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Palmers Chipmunk (<u>Tamias</u> <u>palmeri</u>) Ecology and Monitoring Protocols in the Spring Mountains National Recreation Area, Nevada.

Long-term Conservation Strategy for the Palmers Chipmunk (*Tamias palmeri*) within the Spring Mountains, Nevada.

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Clark County

Multiple Species Habitat Conservation Plan

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

WESTERN ECOLOGICAL RESEARCH CENTER

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EXECUTIVE SUMMARY

The Palmers chipmunk (*Tamias palmeri*) is an endemic ground-dwelling small mammal inhabiting conifer forests in the Spring Mountains of southern Nevada. The Spring occur in the southern basin and range, which consists of a series of isolated mountain ranges. The species is entirely isolated within the confines of this relatively remote mountain range, with no possibility of immigration or emigration occurring. As a result of this isolation, the species is recognized as threatened or otherwise at risk by several U.S. and state government agencies and non-governmental conservation groups. Presently, relatively little is known about the basic distribution, ecology, and population dynamics of *T. palmeri*. From the few studies that have been done, it is clear the species is an integral part of the Spring Mountain range ecosystem. *T. palmeri* is the most abundant diurnal small mammal in the range, and is therefore a primary prey source for many predators (Lowrey 2002). Like all chipmunks, *T. palmeri* caches seeds, and the presence of seed-caching rodents is known to increase the probability of conifer seedling establishment, which may be important in the relatively dry environment of the Spring Mountains (Vander Wall 1997). A broad-scale evaluation of population ecology and distribution of this species is therefore a critical component of conservation planning in this region. Our objectives for this project were: 1) Provide a scientific basis for a range-wide Palmer's chipmunk distribution map; 2) Determine the feasibility of a track plate survey method as an alternative to trapping; and 3) Recommend long-term monitoring sites for the species.

During the summer months (*T. palmeri* active season) of 2009 and 2010, we intensively surveyed for *T. palmeri* across the entire Spring Mountain range using transects and grids distributed across four major habitat types: alpine (areas above tree the line), high elevation conifer forest (Bristlecone-white fir-limber pine and white fir-ponderosa associations), low elevation woodland (Pinyon pine-mountain mahogany associations), and riparian areas. We surveyed 41 transects and 24 grids each year for two years. Over 260 animals were captured as part of the distribution aspect of the project, and these results are pending from the UNLV genetic lab and will be in the final report. At the macrohabitat level, defined as the entire Spring Mountain range, four major components contributed to greater probability of *T. palmeri* occurrence: relatively lower slopes, northern facing aspects, nearness to permanent water sources, and the white fir-limber pine forest classification type (as classified by the Regional Gap Analyses Project). At the microhabitat level, defined as the 3.6 hectare area of the trapping grid, greater population densities occurred within the white fir-Limber pine forests, which is located between the higher bristlecone and lower ponderosa pine forests. The age of the forest also explained *T. palmeri* population variability, with increasing maturity (specifically, fewer understory fir trees) positively contributing to population density. Increasing currant-berry shrub cover (*Ribes cereum*), also contributed positively to population density. We found decreasing understory fir also contributed positively to survival rates. Greater population size contributed positively to survival rates, suggesting potentially density dependent processes. A probability of occurrence model indicates the northeastern side of the range incorporates most of the higher quality habitat for *T. palmeri*. A comparison of track plate numbers (average number of plates with tracks) to population estimates demonstrates that track plates are not a valid tool for population estimation for this species. We also provide a protocol for long-term habitat monitoring, including suggested locations, personnel requirements, materials needed, and trapping and vegetation collection protocols.

INTRODUCTION

Description of the Project

      We used small mammal trapping, track plates, vegetation and topographic measures, and genetic analyses to address several previously unanswered ecological questions concerning Palmers chipmunk, an endemic species inhabiting the Spring Mountains, Nevada. We documented species distribution across the Spring Mountain range, habitat associations, and the efficacy of a track plate technique. A long-term monitoring plan consistent with these findings was also produced.

Background and Need

    The monitoring of wildlife populations is an essential aspect of any wildlife conservation effort. Determining the overall distribution, ecological causes for differences in relative abundance, and establishing long-term monitoring guidelines are fundamental to understanding population dynamics, evaluating the efficacy of management practices, and establishing compliance with regulatory requirements (Gibbs et al. 2000).

