and intersexual overlap in home ranges (MacMillen (1964), Maza et al. (1973)). Male *C. formosus* had larger home range size than females and longer distance excursions compared to females during the breeding season, suggesting that this species either had a polygnous or promiscuous mating system (Maza et al. 1973). In a long-term study near the Nevada Test Site, dispersal within several species of heteromyids appeared to be random and males tended to disperse long distances more often than females (French 1968).

**Methods**

**Study Site.** - - A mark recapture study was conducted on a 180-acre parcel of land that encompasses the remnant Las Vegas Springs habitat, southwest of the I-95 and I-15 (Fig. 2). This study site will be the future home of the Las Vegas Springs Preserve (hereafter referred to as the Preserve) and is located in the middle of the urbanized city of Las Vegas, NV. Due to land use over the last fifty years the area left today is a mosaic of highly disturbed habitat with patches of intact pristine cottonwood/willow, mesquite bosque and desert scrub communities.

Trapping Grid Locations and Habitat Description. -- A previous baseline survey provided areas on the Preserve where *C. p. sobrinus* were located (O’Farrell 1998). Three habitat types were selected for census every third month (during the first year of the study) and monthly (during the second year)(Table 1). The three habitat types were selected in a stratified manner (Fig.3).

Six circular quadrats 100 m² were used to sample the perennial vegetative community throughout the three habitat types. Habitats varied in soil composition (Fig. 4 and 5), percent
plant cover, and vegetative composition (Fig. 6). Species diversity was measured using a Jackknife Method and Species Richness curve (Fig. 7).

Table 1. Trapping schedule for year one and two

<table>
<thead>
<tr>
<th>Hab</th>
<th>7/99</th>
<th>8/99</th>
<th>9/99</th>
<th>10/99</th>
<th>11/99</th>
<th>12/99</th>
<th>1/00</th>
<th>2/00</th>
<th>3/00</th>
<th>4/00</th>
<th>5/00</th>
<th>6/00</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Two</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Three</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

Habitat one was located in the extreme northeastern corner of the Preserve. The dominant vegetation consisted of globe mallow (*Sphaeralcea ambigua*), goldbush, (*Isocoma acradenia*) and saltbush (*Atriplex canescens*). The soil in habitat one can be classified as “Sandy Loam” (USDA 1993). Habitat two lies within a remnant riparian corridor and has the highest total canopy cover yet the lowest species diversity. Inkweed (*Sueda moquinii*) is the dominant species within this area. Soil composition in habitat two can be classified as “Sandy Clay Loam” (USDA 1993). Lastly, habitat three is located on a remnant springmound. Its dominant species include, shadscale (*Atriplex convertifolia*) four-winged saltbush (*Atriplex canescens*), mormon tea (*Ephedra nevadensis*) and white bursage (*Ambrosia dumosa*). Soils in this habitat can be described as “Loamy Sand” (USDA 1993).

First Year:

**Abundance and Demographics.** The first year, radial trapping webs were used to measure density within the different habitat types and to gather demographic information. Two trapping webs were set up in each habitat during the week of the new moon. Trapping webs
were ran for a minimum of four consecutive days and were ran longer if new individuals were captured within the first ring of the trapping web on the fourth day (Anderson et al. 1983). The webs in this sampling method are circular grids that were designed to model point transect sampling theory in which the probability of detection decreases as one moves farther away from the center. Each trapping web sampled an area of 0.785 ha; thus a total of 1.57 ha was sampled per habitat type. Twelve lines radiated out from the web center with seven Sherman live traps placed on each line. Four additional traps were placed one meter north, south, east and west of the center point ((7 traps * 12 lines) + 4 traps = 88 traps per web). In each line the first four traps were placed at 5-m intervals, then at 10-m intervals from trap # 4 to trap # 7. The radius of each trapping web equaled 50 m (Fig. 8).

The program DISTANCE was used to estimate absolute abundance during the first year. Each trapping web was estimated separately and then averaged within each habitat. Populations were assumed to be closed during the sampling period. By estimating density using this methodology the following assumptions were made (Anderson et al. 1983): C. p. sobrinus at the center of the trapping web were captured with probability = 1 by the end of t occasions (t= > 4 trap nights); movement is stable with respect to the trapping web; distances from the center of the web to each trap are measured accurately; and captures are independent events. The relative frequency histograms of capture allowed truncation points to be established so that complications due to animals attracted to the baited trap stations near the outer perimeter of the trapping web would be eliminated (Anderson et al. 1983).

Each C. p. sobrinus individual was weighed and sexed. Individuals were marked using Passive Integrated Transponder (PIT) tags and assigned a unique identification number. Reproductive conditions were recorded and age class assessed (Table 2). Age classes were separated into groups within this population by the following criteria; juveniles had a sparse pelt and weighed between 10 – 13 g, subadults had molted their juvenile pelt and typically weighed between 13 – 15 g. Subadults and juveniles (occasionally) were PIT tagged if they had at least molted their natal pelt and weighed > 13 g.
Table 2. Classification used for reproductive condition and age class assessment.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age Class</th>
<th>Wt (g)</th>
<th>Morphology</th>
<th>Breeding Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>Juvenile</td>
<td>&lt;13</td>
<td>Sparse, fine pelt</td>
<td>Non-reproductive</td>
</tr>
<tr>
<td>Female</td>
<td>Subadult</td>
<td>&gt;13</td>
<td>Intermediate pelt (half juvenile and half adult), prominent nipples at times</td>
<td>Non-reproductive, or reproductive if nipples were prominent</td>
</tr>
<tr>
<td>Female</td>
<td>Adult</td>
<td>15-25</td>
<td>Prominent nipples or lactating or more than 25 g and prominent</td>
<td>Adult, Lactating, Pregnant</td>
</tr>
<tr>
<td>Male</td>
<td>Juvenile</td>
<td>&lt;13</td>
<td>Sparse, fine pelt</td>
<td>Non-reproductive</td>
</tr>
<tr>
<td>Male</td>
<td>Subadult</td>
<td>&gt;13</td>
<td>Intermediate pelt</td>
<td>Non-reproductive</td>
</tr>
<tr>
<td>Male</td>
<td>Adult</td>
<td>15-25</td>
<td>&gt;15 g, &gt; 15 g and scrotal sac descended</td>
<td>Non-reproductive adult, reproductive adult</td>
</tr>
</tbody>
</table>

Second Year:

Abundance and Demographics. —During the second year (2000 – 2001), six 8 x 8 square shaped quadrats replaced the circular trapping webs. There were two grids per habitat. Within grids, traps were spaced at ten-meter intervals (grid lines = 8, traps per line = 8, 8 lines x 8 traps = 64 traps per grid). The total area trapped for each grid was 0.49 ha (Fig. 9). Each grid was trapped simultaneously for four consecutive nights. Each month the grids were ran for four consecutive days except during the breeding season when five consecutive trap days were used in order to ensure all individuals were captured. The new grid design ensured that trap spacing was constant (10 m) and allowed movement throughout the grids to be monitored.

The Robust Method (Pollock, 1982) was used to estimate absolute abundance, probability of survival and the dilution rate of the population during the second year. This method incorporates both open population systems (population changes in size and composition due to births, deaths, and movement) and closed population systems (population does not change in size during the course of the study period). The Schnabel Method was used to estimate abundance (N). The Jolly-Seber method was used to calculate the probability of survival and the dilution rate into the population. The following assumptions were made in order to use this method; every individual has the same probability of being caught by the t-th sample session (t =
4), every marked individual has the same probability of survival, individuals do not lose their marks, and sampling time is negligible in relation to intervals between sampling sessions. Survivorship was also compared between age classes (juvenile and subadults to adults) and between sexes using a chi-square test.

The Leslie, Chitty, and Chitty test (Leslie et al., 1953) was used to test for equal catchability throughout the second year of trapping. There were slight variations in catchability observed in this population and a completely open model could not be used. Manly's test was used in order to test for the effect of marking with PIT tags (Manly, 1971). There was no significant difference in survival between individuals newly exposed to marking and all others ($G = 0.211, P<0.05$). In a previous study Schooly et al. (1993) conducted a two-year study to investigate the effects of PIT tags on towsend's ground squirrel, Spermophilis townsendii. They observed no known deaths due to PIT tags and little infection at the implantation site. Thus it was assumed that PIT tags did not have a negative effect on C. p. sobrinus survival.

Seasonal abundance estimates continued to be monitored. Seasonal activity patterns and reproductive trends were also followed on a larger scale (all three areas per trapping session), thus allowing for a broad comparative analysis of demographic trends across habitat types.

The Jolly - Seber model and the Schnabel Model both were used to estimate abundance within each habitat with pooled capture data from both grids. The pooled data increased sample size and tightened confidence intervals in both models. Confidence intervals (95%) were calculated using the Poisson Distribution (Krebs 1999).

Results

Population Demographics. -- A total of 28,000 trap nights were successfully completed and roughly 384 individual C. p. sobrinus were marked over the two-year period of time. The frequency of capture within this population was highly skewed, with the majority of the individuals captured only once. Recapture frequencies between the sexes was not significantly different ($\chi^2 = 0.022, df = 1, P > 0.05$) and recapture frequency also did not vary among habitat types, thus
trapping efficiency did not appear to vary within different habitat types \( (G_p = 13.94, \ df = 2, \ P > 0.05) \) or between sexes.

Sexual size dimorphism was observed within this population. Median weight (g) of non-breeding males was significantly larger when compared to females \( (W = 113359.5, n = 376, \ n = 304, \ P = 0.000) \). The average non-breeding adult male weighed 20 g whereas females tended to weigh slightly less than 19 g on average.

The maximum life spans that were observed in \( C. \ p. \ sobrinus \) were 14 months for two male adults and 16 months for one female adult. The frequency of males and females to survive from one year to the next was not significantly different \( (x^2 = 0.23, \ df = 2, \ P > 0.05) \). When juveniles and subadults of the opposite sex were compared there was also no significant difference observed between the frequency of male and female captured from one year to the next \( (x^2 = 1.76, \ df = 2, \ P > 0.05) \).

\( Chaetodipus. \ p. \ sobrinus \) seasonal activity was positively correlated with average minimum ambient temperatures \( (r = 0.44, n = 25, \ P < 0.05) \) (Fig. 10). During both years there was a large decline in activity that occurred during the winter months (approximately December to February) (Fig. 11). Several individuals found in traps during the month of November 1999 (1\textsuperscript{st} year of the survey) died due to exposure to low temperatures. The average ambient temperature at night was 9 °C during the November 1999 trapping session. Critical minimum temperature for \( C. \ penicillatus \) has previously been documented between 13 – 15 °C (Grubbs 1974). The mortality that was observed during this month suggests that \( C. \ p. \ sobrinus \) at the Preserve site may have similar lower critical temperature thresholds.