    The goals of managing natural wildlife populations are frequently expressed in terms of animal abundance, and wildlife managers often use abundance estimates as a means of assessing the viability of animal populations and success or failure of management practices (Sinclair 1991). However, an estimate of abundance at one point in space and time is often of little value, and provides less information about the status of a species than is commonly thought (Nichols and Pollock 1983). Establishing the causation of differences in animal abundance is a difficult but necessary aspect of successful wildlife management, and hypotheses about habitat variables that relate to relative abundance must be incorporated into any plan that intends to conserve species. Long-term monitoring designed to address hypotheses of animal abundance is therefore essential for proper wildlife management. Ideally, monitoring methods should be precise, inexpensive, and provide reliable estimates of wildlife population trends over time and space (Lancia et al. 1994).

      Resource managers from the U.S. Forest Service, U.S. Fish and Wildlife Service, Nevada Division of Wildlife, and Clark County, Nevada, are concerned about the long term conservation of *T. palmeri*. This chipmunk is a high elevation species endemic to the Spring Mountain range of southern Nevada (Best 1993). *Tamias palmeri* occurs across at least three habitat types from near 2300 m to the timberline (ca. 3400 m) and is the most abundant diurnal mammal above 2500 m in the Spring Mountains (Deacon et al. 1964, Lowrey 2002). *T. palmeri* is thought to be most abundant along the eastern side of the range at elevations of 2400 m to 2700 m within the ponderosa pine-white fir community. Areas near water and on lower slopes where shrub cover is greater may also contribute to *T. palmeri* abundance (Lowrey 2002). Burrows serve as a retreat from weather, conspecifics, and predators as well as a nursery and hibernaculum (Svendsen and Yahner 1979). *T. palmeri* eats seeds, fruits, fleshy fungi, green vegetation, flowers, and insects although most of the diet consists of fruits of conifers (WESTEC 1980, Best 1993). This species serves as a primary prey source for several species within the range,

and may also serve as an important coniferous tree seed disperser (VanderWall 1995, 1998, Lowrey 2002). *T. palmeri* is sympatric with three other ground squirrels: *Spermophilus lateralis* occurs within most of *T. palmeris'* range except perhaps at the highest elevations (Lowrey, pers. obs.), *Spermophilus variegatus* is an infrequently occurring species, occurring mostly near rocky outcroppings. *Tamias panamintinus*, the only other chipmunk, is sympatric with *T. palmeri* at the lower elevations where pinyon pine (*Pinus monophylla*) and mahogany (*Cercocarpus ledifolius*) species occur (Best 1993, 1994). Although Panamint chipmunks primarily inhabit the pinyon pine/Mountain mahogany association, they have been captured as high as 3,100 m in other mountain ranges (Best 1994). *Tamias palmeri* is primarily at risk due to the isolation and restricted size of Spring Mountain range (International Union for the Conservation of Nature 2004) (IUCN). Further potential risks include potential competition with recreationists over spring and stream areas (Lowrey 2002), urban development, feral cats, (Tomlinson, pers. com.), and increased risk of fire due to human activities. *T. palmeri* is a covered species under the Clark County Multi Species habitat Conservation Plan, considered threatened by the state of Nevada, and as endangered by the IUCN and the Nevada Natural Heritage Program. In order to promote the long-term population viability of this endemic species, we have conducted this study to meet the following management actions, goals, and objectives.

Management Actions Addressed (as identified in the Clark County Nevada MSHCP)

USFS (19) – Palmers' chipmunk: Features and movements of home ranges and dispersal patterns as related to habitat condition.

USFS (20) – Inventory of populations of rare fauna on an annual basis.

USFS (24) – Use the results of monitoring activities to refine management strategies for protection of the species of concern. Where monitoring has indicated status decline or habitat degradation for the species of concern, develop and implement strategies to avert further decline or degradation, and improve species status and habitat quality.

USFS (27) – Develop a Palmer's chipmunk monitoring plan, emphasizing population and habitat monitoring. Frequency and intensity of monitoring identified in plan will be based on population status, abundance, and threats.

NDOW (32) – Participate in development of monitoring plans for Palmer's chipmunk in the Spring Mountains NRA.

NDOW (33) – Participate in monitoring of populations of Palmer's chipmunk in the Spring Mountains NRA.