Sex ratios in \( C. \ p. \ sobrinus \) were typically 1:1, except during the early spring months both survey years. Sex ratio during the early springtime favored males. During the first year this occurred during April and March and the second year this occurred over a longer period of time from February to March (Fig. 12).

The reproductive season began between March and May both years with the presence of scrotal males in the population. Males were reproductive from May to October. Pregnant females were encountered as early as June and documented up until September. Lactating
females and the presence of subadults and juveniles peaked during July and August, although a few young were present in the population as early as June (Fig. 13).

**Abundance Year One.** -- *Chaetodipus. p. sobrinus* abundance peaked between July and October. Peak abundance coincided with production of new seed crops throughout the Preserve and with the recruitment of new individuals into the population. Abundance decreased during the colder months (December – March)(Table 3).

<table>
<thead>
<tr>
<th>Month</th>
<th>Habitat</th>
<th>(N)/ha</th>
<th>95% CI lower</th>
<th>95% CI upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>July</td>
<td>1</td>
<td>107.52</td>
<td>48.44</td>
<td>243.18</td>
</tr>
<tr>
<td>August</td>
<td>2</td>
<td>91.79</td>
<td>38.95</td>
<td>225.10</td>
</tr>
<tr>
<td>September</td>
<td>3</td>
<td>60.86</td>
<td>19.72</td>
<td>192.78</td>
</tr>
<tr>
<td>October</td>
<td>1</td>
<td>66.83</td>
<td>24.38</td>
<td>191.07</td>
</tr>
<tr>
<td>November</td>
<td>2</td>
<td>255.80</td>
<td>130.26</td>
<td>507.16</td>
</tr>
<tr>
<td>December</td>
<td>3</td>
<td>7.92</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>January</td>
<td>1</td>
<td>5.55</td>
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<td>NA</td>
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<td>February</td>
<td>2</td>
<td>3.02</td>
<td>NA</td>
<td>NA</td>
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<td>March</td>
<td>3</td>
<td>2.54</td>
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<td>April</td>
<td>1</td>
<td>46.71</td>
<td>13.03</td>
<td>169.54</td>
</tr>
<tr>
<td>May</td>
<td>2</td>
<td>41.83</td>
<td>17.27</td>
<td>104.54</td>
</tr>
</tbody>
</table>

**Abundance estimates for the month of November were problematic due to a substantial overestimate that may have been due to trap spacing near the center of the trapping web (Parmenter et al. 1989).**

**Abundance Year Two.** -- Abundance during the second year was estimated each month. During most periods of activity abundance estimates averaged 5 – 15 individuals/ ha (Table 4).

The second year also showed peak numbers during the breeding season (May – November) and was followed by a sharp decrease in numbers during the winter months (January – February). There was a slight increase in abundance during the month of March right before the onset of the breeding season, which corresponded with an increase of male mobility and mate finding.

Abundance varied between habitat types ($F = 3.96$, df = 2, $P = 0.029$). Habitat two had significantly higher numbers when compared to habitat one over a one year period of time ($F = 3.96$, df = 2, $P = 0.029$). Habitat two also had slightly higher mean abundance estimates when
compared to habitat three, but the difference was not significant. There were no significant
differences between habitats one and three. The highest abundance occurred in habitat two and
was around 24 individuals per hectare (95% CI 14.45 – 41.1), (Table 4).

Table 4 Schnabel abundance estimates 2000 - 2001.

<table>
<thead>
<tr>
<th>Mo.</th>
<th>Habitat One (N) per ha</th>
<th>95% L</th>
<th>95% U</th>
<th>Habitat Two (N) per ha</th>
<th>95% L</th>
<th>95% U</th>
<th>Habitat Three (N) per ha</th>
<th>95% L</th>
<th>95% U</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td>10.7 4 39.1</td>
<td></td>
<td></td>
<td>J 16.4 7.3 26.1</td>
<td></td>
<td></td>
<td>J 6.5 3.44 15.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>8.1 3.7 20.6</td>
<td></td>
<td></td>
<td>A 12.6 10.3 27.3</td>
<td></td>
<td></td>
<td>A 15.2 8.67 18.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>11.9 5.5 27.2</td>
<td></td>
<td></td>
<td>S 18.4 10.3 27.3</td>
<td></td>
<td></td>
<td>S 15.5 9.14 27.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>8.6 1.6 168.5</td>
<td></td>
<td></td>
<td>O 20.8 14.4 31.1</td>
<td></td>
<td></td>
<td>O 14 9.61 21.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>4.7 1.2 15.3</td>
<td></td>
<td></td>
<td>N 23.5 14.4 41.1</td>
<td></td>
<td></td>
<td>N 16 8.83 26.4</td>
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<tr>
<td>D</td>
<td>0 NA NA</td>
<td></td>
<td></td>
<td>D 16.2 9.8 28</td>
<td></td>
<td></td>
<td>D 9 4.21 20.6</td>
<td></td>
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<tr>
<td>J</td>
<td>0 NA NA</td>
<td></td>
<td></td>
<td>J 0.8 NA NA</td>
<td></td>
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<td>J 2.3 NA NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>0 NA NA</td>
<td></td>
<td></td>
<td>F 4.7 NA NA</td>
<td></td>
<td></td>
<td>F 5.2 NA NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>5.3 2.3 13.5</td>
<td></td>
<td></td>
<td>M 4.3 1.2 24.2</td>
<td></td>
<td></td>
<td>M 14.8 6.64 37.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>0 NA NA</td>
<td></td>
<td></td>
<td>A 3.1 1.6 6.64</td>
<td></td>
<td></td>
<td>A 6.2 2.81 15.9</td>
<td></td>
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<tr>
<td>M</td>
<td>6.5 2.6 18.9</td>
<td></td>
<td></td>
<td>M 6.2 2.3 22.9</td>
<td></td>
<td></td>
<td>M 3.9 1.76 9</td>
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<tr>
<td>J</td>
<td>3.9 1.3 14.3</td>
<td></td>
<td></td>
<td>J 10.4 4.8 23.9</td>
<td></td>
<td></td>
<td>J 9.8 5.23 23.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Immigration and emigration rates were also tracked during the second survey year.
Habitats varied throughout the year, but overall there was not a significant difference observed
between habitat types (F 3, 33 = 0.32, P = 0.726). All habitats had the highest additions to the
population from July to October. This occurs during the breeding season and is most likely due to
new recruitment into the area. However, all habitats also exhibited partial increases during the
early spring (February-March). During this month most captures are males and this may be due
to males moving larger distances (expanding home range) due to the breeding season onset.
Lastly, during late fall and winter months (October – December) there is a loss of individuals from
each habitat that may be due to young dispersing out of the area or due to high mortality rates
during the winter months.

The definition of survival in this study means staying alive and remaining on the study
area. The Jolly – Seber estimate corrects for accidental deaths and removals, however it is not

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able to distinguish between mortality and emigration. The probability of survival was not significantly different depending on habitat type (F 3, 24 = 3.04, P = 0.067), although habitat one did have a smaller probability of survival (0.4136) compared to habitats two (0.697) and three (0.691).

Discussion

*Chaetodipus. p. sobrinus* appears to have a cyclical activity pattern that is driven in part by ambient temperature. *Chaetodipus. p. sobrinus* activity was significantly correlated with minimum ambient temperature. Activity began in early spring and lasted until late fall. During the winter months (December, January, and February), *C. p. sobrinus* becomes seasonally dormant. This typically occurred when ambient temperature fell below 13-14 °C, which is close to the documented lower critical temperature of *C. penicillatus* (Grubbs 1974). However, there were always a few individuals captured throughout the winter. These individuals appeared to be subpar in weight and may not have had sufficient resources to last throughout the dormancy period. O'Farrell (1974) found that Great Basin pocket mouse, *Perognathus parvus* spent more time foraging above ground when food resources were scarce and suggested that a "minimal cache" may be needed for species to remain dormant during colder season.

During the early spring non-scrotal males become active after the seasonal dormancy. The sex ratio at this time shifts from 1:1 in favor of males while females remained dormant for one to two months longer. In many hibernating species males emerge a few weeks prior to females (O'Farrell et al. 1975). The early emergence of males may be due to the onset of the breeding season and the need for the males to establish home range areas that maximize emerging females later. French (1977) found that surface activity is typically resumed in the spring near the same time each year. *Chaetodipus. p. sobrinus* appeared to emerge from seasonal dormancy between March and April each year. Minimum ambient temperature during both years at this time was approximately 15°C. French (1977) also found that emergence from torpor in the Pacific pocket mouse, *Perognathus longimembris* may be due to a shift in soil temperatures and that this may be an important factor in stimulating *P. longimembris* to terminate torpor. A shift in
soil temperature may also be a factor that stimulates arousal from torpor in *C. p. sobrinus*. However, environmental and physiological factors that contribute to emergence from torpor are not well defined.

The maximum life span detected so far on the Preserve was 16 months. Porter (1994) found that annual population turnover in *C. penicillatus* was very high, approximately 95%. On the Preserve annual turnover was between 87-90%. Brown and Zeng (1989) found that maximum longevity was 26 months. Long term monitoring may better describe maximum life span on the Preserve. This study encompassed two years whereas Brown and Zeng (1989) monitored populations for 7.5 years. Currently this population is being monitored throughout the construction and development of the Las Vegas Springs Preserve project.

Recruitment into the population occurred as early as June and ended in early September. Price (1999) noted that during years of good resource production and weather, *C. penicillatus* young born during the early spring might reproduce in the late summer. Observations of pregnant subadults on the Preserve appear to follow this pattern as well.

Abundance data on *C. p. sobrinus* varied per habitat type. Habitat two had significantly higher abundance estimates when compared to habitat one. Recruitment also appeared to be higher in habitat two, although recruitment did not differ among habitat types. Habitat one had consistently lower abundance estimates when compared to habitat two and three. During the months of January, February, and April there were no individuals captured in habitat one. Both habitats three and one had lower canopy cover when compared to habitat two. However, habitat one and three had higher plant species richness. The dominant plant species within habitat two is inkweed (*Sueda moquinii*). Inkweed seeds were never collected from cheek pouches (Micone, 2001, unpublished data). It may be that *C. p. sobrinus* abundance is associated with the structural physiognomy of the plant canopy cover that this plant species offers (Rosenzwieg 1973). Habitat two remains connected to a large intact piece of undisturbed land along the northern half of the Preserve, whereas habitat one and habitat three have been fragmented and become more isolated over time. The size (area) of this connected habitat type may be better able to support larger population sizes over time.
The population size of *C. penicillatus* at the Preserve appears to be relatively large when compared to abundance estimates made elsewhere (Table 5). However, variance in abundance estimates for small mammals is extremely large over time and space.