Project Goals and Objectives

Goal 1: Test and provide a scientific basis for the range-wide *Tamias palmeri* distribution map.
Objective 1a: Conduct surveys throughout the Spring Mountains to document distribution.
Objective 1b: Collect data on vegetation and topography at all survey locations.
Objective 1c: Test and refine habitat model using survey data combined with past data.

Goal 2: Determine feasibility of the track plate survey method as an alternative to trapping.
Objective 2a: Compare and correlate results from concurrent track plate and trapping surveys.

Goal 3: Recommend long-term monitoring sites and develop a monitoring toolbox.
Objective 3a: Working with NDOW, recommend future long-term monitoring sites based on results of this and other studies.
Objective 3b: Working with NDOW, develop a monitoring toolbox that will detail the various monitoring options based on habitat type, cost, and expected results. This toolbox will assist agencies in choosing the appropriate monitoring methods based upon the specific management objectives.

Hypotheses and Predictions

Predictive hypothesis for *Tamias palmeri* distribution: Because conifer trees, *Pinus ponderosa*, *Abies concolor*, and *Pinus longaeva* are the primary food source and provide cover from predation, the range-wide distribution of *T. palmeri* will be correlated with the distribution of these tree species in the Spring Mountains, Nevada.

Predictive hypothesis for *Tamias palmeri* habitat use: Because the relative abundance of *T. palmeri* is dependent upon areas with lower slopes and within 200 m of water sources. Habitat with these attributes will have a greater relative abundance of Palmer's chipmunk than areas without these attributes.

Predictive hypothesis for population monitoring methodology: Track plate methodology is an effective alternative to trapping when estimating relative abundance of *T. palmeri*. Thus, there will be a linear, positive correlation between track plate and trapping estimates of relative abundance of *T. palmeri*.

STUDY AREA

The Spring Mountains of southern Nevada are located within the northern Mojave Desert (Figure 1). The range is approximately 110 km long by 45 km wide, has a northwest orientation, and is characterized by steep, rocky slopes and high limestone

cliffs. There are over 10 peaks above 3,300 m, the highest being Mt. Charleston at 3,632 m. The Spring Mountains are completely isolated by the surrounding desert floor that is just above 700 m in elevation. This range has an arid to semi-arid climate influenced by a rain shadow created by the Sierra Nevada and other mountain ranges to the west. Annual precipitation is typically less than 13 cm in the lower areas and as high as 71 cm in the higher elevations with the east side of the range receiving the majority of rain and snow. The upper slopes are further subject to extreme seasonality with snow cover 5-7 months of the year. Mean yearly average temperature is 10° C at 2000 m. There are six major vegetation associations in the mountain range. From lowest to the highest elevations, they include: desert shrublands, with blackbrush (*Coleogyne ramosissima*) as the primary indicator species; low conifer woodland, with pinyon pine (*Pinus monophylla*), Utah juniper (*Juniperis osteosperma*), mountain mahogany (*Cercocarpus ledifolius*) and sagebrush (*Artemisia tridentata*) as indicator species; high conifer forest with ponderosa pine (*Pinus ponderosa*), white fir (*Abies concolor*), limber pine (*Pinus flexilus*), and bristlecone pine (*Pinus longaeva*) as primary indicators; and alpine zones with Hidden Ivesia (*Ivesia cryptocaulis*) as the primary indicator. Two other associations occur at all elevations: steep slopes and clifflands (no indicator for both, although *Cercocarpus intricatus* is an indicator for clifflands), and riparian and spring zones, with *Rosa woodsii* as the broad indicator for the type (Nachlinger and Reese 1996).