### Table 5 Relative abundance estimates of *C. penicillatus* and its sister species *C. eremicus* throughout portions of its range.

<table>
<thead>
<tr>
<th>Study</th>
<th>Location</th>
<th>Abundance</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hoover et al. (1977)</td>
<td>Las Cruces, Dona Ana County, New Mexico</td>
<td>1-9/ ha grid one</td>
<td>One-year study (C. eremicus)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 - 12/ ha grid two</td>
<td></td>
</tr>
<tr>
<td>Price (1984)</td>
<td>Santa Rita Experimental Range, Arizona</td>
<td>1.75 indv/ trapping period</td>
<td></td>
</tr>
<tr>
<td>Brown and Zeng (1989)</td>
<td>Portal, Arizona</td>
<td>0.39/ ha</td>
<td></td>
</tr>
<tr>
<td>Micone, unpublished data</td>
<td>Overton Wildlife Refuge, Nevada</td>
<td>1-3/ ha</td>
<td>September 1999</td>
</tr>
<tr>
<td>Micone, this study</td>
<td>Las Vegas Springs Preserve, Nevada</td>
<td>14.73/ ha</td>
<td>Average per habitat type, November 2001</td>
</tr>
</tbody>
</table>

The Preserve is currently an isolated, relic piece of springland habitat that has been completely surrounded by urbanized development. The alterations and disturbances to this habitat over time have been severe. Vernon Bailey's 1891-field notes documented that *C. p. sobrinus* was actually collected in three different elevations within the Las Vegas Valley, the Preserve being one of the three locations. At that time, the riparian shrubland that is now the Preserve could have maintained a connective corridor of potentially suitable habitat all the way down to the Colorado River drainage. Currently there is limited information on the location of other active populations of *C. p. sobrinus*. The next appropriate course of action would be to sequentially monitor populations at different known localities over time and compare demographic trends within multiple populations in various parts of this subspecies distribution. If the Preserve currently harbors a viable and healthy population, then one would expect demographic
parameters to follow a fundamentally similar pattern observed in other areas nearby. Demographic information as well as seasonal activity patterns such as the breeding season or periods of seasonal dormancy are necessary life history traits that need to be known in order to properly mitigate and manage current extant populations effectively.
CHAPTER TWO

HOME RANGE, DISPERsal AND MATING SYSTEMS

Introduction

Home range has been defined as the area in which an animal performs most of its normal activities such as food gathering, mating, and caring for young (Burt 1943). Stamps (1995) stated that a home range allows an individual the ability to learn “site specific serial motor programs” that enhance the individual’s ability to maneuver through their environment. Numerous techniques and methods have been developed to allow researchers to assess movement of animals over time. Overall, home range size, home range overlap and maximum distances moved have been used to infer types of mating systems or strategies that are used by certain species as well as to provide information on spatial requirements, spatial distribution patterns and connectivity of populations throughout the landscape.

Pocket mice in the genus Chaetodipus have been reported as having a solitary social system with individual adults living alone in separate home ranges (Jones 1993). Mutual avoidance and antagonistic behavior is generally the case in most heteromyid species, even in male-female encounters, unless the female is in estrus (Jones 1993). Prior research on home range overlap in both C. fallax and C. formosus has shown different patterns of home range overlap for each species. MacMillen (1964) found that there was very little intrasexual overlap in C. fallax. However, Maza et al. (1973) found that C. formosus had both intrasexual (individuals of the same sex) and intersexual (individuals of the opposite sex) overlap occurring within his study population. Home range size in C. formosus and mean distance between farthest capture points was also greater for males compared to females.
Territoriality and Animal Movement. — Territoriality in most organisms is associated with high physiological cost and heightened mortality. One would assume that coexistence within a home range would evolve if the benefit of guarding valuable resources does not outweigh the energetic cost of guarding them. However, if territoriality is adaptive, then individuals capable of defending and holding a "high quality" territory should have greater reproductive success. Jones (1993) noted that the most direct evidence of territoriality would be observations of aggressive behavior in the field, which would include individuals defending burrows or home range area. However, direct observations are difficult to make when studying a nocturnal species like *C. penicillatus*. Observing behavior in laboratory settings, assessing dispersion of home range over the landscape or simply measuring the degree of home range overlap are indirect tools that can be used to infer territoriality.

One of the leading hypotheses for territoriality in small mammals is that spatial distribution, abundance, and renewal rate of food resources determine whether or not females defend territories, whereas, male territoriality is determined by the spatial and temporal pattern of females (Ostfeld 1990). This hypothesis states that females relying on food sources that are relatively sparse, patchy, and slowly renewed are expected to defend territories encompassing food patches. The need for females to optimize food sources comes from the increase in physiological (energetic) demands needed for reproduction. The energetic demands for a reproductive female in various species tend to be much higher when compared to non-reproductive males and females (Millar 1978; Kaczmarski 1966). Due to the patchy distribution of food resources (seeds) in granivorous small mammals, spatial distribution of reproductive females should tend to be centralized in areas of high seed resources and good burrowing and foraging habitat.

Patterns of home range overlap have been used to deduce territorial behavior in many organisms (Powell 2000). By using overlap indices that measure the degree of use within an overlapping home range area, one can infer territoriality of an individual. An individual with a low degree of overlap (low index value) would either not utilize or would have a small probability of using an area within their home range that overlaps with another individual's home range. This
pattern could indicate agonistic behavior by one individual towards another and thus indicate a higher degree of territoriality.

*Mating Systems and Animal Movement.* -- Prior research on mating systems within the genus *Chaetodipus* has found evidence of a promiscuous (indiscriminate mating of both males and females) or polygynous (males mate with several females) mating system (MacMillen 1964 and Maza et al. 1973).

Polygyny is highly dependent on ecological or social factors that influence the spatial distribution of females (Emlen and Oring 1977). If spacing of females is random, making it difficult for males to defend females, then the mating system can switch towards promiscuity or to a polygynous mating system termed “Scramble Competition Polygyny” (SCP). SCP mating systems occur when females mate with various accessible males and males “scramble” to cover as much ground as possible in order to increase their odds of encountering receptive females (Alcock 2001).

Another manner in which males may achieve polygyny would be to defend and control resources against other males, which dictate female spatial distribution. Thus the more resources a male can acquire the more likely he is to come into contact with female mates. This form of polygyny has been termed “Resource Defense Polygyny” (RDP) (Alcock 2001).

Males using the scramble mating strategy would exhibit less territoriality compared to males using the resource defense mating strategy. For males using the scramble strategy the benefit does not outweigh the cost in guarding and defending a territory because females are not easily monopolized and the probability of encountering a receptive female is random or haphazard. Males using the resource strategy would have a larger probability of mating with a reproductive female if they were able to ward off other potential male competitors, thus the increased probability of mating does outweigh the cost of guarding and maintaining a territory.

Another indicator of a polygynous mating system is sexual dimorphism, whereas, monomorphism is associated with monogamy (Ralls 1977). Larger size may enhance a male’s ability to defend breeding territory against competitors of the same sex and also improve successful breeding attempts with females. Ralls (1977) found that in many rodent species there

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appears to be little sexual dimorphism. Larger size may be just as important to females as it is to males in defending and allocating home range areas of high resource quality (Jones 1993), thus larger females may have an advantage when competing with smaller females for space. Behrends (1986) noted that in kangaroo rats there was an absence in home range size differences between males and females when there was not a strong size dimorphism.

*Dispersal and Animal Movement.* — Prior knowledge of a species mating system allows dispersal patterns to be understood (Jones 1993). Most working hypotheses on dispersal patterns either tie dispersal to competition for mates (Greenwood 1980) or to inbreeding avoidance (Packer 1979). Most mammals have a low paternal investment in their young and tend to have polygynous or promiscuous mating systems. Due to the higher male-male competition that is observed in polygynous mating systems it would seem likely that sex biased dispersal in favor of males would be more prevalent. Dispersal studies conducted on *C. formosus* have revealed that within this species there was no observed sexual bias in long distance dispersal (Allred and Beck 1963). French et al. (1968) found that 25-30 % of the *C. formosus* population dispersed farther than 500 feet and Maza et al. (1973) found that individual *C. formosus* shifted home range around 5% of the time.

Inferences about territoriality, mating strategies or systems, and dispersal tendencies of *C. p. sobrinus* can be made by observing patterns of movement over time. Greater distances moved or larger home range areas in males compared to females would be indicative of polygynous or promiscuous mating systems. Patterns of intersexual (home range overlap between sexes) and intrasexual (home range overlap within the same sex) overlap can also describe the mating system practiced by *C. p. sobrinus*. Home range overlap in males would tend to have higher overlap with nearby females and less overlap with nearby males in a polygynous mating system. Home range overlap can also be used to infer the degree of social tolerance or territoriality that *C. p. sobrinus* exhibits. A large index of overlap would indicate higher social tolerance; lower indices would indicate less social tolerance or increased territoriality.
Methods

Movement of *C. p. sobrinus* was recorded throughout the trapping grids during the second year of this study. Sampling intervals were divided into monthly trapping sessions in order to assume that locations were independent of one another. Location points may be autocorrelated if there is not a sufficient amount of time allowed to pass between each sampling intervals. (Dunn and Gipson 1977). Individuals were included in the analysis if they were captured six or more times. Ninety five percent minimum convex polygons (MCP) were calculated for each individual (Powell 2000). Home range estimates were calculated with "Animal Movement", an extension of ArcView version 3.2. Home range area (ha) and home range overlap was estimated using the Arc View extension "X tools". Home range area (ha) was log-transformed and a two-sample t-test was used to compare female and male home range areas.

Using 95% MCP for estimates of home range is suitable for data sets with small sample sizes because it does not assume animal movement follows a statistical distribution which is a common component to other home range estimators. A weakness of the 95% MCP is that home range estimates provide only an outline of an individual's movements and are highly sensitive to extreme data points. However, this estimate of home range enables a gross comparison of actual area used and comparisons between sexes to be made. When analyzing home range overlap, intensity of use within areas of overlapping home ranges was addressed in more detail.