METHODS

Distribution

Although it is well known that *T. palmeri* is found in the conifer-forested areas of the Spring Mountains, Nevada, the extent this species might occur below and/or above this habitat type is unknown (Ambos and Tomlinson 1996, Lowrey 2002). To establish the extent of *T. palmeri* distribution, 41 trapping transects were used to systematically sample the Spring Mountain Range from June through August of 2008 and 2009 (Figure 2). With four exceptions (when transects were placed along ridgelines), transects were placed parallel to the elevation gradient (run downhill). Transects were placed completely within specific habitat types (ex. Ponderosa), crossing through habitat transition zones (ex. from bristlecone to above tree line), and completely outside known *T. palmeri* habitat types (above and below tree line). Transects were 2 km in length and placed not less than 2 km or more than 5 km apart. Within each transect, we placed one 25 cm x 9 cm x 8 cm folding aluminum trap (H. B. Sherman Trap Co., Tallahassee, FL.) every 40 m along a single line for four days. We baited traps with one gram of an oat-peanut butter mixture and checked each trap daily. Traps were kept shaded from the sun and away from ant colonies to prevent mortalities. To collect the genetic material needed for positive identification between Palmers' and Panamint chipmunks within the lower Ponderosa pine/Pinyon pine transition zones, an ear clipping from the top 3 mm of the ear was taken and genetic analyses performed by the University of Nevada, Las Vegas. Distribution of *T. palmeri* was determined by mapping the locations of traps successfully
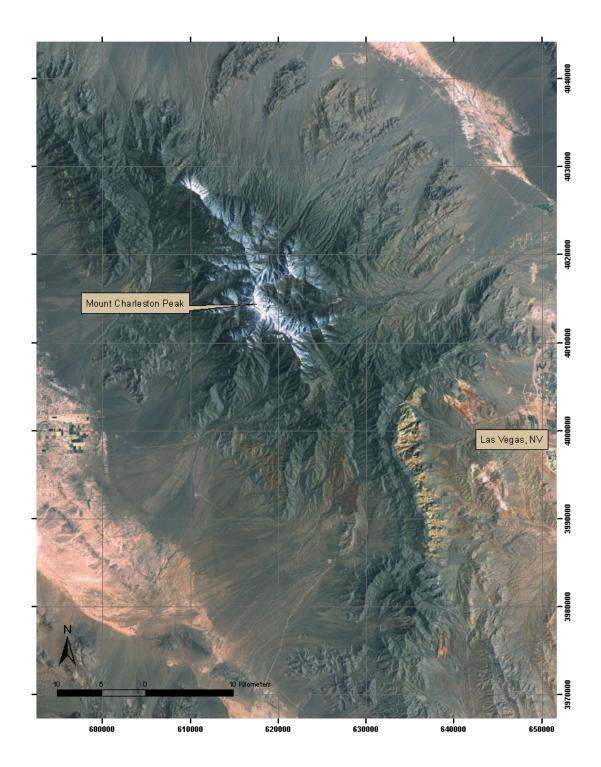
Figure 1. Map of the Spring Mountain range, Nevada, 2009.

capturing *T. palmeri* and *T. panamintinus*, and then extrapolating that information to determine the range of overlap across the greater Spring Mountain range area using a geographic information system (GIS) (ArcMap 9.3, ESRI Redlands, CA.).

Relative Population Abundance and Survivorship

If conservation of species is the goal, then we cannot overemphasize the importance of measuring demographic parameters, such as abundance and survivorship. The ability to ascertain the population viability of a species is most directly measured through determining demographic processes (White 2000). Significantly greater relative abundance and survival of wildlife has been positively correlated with greater quality habitat (Sinclair 1991). Although this principle does not hold true in all cases (Van Horne 1983), the behavioral and ecological characteristics (non aggression towards conspecifics, non-territoriality, short active season) underlying many small mammal communities strongly support this assumption (Morris 1987, Skalski and Robson 1992). We estimated relative abundance and survival rate estimates from trapping grids from the Jolly-Seber open population model (Jolly 1965) using the Ecological Methodology software program 7.0 (Exeter Software Co., Setauket, New York). An open population model assumes population size is fluctuating naturally and is therefore more realistic than closed models where the population is assumed to be unchanging. This model can be used to estimate population size and, unlike the closed models, survival and number joining the population (births or immigration). The additional ability of the open population model to estimate survival rates is important. Comparisons of survival rates in addition to abundance may lead to more direct inference about the importance of a particular habitat, and both researchers and managers often emphasize this approach (Lebreton et al. 1992).

We trapped eight independent grids simultaneously during each month of the 3-month active season of this species (June, July, and August of 2008 and 2009). Grids had a configuration of eight by five (25 cm x 9 cm x 8 cm) folding aluminum Sherman traps (H. B. Sherman Trap Co., Tallahassee, FL.) spaced 30 m apart to create an effective rectangular trapping area of approximately 3.6 hectares. This grid size was chosen through several previous experimentations (during three pilot studies conducted from 1999 to 2002) in trap spacing and configuration to develop a trapping area able to sample both the heterogeneity of an area and capture enough animals to properly calculate population abundance and survival. Grids were trapped for eight full days and traps were checked twice per day, at sunrise and just before sunset. One gram of an oat and peanut butter mixture was used as bait. Animals were marked with aluminum ear tags (5.0 x 1.5 mm) (Monel 1005-1, National Band and Tag Co., Tallahassee, FL.), weighed, gender and reproductive condition determined, and released. The eight grids were reestablished at new locations each month for a total of 24 independent population estimates per year (Figure 3).
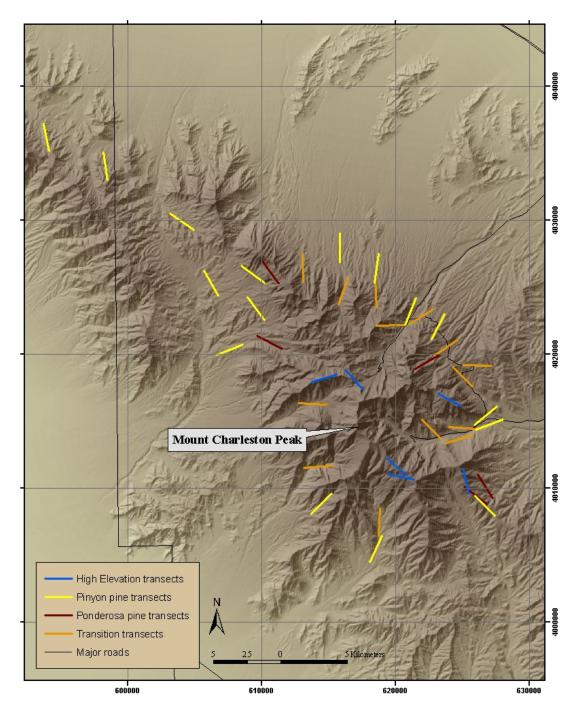
Figure 2. Location of trapping transects for Palmers chipmunk (*Tamias palmeri*) within the Spring Mountains, Nevada, 2008-2009.
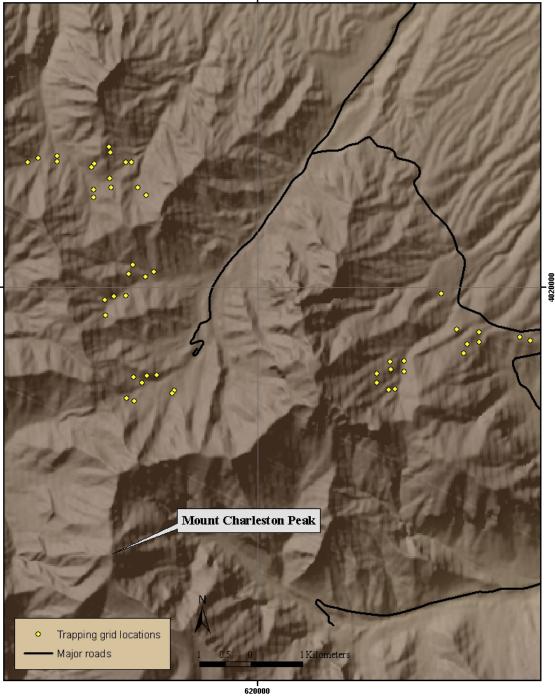
Figure 3. Trapping grid locations for Palmers chipmunk (*Tamias palmeri*). Spring Mountains, Nevada, 2008-2009.

<u>Vegetation and Topographic Data Collection</u>

Vegetation species composition, structure, and topographical variables were measured within eight-meter radius plots centered on each trap (40 traps per grid) within each grid for a total of 1,920 plots measured. In addition to those that had been correlated with *T. palmeri* occurrence in past studies (Ambos and Tomlinson 1996, Lowrey 2002), we measured several habitat variables thought to contribute to *T. palmeri* occurrence and survival (Table 1, Table 2). Percent tree, shrub, and forest litter cover were estimated by standing at 20 systematically placed points within each plot and looking straight up (canopy) and down (shrub, litter) through a 20 cm long by 3 cm diameter tube. Percent cover was derived by counting the number of times the canopy (or shrubs) covered the line of sight (hits) and dividing that number by 20 (total) (modified from Dueser and Shugart 1978). Tree heights were measured with a hypsometer. Density of trees, shrub, snag, and large rocks was measured by counting each within each plot. These counts, which systematically measured over 20% of each grid, were then extrapolated to estimate vegetation density over the total grid area. Overstory (trees > 10 m in height) and understory (trees < 10 m in height) were measured as separate categories. We defined downed logs as >0.5 m in diameter and >2 m in length and shrubs as species > 0.25 m and < 2.0 m. Large rocks were defined as both height and width > 1 m. Water source locations, either wet ground or open water, were also documented. Slope (measured in percent), aspect (transformed into a categorical variables of north facing and south facing slopes), and distance to water variables were measured with a GIS (ArcMap 9.3). All spatial data, including trap, track plate, grid, transect, water source locations, and vegetation plot locations, were recorded with a GPS unit (Garmin Map76, Garmin Corp., Olathe, KS.) that has an estimated positional error of one to three meters. Data was collected in a UTM format using the NAD 83 Datum.