Home range overlap was analyzed by using two indices of pairwise overlap. The first index used was the Simple Probability Index (Ip) (Powell 2000). This index is the simple probability that two animals (indv A and indv B) will be in their area of overlap at the same time were they to move independently of each other. Probability of being in the area of overlap was calculated by dividing the number of times an individual was captured within the area of overlap by the total number of times the individual was captured. Ip values range from 0 to 1.

\[
Ip = \sum P_{indv A} \cdot P_{indv B}
\]

Where \( P_{indv A} = \frac{\# \text{ of captures within area of overlap of individual } A}{\text{total } \# \text{ of captures}} \)

Where \( P_{indv B} = \frac{\# \text{ of captures within area of overlap of individual } B}{\text{total } \# \text{ of captures}} \)
A second similar index was calculated using Lloyd’s (1967) index of mean crowding, or \( m \). This index measures the probability of two individuals encountering or crowding one another and if this probability is higher or lower than would be expected if both individuals were uniformly distributed over their available space. This index standardizes overlap by the probability of both animals being in the same cell at the same time were each to use all cells in the combined home ranges evenly and without respect to one another:

\[
m = N \cdot \sum P_{indv A} \cdot P_{indv B}
\]

Where \( P_{indv A} = \) # of captures within area of overlap of individual A/ total # of captures
Where \( P_{indv B} = \) # of captures within area of overlap of individual B/ total # of captures
Where \( N = \) number of cells (trap sites) in which indv A or indv B (or both) has a nonzero probability of use.

Because each individual’s home range could overlap with more than one individual within the study site, pairwise index values are not strictly independent in the statistical sense. Index of overlap was divided into three groups, intrasexual overlap between females, intrasexual overlap, and intersexual overlap between males. The simple indices of overlap could not be transformed to fit a normal distribution and where compared using Kruskal-Wallis and Mann-Whitney U tests. Lloyd’s index of mean crowding was compared between each overlap group by log-transforming the indices and running a one-way ANOVA.

Dispersal distance was qualitatively investigated within the trapping grids by looking at the maximum distance moved by each individual trapped in at least two monthly trapping sessions. Random linear transects were also placed haphazardly throughout the study site (outside of the grid areas) in order to locate individuals who may have dispersed out of the trapping grid locations. The linear transects were ran a total of four times each year, twice in the early spring (April-May) and twice the following fall (October-November). In order to detect sex-biased dispersal, I compared the frequency of recapture for subadult/ juvenile females and males from one year to the next.
Results

Frequency of home range size (ha) was highly skewed to the right. The mean home range was 0.0625 ha and the median home range was 0.0314 ha. Home range area ranged from 0.0019 ha to 0.446 ha. Using log-transformed estimates, home range estimates were significantly larger for males compared to females (T = -1.75, df = 32, P = 0.05) (Table 6).

Table 6. Home range estimates for male and female C. p. sobrinus.

<table>
<thead>
<tr>
<th>Sex</th>
<th>N</th>
<th>Mean (ha)</th>
<th>Median (ha)</th>
<th>St Dev (ha)</th>
<th>SE Mean (ha)</th>
<th>Min (ha)</th>
<th>Max (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>14</td>
<td>0.0935</td>
<td>0.0366</td>
<td>0.128</td>
<td>0.0342</td>
<td>0.0055</td>
<td>0.446</td>
</tr>
<tr>
<td>Female</td>
<td>20</td>
<td>0.0407</td>
<td>0.0287</td>
<td>0.0425</td>
<td>0.0095</td>
<td>0.0018</td>
<td>0.155</td>
</tr>
</tbody>
</table>

Home range size was not significantly different among habitat types (F = 3.13, P = 0.198). Individuals in habitat one appeared to have slightly smaller home range size, but sample size within this habitat was low (N = 6).

Home range size was positively associated with average body weight for each individual (r = 0.459, n = 34, P = 0.006). When sexes were split, this relationship was only found to be significant for females, not males (r = 0.537, n = 20, P = 0.015) (r = 0.200, n = 14, P = 0.493). However, with one outlier removed from the data, average male weight was significantly associated with home range size (r = 0.553, n = 13, P < 0.05).

Degree of overlap (as a percentage of total home range size) had a skewed distribution. Mean percent overlap was 26.21% (median = 12.94 %), which was roughly the same for both male and females (25.68 % and 26.77 %); (median = 12.55 % and 13.34 %) respectively.

Chaetodipus. p. sobrinus home range overlap varied between females and males. There was a significant difference found between simple probability indices within the three types of overlap (f-f intrasexual, m-m intrasexual, and intersexual) (H = 13.48, d.f. = 2, P = 0.001). Female intrasexual overlap was significantly greater when compared to male intrasexual overlap (W = 173.0, n = 12, n = 10, P = 0.0229). Female intrasexual overlap was also greater than
overlap between males and females or intersexual overlap ($W = 340.5, n = 12, n = 25, P = 0.0003$). Simple probability indices of intrasexual overlap and intersexual overlap did not differ significantly in males ($W = 430.05, = 25, n = 10, P = 0.4878$).

Variation in home range overlap between sexes was also observed using Lloyd's index of mean crowding ($F_3, 44 = 5.56, P = 0.007$). Female intrasexual overlap had higher indices of mean crowding when compared to intersexual overlap. However, female intrasexual overlap was not significantly greater when compared to male intrasexual overlap using this index. Again male intrasexual overlap and intersexual overlap indices did not differ significantly (Table 7).

| Type of Overlap | Probability Index (Ip) | SD | Lloyd’s Index (m) | SD | Median Degree of Overlap (%) | SD (%)
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Intrasexual</td>
<td>0.262</td>
<td>0.134</td>
<td>2.36</td>
<td>1.15</td>
<td>27.62</td>
<td>33.85</td>
</tr>
<tr>
<td>Intersexual</td>
<td>0.106</td>
<td>0.111</td>
<td>1.11</td>
<td>0.994</td>
<td>9.62</td>
<td>27.58</td>
</tr>
<tr>
<td>Male Intrasexual</td>
<td>0.148</td>
<td>0.145</td>
<td>1.61</td>
<td>1.51</td>
<td>16.69</td>
<td>26.89</td>
</tr>
</tbody>
</table>

There was no dispersal detected between habitat types throughout the two-year mark recapture study. There was also no movement outside of the trapping grids while trapping linear transects throughout the study area over the two-year period. The mean maximum distance moved per individual over the second year of study was approximately 36 meters (SD = 29.13 m). Maximum linear distance was not significantly different between sexes ($T = 0.37, df = 80, P = 0.71$), although males did tend to move farther. The maximum distance moved for a male was 132.70 m, whereas, the maximum distance moved for females was 114 m.

Sex-biased dispersal was not observed in *C. p. sobrinus* within the Preserve population. If male subadults were dispersing at a higher rate from the natal area one would expect a higher frequency of females to occur within the trapping grid the following breeding season. This was
not the case. The frequency of subadult males and females did not differ from one year to the next ($x^2 = 1.76, \ df = 2, P > 0.05$). Adult females also did not occur at a significantly higher frequency within the study area from one year to the next ($x^2 = 0.23, \ df = 2, P > 0.05$).

**Discussion**

Measurement of home range size, home range overlap and dispersal distance in this relic population provides new information about *C. p. sobrinus* population biology. Average home range size for this population was 0.0625 ha. Males had significantly larger home range size than females. Female *C. p. sobrinus* overlapped significantly more often with other females (f-f intrasexual overlap). Male *C. p. sobrinus*, in general, had low overlap with both males and females (m-m intrasexual or intersexual).

Previous studies conducted on *C. formosus* (Maza et al. (1973)) and *C. fallax* (MacMillen (1964)) and this current study of *C. p. sobrinus* demonstrate that pattern of overlap does vary within the genus *Chaetodipus*. *Chaetodipus fallax* overlapped individuals of the opposite sex more often than congers of the same sex. *Chaetodipus formosus* was found to have both intersexual and intrasexual overlap occurring within Maza et al’s (1973) study population. In this study, *C. p. sobrinus* was observed to have a significantly higher index of female intrasexual overlap compared to male intrasexual overlap and intersexual overlap. However, the tendency for males to have larger home range sizes or move farther distances compared to females, appears to be the same in all three species (*C. formosus, C. fallax* and *C. p. sobrinus*) within this genus.

*Territoriality in C. p. sobrinus.* --One of the leading hypotheses for territoriality in small mammals is that spatial distribution, abundance, and renewal rate of food resources determine whether or not females defend territories, whereas, male territoriality is determined by the spatial and temporal pattern of females (Ostfeld 1990). According to this hypothesis, female species that rely on food resources that are relatively sparse, patchy, and slowly renewed are expected to defend territories encompassing food patches. Using overlap indices, one can infer territoriality of
an individual. Thus an individual with a low degree of overlap (low index value) should have lower home range overlap and may be due to increased territoriality.

In this study population *C. p. sobrinus* females are particularly likely to overlap in home range with other females and exhibit stronger social tolerance compared to males. It may be that food resources within their home range are not limited during their active season (spring through fall). Conversely, males had significantly lower indices of overlap compared to females and appear to be more territorial. However, intersexual overlap appears to have the lowest indices overall. This could mean be due to various reasons, the first being that females are actively defending their home ranges against incoming "strange" males that may be a potential threat to their young. This hypothesis is supported by the significant differences observed in intrasexual overlap and intersexual overlap indices in females. Females may be actively defending or warding off males more often than other females that may intrude on their home range.

Another possibility is that males could be actively defending their home range areas against females. Males could in fact only allow females to frequent their home range areas when the female is in estrous and females who are not reproductively receptive would be aggressively warded off out of the male's territory during other non-reproductive times. Jones (1993) described this overall pattern of mutual avoidance in most heteromyid species and that relaxation of territoriality only occurs during brief periods of the mating season when females are receptive.

Lastly males could be on the move so much that frequency of capture within a female's home range would be smaller compared to other surrounding females who's home ranges are smaller and clumped together around seed resources that are patchy and slowly renewed. Home range size differences found within this population appear to support this last hypothesis as well. Average home range size for males was significantly larger when compared to females and in males there was no significant differences in intersexual overlap and male intrasexual overlap. Thus males appeared to have the same probability of overlapping with either males or females, but overall probability of using the area of overlap in general was not high.

When using the simple probability index, males tended to exhibit higher degrees of territoriality. Although Lloyd's index of mean crowding did not significantly detect a difference
between female and male intrasexual overlap, the same rank order produced by the simple probability index was observed (female intrasexual overlap > intersexual overlap > male intrasexual overlap). Thus in C. p. sobrinus females appear to demonstrate less territoriality and more spatial tolerance towards other females and males may be actively defend territories against other females and males or just moving around so much that overlap is hard to detect given this sampling methodology (monthly mark recapture). The spatial tolerance of females observed in this population could be due to the simultaneous occurrence of seed production and the reproductive season. The high seed production during this time may preclude the need to defend one’s home range.

O'Farrell (1980) found the same pattern of greater female intrasexual overlap in P. longimembris. This increase in female intrasexual overlap was distinctly different compared to six other heteromyid species monitored, which had higher male intrasexual overlap occurring. O'Farrell (1975) also found that P. longimembris males moved significantly greater distances when compared to females, which is similar to the difference in overall home range area between C. p. sobrinus sexes. Jones (1993) noted that species of Perognathus and Chateodipus appear to have very similar social systems. Future research should examine the relationship of the overlapping females within both of these species, and ask whether female intrasexual overlap is greater between close relatives versus non-relatives. This would further our understanding of sociality in heteromyid species, especially regarding social behavior in pocket mice.

Another interesting hypothesis that one could investigate is that territoriality in female small mammals is driven in part by a female’s need to defend a nest site and deter infanticide (Wolff 1993). Under this hypothesis one would assume that defense of a food resource may simply be a byproduct of defending young from potential intruders who may practice infanticide. If male C. p. sobrinus tend to practice infanticide more often than females, one would expect C. p. sobrinus females to defend their home range area from potential male intruders and tolerate intrusion (or overlap) from surrounding females, which would describe the pattern observed in this population. An experiment could be designed in which seed resources are manipulated,
infanticide events/ attempts documented, and home range overlap estimated in order to test this hypothesis.

Mating Strategies. —Polygynous and promiscuous mating systems have been documented thus far in two chaetodipid species, *C. fallax* and *C. formosus* respectively (McMillan 1964 and Maza et al. 1973). Results from this study on *C. p. sobrinus* also show evidence of polygyny or promiscuity based on the differences observed between male and female home range area, males had significantly larger home ranges when compared to females.

Two polygamous mating strategies could be utilized within this population. Resource defense polygyny (RDP) would entail male *C. p. sobrinus* actively guarding an area with important resources needed by females such as food resources or important habitat resources. This would ensure that males would encounter multiple female mates. The second mating strategy would be to utilize scramble competition polygyny. In this situation male *C. p. sobrinus* would not be able to effectively guard resources utilized by females due to widely dispersed resources and unpredictable female occurrence and would opt to move about or “scramble” in order to encounter as many receptive females as possible. Scramble competition polygyny can also be utilized when there is a limited time frame in which females are receptive to mating. Thus, it becomes extremely important for males to encounter as many females as possible within a limited amount of time. *Chaetodipus. p. sobrinus* has a short breeding season (female reproduction occurred from June to September) and females have been documented as having an average gestation time of roughly 26 days (Jones 1993). Thus there may only be a short period of time for a male to encounter a receptive female and the competition between males during this time is probably fairly intense. It could also be that most mating systems utilize aspects of both RDP and SCP mating strategies. Males could “try” to defend as much quality habitat as possible, but still have to scramble and compete with other males during the mating season.

Index of home range overlap in this population showed significantly higher intrasexual overlap in female *C. p. sobrinus* compared to intersexual overlap and male intrasexual overlap. Females had a higher probability of utilizing the overlapping portions of their home range with
other surrounding females. This social tolerance would allow groups of females to form into units that male *C. p. sobrinus* could monopolize. However, in order to differentiate between both RDP and SCP mating strategies further experimentation on the location and habitat types of both females and males would need to be investigated. Studies would also need to compare movement during both reproductive and non-reproductive time periods.

Within this population, adult male *C. p. sobrinus* had significantly larger body sizes when compared to adult females. This size dimorphism is also evidence of a non-monogamous mating system. However, body size was significantly associated with larger home range size for females and males appeared to follow the same trend, although it was not significant. The positive association between body weight and home range size may also simply be due to metabolic requirements for larger individuals. Simply put, larger individuals may need more area in order to allocate sufficient resources to support their size.

*Dispersal in C. p. sobrinus.* – There was no apparent evidence that dispersal within *C. p. sobrinus* is sexually biased. Allred and Beck (1963) observed similar patterns in *C. formosus*. *Chaetodipus p. sobrinus* females and males did not move significantly larger linear distances within trapping grid areas. However, trapping grids are often too small to detect long-distance dispersal (Burt 1940, Merriam 1995). There was also no difference in the number of juvenile/subadult males and females observed in each habitat from one year to the next. One would expect to find lower frequencies of males captured from the previous year in the same habitat the following year if there was a sex bias in dispersal events.

Trapping efforts outside of the trapping grids failed to detect tagged individuals who may have dispersed outside of the trapping grid areas. There was also no known dispersal occurring between habitat types on the study site, but movement between trapping grids within habitat types was detected. The maximum distance that was moved within this population was an individual male that moved a distance of 132.7 meters.

Dispersal throughout the study site may be limited due to the highly fragmented landscape. Habitat one is was separated from habitat two by a large stormdrain channel that effectively blocked dispersal into the northeastern corner of the study site. This storm channel
flowed continuously throughout the active season (April – November) of \textit{C. p. sobrinus}. This storm drain channel is filled by water from residential and commercial run-off located nearby. Habitat one and habitat three were separated by a large detention basin which contained low quality habitat (low canopy cover, low food resources) and would be a large “sink” area for any potential dispersers due to increased predation risk and scant food resources. The detention basin also separates habitat three and habitat two to some extent. However, there is a small strip of contiguous habitat that ran along the western edge of the detention basin that could have been used as a dispersal corridor. Haphazard linear transects placed within this corridor did not detect any dispersing individuals and produced only one unidentified male \textit{C. p. sobrinus} during a spring trapping session.

Due to the collectively scant information on dispersal within this population a conservative approach would be to assume that dispersal throughout the study site is at an extreme minimum. French et al. (1968) found that 25% to 30% of the individuals in their study site made dispersal movements greater than 500 ft (approximately 152.40 meters). What is known is that within this population there is not male biased dispersal and long distance dispersal is unknown. In order to maintain a demographically variable and thus more viable population, connectivity within this study site should be restored. The width of the dispersal corridor should be at least the size of the maximum male home range (0.446 ha) with additional area on both sides that would buffer the negative impacts of edge effects.

\textit{Chaetodipus. p. sobrinus} movement provides important information needed in order to effectively manage the population on the Preserve. Changes in home range size can be monitored over time and associated with changes in relative abundance and demographic trends or with changes in ongoing or future disturbances caused by the development of the Las Vegas Springs Preserve. If food resources were limited, one would predict that home range size would expand due to the need to cover more area in search of food. If abundance increases, one would expect home range sizes to decrease, due to competition for food resources and adequate foraging and burrowing habitat.
Following movement patterns over time will also provide data on the effectiveness of habitat restoration. Changes in movement patterns throughout restored areas will allow land managers to determine the most effective restoration processes to use when restoring critical habitat for \textit{C. p. sobrinus}. A number of questions can be asked during and after habitat restoration. For example, when currently disturbed habitat is restored will home range area increase or decrease? Is there a minimum size required for habitat corridors? Does movement or dispersal differ between habitats restored with different dominant vegetation (e.g. desert scrubland versus mesquite bosque)? Lastly, movement patterns among other extant populations of \textit{C. p. sobrinus} will allow a better understanding of how to plan and mitigate for this subspecies on a more regional scale.
CHAPTER THREE

MICROHABITAT SELECTION

Introduction

Microhabitat can be defined as an area so small that an organism may be able to traverse across many different microhabitat patches while foraging (Pulliam 1976). Thus a mosaic of microhabitats can occur within an organism’s home range. Factors that contribute to microhabitat selection are specific and unique for each species and depend on the ecological niche that the species fills. There has been considerable research conducted in microhabitat partitioning that occurs within the Nearctic desert granivorous rodent guild, which include a number of the species in the family Heteromyidae. Most studies have shown that heteromyid species in general exhibit non-random microhabitat associations. From this extensive research, two major factors appear to be important to C. p. sobrinus in selection of microhabitat: soil and vegetation.

Soil --As early as 1954, Denyes observed soil-related differences in digging and burrowing ability in C. penicillatus. Chaetodipus penicillatus was not able to dig as efficiently in clay loam soils, which had been wetted and allowed to slowly dry, creating a hard surface crust. Bateman (1967) noted that C. penicillatus were present where soils were more "friable", however friable was never defined within the study. In a subsequent study conducted by Rosenzweig and Winakur (1969) at the same study location, soil particle size distribution had no significant influence on C. penicillatus density.

Several years later, Hoover et al. (1977) studied the effects of soil particle size on the distribution of C. p. eremicus (now considered a separate species C. eremicus) and C.
intermedius. Soil samples taken at depths of 10 cm and 20 cm outside of active burrows showed significant differences in particle size distribution. The top 20-cm of C. eremicus burrows had a consistently higher percentage by weight of small particle sizes (particle size range = 0.002 mm - 2.0 mm) compared to samples from C intermedius burrows. Soils where C. eremicus were found had consistently lower mean soil temperatures during the summer months and soil temperatures stayed consistently higher during the winter months. Soil types collected at C. intermedius burrows had higher CO2 concentrations as well. Hoover et al. (1977) also observed highly aggressive behavior in C. eremicus when encountered by C. intermedius in a laboratory setting. They concluded that C. eremicus aggressively defended areas with specific soil types (i.e. soils with smaller particle sizes) against C. intermedius intruders.

Lastly, Price and Heinz (1984) found that soil particle size also effects the harvesting rate in C. penicillatus. Chaetodipus penicillatus demonstrated a steep decline in the rate of harvesting millet seeds when soil particle size was larger than 2.4 mm.