Table 1. Habitat variables measured for the Palmers' chipmunk microhabitat study in the Spring Mountains, Nevada, 2008-2009.

Habitat Variables Measured	
Tree* percent cover	Downed logs density (#/plot, #/grid)
Tree density (#/plot, #/grid)	Large rock density (> 1 m diam) (#/plot, #/grid)
Tree height (m)	Forest litter percent cover
Shrub† percent cover	Aspect (categorical: North, South)
Shrub density (#/plot, #/grid)	Distance to water (m)
Snag density (#/plot, #/grid)	Slope percent

* 8 species of trees measured

† 3 species of shrub measured

Table 2. Vegetation species measured for the Palmers' chipmunk microhabitat study in the Spring Mountains, Nevada, 2008-2009.

Tree Species	Shrub Species
Mtn Mahogany (*Cercocarpus ledifolius*)	Currant berry (*Ribes cereum*)
White Fir (*Abies concolor*)	Juniper (*Juniperis communis*)
Bristlecone (*Pinus longaeva*)	Rabbit brush (*Chrysothamnus nauseosus*)
Limber Pine (*Pinus flexilus*)	Other shrubs (infrequent species)
Ponderosa (*Pinus ponderosa*)	
Pinyon pine (*Pinus monophylla*)	
Juniper (*Juniperus osteosperma*)	
Aspen (*Populous tremuloides*)	

Relationship between Habitat Variables and *T. palmeri* Occurrence, Abundance, and Survival Estimates

We addressed the relationships between habitat and *T. palmeri* population dynamics at two different scales. At the microhabitat scale, relative abundance and survival estimates (dependent variables) were regressed on the means of habitat variables (independent variables) measured within each grid (3.6 hectare area). We assumed each grid each year as independent measures of population abundance and survival (n = 48). At the macrohabitat scale, which we defined as those areas within the Spring Mountain range above 1800 m, habitat variables (independent variables) (Table 3) occurring at traps successfully capturing *T. palmeri* were compared to those same variables occurring at both unsuccessful traps and random points with a binary logistic regression (dependent variables: successful trap = 1, unsuccessful + random = 0). When necessary to meet the normality and equality of variance assumptions of regression, habitat variables were transformed.

Table 3. Habitat variables measured for the *Tamias palmeri* macrohabitat study and habitat modeling in the Spring Mountains, Nevada, 2008-2009.

Habitat Variables Measured
Slope percent
Distance to water (m)
Aspect category (North, South)
Tree type category (White-fir, Ponderosa, Pinyon pine/non-conifer)

<u>Habitat Modeling</u>

Modeling species habitat is an important step toward the prediction of species occurrence, hypothesis testing, and conservation planning. Lowrey (2002) previously developed a GIS-based model to predict habitat quality of *T. palmeri* using slope, distance to water, and aspect as independent variables and population size as the dependent variable in a binary logistic regression. We used this past data (the model) as part of our objective to test and refine the chipmunk macrohabitat model. Testing models requires new, independent data sources, and models are most vigorously tested by using new methods across different time frames. We tested this model by randomly placing trapping grids within and outside those areas predicted to have greater density and survival rates. The 24 grids/year were placed in areas of slopes of both greater and less than 25%, within and outside 200 m distance from permanent water sources, and on both northern and southern aspects. All possible combinations of slope, aspect, and distance to water were included in the design. Additionally, three types of conifer forest type, white fir-limber pine mixed conifer, Ponderosa pine mixed conifer, and Pinyon pine/non-conifer woodland, were also included in the model. Forest type classifications were provided by the Southwest Regional Gap Analysis Project (ReGap), which uses a multi-spectral analysis of LandSat satellite data (Table 4).