Vegetation. — Bateman (1967) made a broad generalization describing C. penicillatus microhabitat and stated that C. penicillatus was captured more often in bushy or shrubby habitat “where a fairly dense overgrowth of mesquite and other trees were present”. Rosenzweig and Winakur (1969) also found that C. penicillatus were not found in areas where there was no “upper-story vegetation”, which is defined as foliage forms above 45 cm in height. However, in certain areas where upper-story vegetation was present, C. penicillatus were not captured. Thus a strong predictable pattern of occurrence per study plot was not observed. In a follow-up experiment, Rosenzweig (1973) found that when cover was manipulated (augmented and cleared) C. penicillatus responded by shifting microhabitat use. Frequency of captures decreased in areas in which plant cover had been cleared and capture frequencies increased in areas that were augmented. Because this experiment augmented areas with dead plant matter it demonstrated that foliage does provide some type of cue for habitat selection, but that it is rather the shape and structure rather than the species composition that is most important. Wondolleck (1978) found that C. penicillatus selectively foraged in areas with large bushes greater than one meter tall and one meter across. Furthermore, he also noted that there was no observed shift to
other habitat types even when density of conspecifics was low, thus *C. penicillatus* does not appear to be competitively restricted to foraging areas.

The collective evidence supports the hypothesis that selection of habitat by *C. penicillatus* is governed strongly by the occurrence of large bushy shrub physiognomy that provides both cover and height and that smaller soil particle size are positively associated with *C. penicillatus* distribution. Soil particle size appeared to effect both foraging efficiency and burrowing ability. This study investigated whether or not microhabitat selection was occurring on the Preserve site and if so, the environmental factors associated with the selection of microhabitat in *C. p. Sobrinus*.

**Methods**

A microhabitat selection study was conducted on the Preserve study site. In order to do this, a site attribute design was applied, which measures specific habitat variables and then identifies those variables and the values of the variables, which characterize sites in where a specific activity takes place (Garshelis 2000). This study design was scaled to microhabitat selection that occurred at the trap site locality. Since frequency of captures in trapping grids has been associated with foraging activity in *C. penicillatus* (Price 1977), it was assumed that the habitat variables measured would identify suitable habitat for foraging. It was also assumed that foraging activity would determine to some extent habitat selection in general. This species appears to exhibit some degree of territoriality and does not randomly move throughout contiguous habitat but rather tends to occupy specific areas (home ranges) for extended lengths of time (Chapter Two). McLellan (1986) noted that an animal familiar with its home range knows the availability and location of resources, and that an animal's location within that area at a given moment in time will represent habitat selection to some extent. Lastly, the assumption that trap sites did not affect the behavior of *C. p. Sobrinus* in an unpredictable way (i.e., *C. p. Sobrinus* was not attracted to the trap site due to factors outside of normal foraging behavior) was made.

Within each grid, a total of twelve traps were selected at random and habitat parameters were measured (12 random traps x 6 grids = 72 samples). Each randomly selected trap formed...
the center of a circular quadrat of three meter radius (total area = 28.26 m²). Within each quadrat, distance to the nearest mesquite (*Prosopis spp.*) or catclaw (*Acacia spp.*), which was the predominant food source found in a qualitative assessment of *C. p. sobrinus* cheek pouches, total canopy cover (m²), maximum plant height (m) was measured. Soil bulk density and soil particle size were calculated.

To measure canopy cover, all perennial vegetation was counted within the quadrat. The maximum and minimum diameter of perennial canopy cover was measured and averaged. Area covered by plant canopy was calculated by taking the average of both diameter measurements and obtaining a circular estimate of area (m²). Total plant cover was calculated by taking the cumulative area covered within each quadrat. Maximum plant height was measured by taking the maximum height observed in the quadrat.

Soils at this study site were too sandy and in certain areas too compacted to obtain cores so bulk density was determined using the excavation method (Elliot et al. 1999). Within each quadrat, a hole was dug approximately 4-cm deep and 10 cm wide and the soil retained. The volume of the hole was measured by filling the excavated hole with a measured volume of sand (Elliot, Heil and Monger 1999). This retained soil was dried and weighed and later used for particle size analysis. Bulk density was calculated by the following formula:

\[
\text{Bulk density} = \frac{(g) \text{ dry soil}}{\text{volume fresh} (l)}
\]

Soil was processed by first sieving the weighed sample through a # 10 (2 mm) mesh sieve, to separate gravel from sand, silt, and clay. Proportions of sand, silt, and clay were determined using the hydrometer method (Day 1966).

Principal components analysis (PCA) was used to control for covariance between habitat variables measured. The original data were log transformed in order to meet a normal univariate distribution, which tends to be associated with multivariate normality. Data points did not have to be rotated, and described the best maximum variance in the original data formation.
Both a binary logistic regression model and an ordinal logistic regression model were used to estimate which habitat variables were important in predicting the presence of *C. p. sobrinus*. Using the site attribute design, a binary logistic regression model was applied using the absence of *C. p. sobrinus* (0) and the presence of *C. p. sobrinus* (1) as the dependent variable, which gave a gross estimate of where *C. p. sobrinus* occurs on a microhabitat level within each habitat type. Binary logistic regression models used in habitat selection must assume that habitat use (or presence) at a site indicates that the site is suitable habitat for the species in question. In order to assess the validity of this assumption, an ordinal logistic regression model was used. The ordinal logistic regression model used the number of unique individuals as the dependent variable (i.e. 0 = no use, 1 = minimal frequency of use, ...6 = high frequency of use) with six unique individuals being the maximum observed at any one trap locality. This model differed from the binary model by differentiating between areas of high and low frequency of use and was able to differentiate high from low quality habitat. The ordinal logistic model also allowed abundance or number of unique individuals to be incorporated into the model.

**Results**

**Principal Component Analysis.** Using PCA, three distinct principal component loadings were determined, which contributed to 72.6 % of the maximum variance within the data set. The remaining principal component axes were dropped using both the Latent Root Criterion (Guttman 1954; Cliff 1988) and the Scree Plot Criterion (Cattell 1966). Fine soil composition loaded highly onto the first PC axis—as percent sand decreases, percent clay and silt increase. The second axis explained variance due to plant cover, plant height, bulk density and course gravel. Plant cover and plant height were positively associated, however both plant cover and height were negatively associated with percent course gravel and soil bulk density. Lastly the third PC axis explained variance due to distance to food sources (mesquite and acacia) and was not associated with other variables within the loading (Table 6).
Table 8  Principal Component Analysis: Eigen values, correlation matrix and structure.

<table>
<thead>
<tr>
<th>Variable</th>
<th>PC1</th>
<th>PC2</th>
<th>PC3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eigenvalue</td>
<td>2.6921</td>
<td>1.9642</td>
<td>1.1434</td>
</tr>
<tr>
<td>Proportion</td>
<td>0.337</td>
<td>0.246</td>
<td>0.143</td>
</tr>
<tr>
<td>Cumulative</td>
<td>0.337</td>
<td>0.582</td>
<td>0.725</td>
</tr>
<tr>
<td>Log Cover (m²)</td>
<td>0.100</td>
<td>-0.576</td>
<td>-0.093</td>
</tr>
<tr>
<td>Log Distance to Mesquite/ Acacia (m)</td>
<td>0.051</td>
<td>0.076</td>
<td>-0.857</td>
</tr>
<tr>
<td>Log Sand (%)</td>
<td>-0.582</td>
<td>-0.070</td>
<td>0.034</td>
</tr>
<tr>
<td>Log Clay (%)</td>
<td>0.527</td>
<td>-0.040</td>
<td>0.002</td>
</tr>
<tr>
<td>Log Silt (%)</td>
<td>0.547</td>
<td>0.002</td>
<td>-0.000</td>
</tr>
<tr>
<td>Log Bulk Density (g/L)</td>
<td>0.009</td>
<td>0.409</td>
<td>0.367</td>
</tr>
<tr>
<td>Log Course Gravel (%)</td>
<td>0.238</td>
<td>0.415</td>
<td>0.118</td>
</tr>
<tr>
<td>Log Plant Height (m)</td>
<td>0.123</td>
<td>-0.563</td>
<td>0.328</td>
</tr>
</tbody>
</table>

** All significant loadings are in bold print and were determined by common rules of thumb discussed by (Hair, Anderson, and Tatham 1987) and Tabachnik and Fidell (1989).

Binary Logistic Regression. -- The full binary logistic regression model included the first three principal component loadings as the predictor variables. The presence or absence of *C. p. sobrinus* in traps was significantly related to microhabitat variables ($G = 11.51$, df = 3, $P = 0.009$; Table 9). PC1 (fine soil composition) did not significantly contribute to the model, whereas both PC2 (plant height and cover; soil bulk density and percent course gravel) and PC3 (distance to the nearest mesquite/acacia) were significantly important in determining *C. p. sobrinus* occurrence throughout all microhabitats sampled (Table 7).
Table 9: Binary Logistic Regression: Pres/Abs versus PC1, PC2, and PC3

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Coef</th>
<th>SE Coef</th>
<th>z</th>
<th>P-value</th>
<th>Odds Ratio</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.2503</td>
<td>0.2947</td>
<td>0.85</td>
<td>0.396</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCI</td>
<td>0.1294</td>
<td>0.1909</td>
<td>0.68</td>
<td>0.498</td>
<td>1.14</td>
<td>0.78</td>
<td>1.65</td>
</tr>
<tr>
<td>PC2</td>
<td>-0.5505</td>
<td>0.2309</td>
<td>-2.38</td>
<td>0.017</td>
<td>0.58</td>
<td>0.37</td>
<td>0.91</td>
</tr>
<tr>
<td>PC3</td>
<td>0.6475</td>
<td>0.3169</td>
<td>2.04</td>
<td>0.041</td>
<td>1.91</td>
<td>1.03</td>
<td>3.56</td>
</tr>
</tbody>
</table>

Log - Likelihood: -34.134

Goodness-of-Fit Test
Hosmer-Lemeshow: Chi-Square = 13.333, df = 8, P = 0.101

PC2 describes variance due to plant physiogamy (cover and height) and soil properties. PC2 correlates negatively with total canopy cover and maximum plant height and positively with soil bulk density and percent gravel (soil particle size > 2.0 mm). As the overstory thins, soil properties change, areas with less overstory tend to have higher coarse gravel composition and higher bulk density. Thus as PC2 increases, soil bulk density and course gravel increase while cover decreases and the odds ratio decreases to 0.58. This means that *C. p. sobrinus* will occur nearly half as often in areas of sparse vegetation and high soil bulk density and high percent course gravel as they would occur near vegetative structures that provide canopy cover and height and lower course gravel composition and soil bulk density.

PC3 describes the variance in the data due to the distance *C. p. sobrinus* was found (captured) from the nearest food source (mesquite/ acacia). As PC3 increases, the distance to the nearest mesquite or acacia decreases and the odds ratio changes to 1.91. *C. p. sobrinus* is nearly twice as likely to occur in areas which are closer to mesquite and acacia.

Ordinal Logistic Model. -- The results of the ordinal logistic model corroborated those of the binary logistic model. The overall model was significant (G = 16.00, df = 3, P = 0.001; Table 8). PC1 did not contribute significantly to the number of *C. p. sobrinus* trapped at each site. PC2 and PC3 were both significant, thus degree of use is also explained by vegetative physiognomy, course gravel composition, soil bulk density, and distance to the nearest food source.
Table 10  Ordinal Logistic Regression: Unique Individuals versus PC1, PC2, and PC3.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Coef</th>
<th>SE Coef</th>
<th>z</th>
<th>P</th>
<th>Odds Ratio</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant 1</td>
<td>-0.2803</td>
<td>0.2960</td>
<td>-0.95</td>
<td>0.344</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant 2</td>
<td>1.4525</td>
<td>0.3512</td>
<td>4.14</td>
<td>0.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant 3</td>
<td>1.9690</td>
<td>0.3982</td>
<td>4.94</td>
<td>0.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant 4</td>
<td>2.6247</td>
<td>0.4841</td>
<td>5.42</td>
<td>0.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant 5</td>
<td>3.8663</td>
<td>0.7733</td>
<td>5.00</td>
<td>0.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant 6</td>
<td>4.591</td>
<td>1.064</td>
<td>4.31</td>
<td>0.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PC1</td>
<td>0.0685</td>
<td>0.1636</td>
<td>0.42</td>
<td>0.675</td>
<td>1.07</td>
<td>0.78</td>
<td>1.48</td>
</tr>
<tr>
<td>PC2</td>
<td>0.7154</td>
<td>0.2314</td>
<td>3.09</td>
<td>0.002</td>
<td>2.05</td>
<td>1.30</td>
<td>3.22</td>
</tr>
<tr>
<td>PC3</td>
<td>-0.4980</td>
<td>0.2412</td>
<td>-2.06</td>
<td>0.039</td>
<td>0.61</td>
<td>0.38</td>
<td>0.98</td>
</tr>
</tbody>
</table>

Log - Likelihood: -74.132
Goodness-of-Fit Test Pearson: Chi-Square = 273.11, df = 333, P = 0.993

The positive coefficient value of PC2, and the odds ratio larger than one, indicates that an increase in PC2 is associated with lower numbers of unique individuals captured at each trap site. Again, an increase in PC2 is associated with an increase in course gravel and soil bulk density, as well as a decrease in plant canopy cover and plant height. Microhabitat lacking plant canopy cover and plant height and composed of higher percent gravel and higher soil bulk density was nearly twice (odds ratio = 2.05) as likely to have less C. p. sobrinus individuals present.

The distance to mesquite and acacia was also significant in determining number of unique individuals found within a microhabitat. As PC3 decreases the distance to the nearest mesquite increases. The odds ratio demonstrates that high numbers of unique C. p. sobrinus individuals are nearly half as likely (odds ratio = 0.61) to occur in microhabitat located far away from mesquite and acacia.

Discussion

As Reichman and Price (1993) noted previously, most heteromyid species exhibit nonrandom microhabitat associations. The population of C. p. sobrinus located within this relic study site appears to selectively forage in areas of high canopy cover and plant height, low soil bulk density and percent course gravel, and more closely to seed resources, which at this...
location are mesquite and acacia. Variation in fine soil composition (soil particles < 2.0 mm) at this study site was not found to significantly effect the selection of foraging microhabitat.

One problem that arises from this study is the inability to "disentangle" plant cover and plant height from soil bulk density and course gravel composition. There appears to be evidence that both factors contribute to microhabitat selection in this subspecies, but all of these factors appear to be highly associated. If plant seedlings germinate better in soil with low percent coarse gravel and bulk density, then it could be that soil appears to be significant to the *C. p. sobrinus* selection process, when in all actuality it is only significant in determining plant distribution. To better address these questions in more detail, further experiments would need to be conducted.

However, previous studies have shown that soil particle size composition does significantly differ in *C. eremicus* habitat compared to a congeneric species (Hoover et al. 1977). Hoover's data set showed that *C. intermedius* habitat has a higher percent of soil particle size within the 1-2 mm range and >2.0 mm range when compared to *C. eremicus* habitat. In this study soil particle size > 2.0 mm (course gravel) was also the significant soil size effecting presence or absence of *C. p. sobrinus*.

Price and Heinz (1984) found that heteromyid foraging efficiency was associated with soil particle size. The number of seeds harvested by *C. penicillatus* declined as soil particle size increased. Price and Longland (1989) later found that certain species of heteromyids significantly harvested more seeds within specific soil types in a laboratory setting and that each soil type was qualitatively similar to soils in which each species was found in nature. These observations suggest that microhabitat selection in many heteromyids reflect specific patterns of seeds and soil properties that are conducive for efficient foraging and this could very well be the case for *C. p. sobrinus*. Another interesting point to note is that previous studies (Price and Waser 1985) found that soils located under shrubs have a higher content of seeds within each sample when compared to soil samples from open areas. Soils located under shrubs would have higher numbers of seeds and smaller soil particle size, which would be conducive to efficient foraging.

*Chaetodipus eremicus* has been associated with sandy soils (soil particle size = 0.5 - 0.05) in past studies (Hoover et al. 1977) Fine soil did not appear to significantly contribute to
microhabitat selection in this C. p. sobrinus population. However, this could be due to the scale in which habitat variables were sampled at the microhabitat level. The average percent sand per habitat type at this study site ranged from roughly 60% to 80%, thus throughout the landscape sandy soils predominate. In order to assess the affect of fine soil composition on habitat selection, future studies may have to be conducted on a larger scale or macrohabitat level. Percent sand may be a very important factor when compared across the regional distribution of C. p. sobrinus. Jorgenson and Demarais (1999) demonstrated how microhabitat partitioning in many species is constrained by local macrohabitat conditions. This would hold true for microhabitat selection as well.

Vegetation height and canopy cover contribute to microhabitat selection in C. p. sobrinus. This is similar to previous studies conducted within this genus (Rosenzweig and Winakur 1969, Rosenzweig 1973, and Wondolleck 1978). The associations with plant cover and height has been attributed to both foraging efficiency and predation pressure.

Price et al. (1984) found that the frequency of capture of C. penicillatus in open areas and under shrub canopy significantly shifted in periods of low and high moonlight. The moonlight effect was interpreted as reflecting a behavioral response to predation risk. Since data for this study was taken over a year period of time and only collected during periods of the new moon (low moonlight) the observed pattern of microhabitat selection does not appear to be driven solely by predation risk.

Rosenzweig (1973) determined that plant physiognomy was the intrinsic pull on C. penicillatus to areas with predominately more canopy cover. This was interpreted from his findings in augmented areas (or open areas supplemented with piles of dead vegetative matter). Since the vegetation was dead and therefore not supplying seed resources, the observed shift of C. penicillatus to the augmented areas that were once open appeared to be related to the structural component of the vegetation. Rosenzweig did not report the moonlight associated with his trapping sessions so it is hard to determine if predation risk was a factor in his observed results. An interesting point that was noted in his study was that certain plots with adequate plant cover had to be discarded from the data set due to lack of C. penicillatus captured in the area.
Thus canopy cover appears to be important, but not sufficient alone to determine microhabitat selection in *C. penicillatus*.

As stated previously, under shrubs seed abundance is higher and soil particle size smaller, which may attract *C. p. sobrinus* due to an increase efficiency in foraging. As with many other granivorous rodent species, selection over time for this subspecies has determined the appropriate and somewhat narrow microhabitat and macrohabitat associations that are currently observed. The overall selection for these areas is probably brought about by numerous factors such as predation, metabolic constraints and physiological requirements and interspecific competition, although at this study site the only other nocturnal granivore present was the house mouse, *Mus musculus* which was captured at relatively low numbers.

This study also showed that the distance to the nearest food resources (mesquite/acacia) significantly effects microhabitat selection in *C. p. sobrinus*. Previous observations have noted the association of *C. penicillatus* and mesquite groves (Deynes 1954), but this is the first study to statistically demonstrate the significant association with food resources and microhabitat selection. The distance to food or seed resources affects the probability of detecting *C. p. sobrinus*. Future studies may want to further address the association with food resources and microhabitat selection. An important question to address would be if this association with seed resources varied between males and females. Questions regarding mating systems can be answered when microhabitat selection between males and females is addressed thoroughly. For example the questions addressed in the previous chapter on Scramble Competition Polygyny and Resource Defense Polygyny can be teased apart when resource use patterns between males and females is better understood.

Conservation and Management. – The small population that currently exists on the Preserve is under increased pressure due to the ongoing construction and development that is currently underway at the Las Vegas Springs Preserve. Information on important factors that contribute to microhabitat selection throughout this study site is extremely important when applying appropriate management prescriptions and mitigating for this subspecies during periods of increased construction. “Key” habitat has been set aside in order to preserve the extant
population on site, but habitat restoration in disturbed areas will be of utmost importance for the long-term viability of this subspecies. Habitat variables such as vegetative canopy cover and height, mesquite and acacia distribution, and soil composition are significantly important in microhabitat selection within this subspecies and will need to be assessed when prescribing landscape restoration in relevant areas.
CHAPTER FOUR

MANAGEMENT RECOMMENDATIONS

The Preserve Study site.—The history of this relic site is extremely important in order to understand many of the conservation issues that currently exist on the Preserve. Land use over the last two hundred years has shaped the current habitat that remains. During the last two centuries humans within the Las Vegas Valley have utilized the site for the abundant water supply that was located at the Preserve and molded the current landscape mosaic that exists. Complete isolation of the site from any adjoining native Mojave Desert landscape occurred during the last quarter of the 19th century (Seymour 2001, Warren 2001). Today the Preserve is completely surrounded by urban development with no immediate habitat corridor in place and the nearest know extant population of *C. p. sobrinus* approximately 22.5 kilometers (14 miles) away (Zane Marshall, personal communication).

The Preserve has been used as an active water pump and reservoir facility by the water district over the last sixty years (Seymour, personal communication). The population of *C. p. sobrinus* that currently exists on the Preserve was protected from development due to the restriction of development and public access to the land during this time. However, due to the focus on water storage and purveying, many of the decisions made during that time were not focused on the preservation of the natural habitat that remained. Thus further habitat fragmentation and disturbance occurred within the Preserve area after the initial isolation event.

Local populations that become isolated face a higher probability of extinction. An isolation event may eliminate access to important resources that are critically needed by the
population and restrict individual emigration and immigration. Loss of movement between populations may affect the overall fitness of the population due to loss of genetic variation over time. Lastly, the small, isolated population that remains is much more susceptible to stochastic demographic events and natural disasters that can drive population numbers down or to extinction.

The desert pocket mouse reaches its northern range limits in southern Nevada. In general, populations along the periphery of their range tend to be more isolated from one another and susceptible to local extinctions even without further habitat fragmentation caused by human disturbance. The envisioned pre-development population structure of *C. penicillatus* in the vicinity of Las Vegas more than likely comprised a metapopulation configuration. As such, local populations are regularly rescued from extinction by immigration from a nearby population following a stochastic disturbance event.

Management of the population of *C. p. sobrinus* on the Preserve study site must first begin with a current assessment of the total amount of habitat available. The management plan also needs to address habitat quality and quantity prior to May 2005 when this site is opened to the public for recreational use. The Preserve is currently 74.45 ha in size (approximately 180 acres). The Preserve will house two large visitor facilities, a large botanic garden, retail and restaurant facility and a large trail system throughout. Of the original 74 ha, only 26 ha or 35% of the area currently has intact *C. p. sobrinus* habitat. Thirty-six percent of the Preserve area is disturbed and remains unused by *C. p. sobrinus*. If the disturbed area is restored properly, then this area could potentially be reclaimed as affordable habitat in the future. Areas within the Preserve will house facilities that will be open to the public and another portion of the Preserve area will be turned into a wetland with caldron pools and running water. These modifications to landscape will consume roughly 30% of the site or 23 ha and will most likely not be used by *C. p. sobrinus* (Table 9).
Table 9  Approximation of land allocated on the Preserve site.

<table>
<thead>
<tr>
<th>Description of Land Use on the Preserve Site</th>
<th>Total Area (ha)</th>
<th>Percent of Preserve Property (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilities &amp; Gardens</td>
<td>19</td>
<td>25</td>
</tr>
<tr>
<td>Wetlands/ Cienega</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Existing Suitable Habitat</td>
<td>26</td>
<td>35</td>
</tr>
<tr>
<td>Existing Disturbed Habitat</td>
<td>25</td>
<td>36</td>
</tr>
</tbody>
</table>

One inference drawn from this two-year mark-recapture study is that there was literally no dispersal occurring between the three habitat types sampled over the entire span of the study. Dispersal throughout the study site may be limited due to the highly fragmented landscape. Habitat one is separated from habitat two by a large storm drain channel that effectively blocked dispersal into the northeastern corner of the study site (Fig. 3). This storm channel flowed continuously throughout the active season of *C. p. sobrinus* (April – November). This storm drain channel is filled by water from residential and commercial run-off located nearby. Habitat one and habitat three were separated by a large detention basin which contained low quality habitat (low canopy cover, low food resources) and would be a large “sink” area for any potential dispersers due to increased predation risk and scant food resources. The detention basin also separates habitat three and habitat two to some extent. However, there is a small strip of contiguous habitat that ran along the western edge of the detention basin that could have been used as a dispersal corridor. Haphazard linear transects placed within this corridor did not detect any dispersing individuals and detected only one unidentified male *C. p. sobrinus* during a spring trapping session.

Due to the collectively scant information on dispersal within this population a conservative approach would be to assume that dispersal throughout the study site is at an extreme minimum. French et al. (1968) found that 25% to 30% of the *C. formosus* individuals in their study site made dispersal movements greater than 500 ft (approximately 152.40 meters). In this study the maximum dispersal distance documented was approximately 133 meters. We do know that within this population there is not male biased dispersal, and long distance dispersal remains...
largely unknown. In order to maintain a demographically variable and thus more viable population, connectivity within this study site should be restored. Additional demographic studies of populations along the Colorado, Virgin, or Muddy rivers would provide valuable information on dispersal patterns in less disturbed habitats.

In order to establish connectivity, careful planning needs to be conducted in order to minimize the mortality rate within the corridors. Habitat corridors need to be designed with environmental parameters that are associated with microhabitat selection in *C. p. sobrinus* in order to attract individuals to the area, but also not large enough to be misinterpreted as resident habitat (Meffe et al 1997). The width of the dispersal corridor should be at least the size of the maximum male home range (0.446 ha) with additional area on both sides that would buffer the negative impacts of edge effects. It has been shown that *C. p. sobrinus* selects habitat proximate to their food resources (mesquite and acacia) and soils composed of smaller particle sizes (< 2.0 mm in diameter). Plant canopy cover and plant height are also selected on the microhabitat level.

The impact of the ongoing construction will inevitably pose a negative impact to the *C. p. sobrinus* population present. Any disturbance to the topsoil or vegetation in *C. p. sobrinus* habitat or surrounding suitable habitat may jeopardize individuals within the area due to chance encounters by construction equipment or due to removal of necessary canopy cover or food reserves (mesquite and acacia). Also, movement of native topsoil or importing topsoil from outside the Preserve can directly affect suitable *C. p. sobrinus* habitat. Ongoing mitigation of construction effects needs to be implemented throughout the development process. Intact habitat that is not projected for development needs to be preserved and left undisturbed, while the remaining disturbed areas should be slated for possible restoration to the original, native landscape.

Any disturbances that may conflict with the normal nocturnal activity pattern of *C. p. sobrinus* should also be mitigated. Night lighting should be kept at a minimum and night activities on the Preserve should not be conducted in or around *C. p. sobrinus* habitat. Lastly, impacts due to pest species need to be in place. Once increased human activity begins, urban wildlife may be attracted to the area due to the introduction of non-native species in the botanic garden.
and due to human refuse that will be contained on site. Indeed, the house mouse (*Mus musculus*) is already a resident in disturbed vegetation on the Preserve, and might become a serious competitor to *C. penicillatus* with increasing disturbance of native vegetation. Urban wildlife may potentially compete with limited food resources or bring in new diseases or parasites currently not found in the population. The probability of these types of stochastic demographic events will be heightened.

A monitoring plan should be designed for the population on the Preserve in order to observe any serious fluctuations in population size. Long term monitoring is necessary in order to assess “unnatural” population fluctuations caused by anthropogenic disturbances. It is also necessary to monitor other pertinent demographic parameters in order to assess the viability of the population from year to year. Due to this subspecies short life span, a relatively small amount of time is all that is needed to drastically reduce population size. Continued vigilance will ensure critical decisions are made in the appropriate time frame.

Regional Management Plan. —This demographic and population ecology study identifies many life history traits of *C. p. sobrinus* that will be important in the development of a regional conservation plan for this subspecies. We can begin to better understand what types of environmental parameters are important in designating suitable habitat for *C. p. sobrinus*. However, a thorough study on macrohabitat selection in *C. p. sobrinus* throughout its regional distribution should be conducted. Population trends should also be assessed regionally. Trends may vary in different localities and regional studies should be conducted before broad management prescriptions are made.

Ongoing research on the population genetics and regional distribution (Part 2 of the Clark County MSHCP Contract no. 1999-LVWWD-1) will also provide strong management tools for this subspecies. Once assessed, restoration and preservation of habitat within the region can be better designed. Restoring connectivity between extant populations on a regional scale can also be prescribed if needed.

The major point that needs to be addressed in the regional management of this species is that policy makers and resource managers begin to assess the ecosystem that this subspecies
is associated with. Once the floral and faunal composition and structure of biodiversity in these areas is better understood, a clear picture will emerge as to what needs to be done to maintain suitable habitat and overall viability of populations of *C. p. sobrinus*. *Chaetodipus p. sobrinus* is associated with dry, sand washes that border major waterways, specifically the Colorado River and its main confluences, the Virgin and Muddy Rivers (Hall 1946; Hoffmeister 1986). The recent (< 100 years ago) disturbances to these major water arterials due to damming, increased agricultural use, human development, and recent invasion of exotic species has severely disturbed, damaged, or completely removed historic habitat. Numerous species ecologically associated with *C. p. sobrinus* are in need of critical management decision-making. An adaptive management strategy, along with an ecosystem approach, will not only benefit this subspecies, but all others that are currently in population decline. What we do know is that any disturbance to specific habitat parameters such as plant cover and height, soil particle size, or food resources (*mesquite* and *acacia*) will probably impact *C. p. sobrinus* negatively to some degree. Potential threats should be identified and plans implemented to mitigate these negative effects, throughout the entire distribution of *C. p. sobrinus*. 

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Fig. 1 – Current combined distribution of *Chaetodipus penicillatus* and *C. eremicus* (from Wilson and Reeder, 1993, on-line version at http://www.nmh.si.edu/msw, as modified by Lee et al. 1996).

Fig. 2 – The location of the Las Vegas Springs Preserve study site within the city of Las Vegas, NV.
Fig. 3 – Locations of the three habitat types monitored at the Las Vegas Springs Preserve study site.

Fig. 4 – Fine soil composition within each habitat type (one, two and three).
Soil Bulk Density and % Course Gravel
(Course Gravel > 2mm)

<table>
<thead>
<tr>
<th>Bulk Density (g/L)</th>
<th>% Gravel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat One</td>
<td>1110</td>
</tr>
<tr>
<td>Habitat Two</td>
<td>1090</td>
</tr>
<tr>
<td>Habitat Three</td>
<td>1100</td>
</tr>
</tbody>
</table>

Fig. 5 – Coarse gravel composition and soil bulk density (g/L) per habitat type (one, two and three).

Percent Canopy Cover Differences Between Habitat Types

Fig. 6 – Percent perennial plant cover within each habitat type.
Fig. 7 -- Species richness within each habitat type.

Fig. 8 -- Radial trapping web used during year one (1999-2000).

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Area = (70 m x 70 m)/10,000 = 0.49 ha

Fig. 9 -- Eight by eight trapping grid used during the second year of study (2000 - 2001).

Ambient Temperature and
C. p. sobrinus Activity

(r = 0.44, n = 25, P<0.05)

Fig. 10 -- Ambient temperature (°C) and the number of C. p. sobrinus captured within each monthly trapping session.

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Fig. 11 — Fluctuations in temperature (°C) and *C. p. sobrinus* activity.

Fig. 12. Sex ratio fluctuations in *C. p. sobrinus*.
Fig. 13 -- Age class structure through the reproductive and non-reproductive seasons.

Fig. 14 -- Emigration and immigration within each habitat type on the Preserve site.
Preserve Area Allocation

Fig. 15 – Current area allocations on the Las Vegas Springs Preserve study site.
LITERATURE CITED


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