A binary logistic regression analysis, using 2739 locations successfully trapping *T. palmeri* (dep. var. = 1) and 3000 random points plus 638 unsuccessful traps (dep. var. = 0) as dependent variables, was used to determine if habitat variables (Table 3) were predictive of chipmunk locations (Manly et al., 2002, Johnson et al., 2006). There is always risk of autocorrelation by using each trap as the sampling unit, however we believe the large spread of the grid relative to the average chipmunk home range (average home range 0.23 ha or approximately $1/15^{th}$ of the grid size), combined with the fact that a single grid might cross several different habitat types, from flat mesic canyons to steep dry ridgelines, significantly reduces this risk (Legendre and Fortin 1989). Although application of logistic regression to use-availability data, for which the sampling fraction of used sites is unknown, produces resource selection function values (RSF) that are simply proportional to the probability of animal occurrence (Manly et al. 2002, Keating and Cherry 2004), this type of analysis has been shown to yield robust and valid estimates of habitat selection (Boyce and McDonald 1999, Johnson et al., 2006). Furthermore, the addition of unsuccessful locations decreases the possibility of contamination (where random sites are the same as the used sites), which is a primary criticism of using logistic regression with use-availability data (Keating and Cherry 2004, Johnson et al. 2006). We used deviation coding (SPSS statistical software, SPSS Inc.) to represent aspect and tree type classes. Deviation coding differs from indicator coding in that the effect of each category of the predictor variable is compared to the overall effect, not an arbitrary reference class (Menard 1995). We used the Hawth's tools© extension within ArcMap to generate the random points within the study area and spatially enforced a minimum distance of 10 meters between points.

We used chi-square tests of the likelihood ratio and Wald statistics to assess overall model fit. The contributions of individual variables to the model were evaluated using the Baysian information criterion (BIC), calculated as the difference between the Wald chi-square of a logistic coefficient and the natural logarithm of the sample size

(Raftery, 1995). Independent variables are interpreted as strong predictors of the dependent variable if the BIC of individual regression coefficients exceed 10 (Raftery, 1995). We entered the logistic regression equation into the GIS raster calculator to generate resource selection function (RSF) values which were then represented on a map of the Spring Mountain range as the *Tamias palmeri* habitat model (Figure 3). These values are proportional to the relative probability of animal occurrence across the available habitat (Boyce and McDonald, 1999, Johnson et al., 2006). The model consisted of distance to known springs and seeps, slope, conifer tree cover (categorized as white fir areas, ponderosa, and pinyon-pine/non-conifer areas), and aspect (categorized as north facing and south facing).

Table 4. Southwest Regional Gap Analysis Project (ReGap) conifer vegetation classifications within the Spring Mountain range, Nevada, used in the analyses of *Tamias palmeri* habitat modeling, 2008-2009.

ReGap Vegetation Classifications
Intermountain Basin Subalpine Limber-Bristlecone Pine Woodland*
Rocky Montane Mesic Mixed Conifer Forest**
Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest†

* White Fir (*Abies concolor*), Limber Pine (*Pinus flexilus*) most common species
** Ponderosa pine, white fir most common species
† Pinyon pine (*Pinus monophylla*), Juniper (*Juniperis osteosperma*), Mountain mahogany (*Cercocarpus ledifolius*) most common species

Testing of Track Plates as an Alternative to Trapping for the Estimation of Relative Abundance

Track plates use animal tracks instead of trapping to estimate population parameters and therefore may be beneficial to managers and researchers by eliminating the need for animal capture (Drennen et al 1998). Concurrent to testing the habitat model, we tested the efficacy of the track plate method (modified from Drennen et al. 1998) for estimating relative abundance of Palmers' chipmunk. For two days immediately before trapping, traps were replaced by 25cm x 7.5 cm x 0.31 cm plastic track plates with carpenters chalk covering 8 cm of each end. A 10 cm piece of contact paper was centered on each plate. One gram of peanut butter-oatmeal was placed at the center of each plate as bait. By placing the Sherman trap on its side and sliding the track plate through the trap, the trap doors were held open and the traps became inoperative, forming a covered tube for the track plate. All data for this objective was collected above 2500 m to avoid confusion with *T. panamintinus*. Densities were calculated from track plate data by counting the number of track plates with tracks per day. We assumed that only one chipmunk visited each track station found with tracks, and that an individual chipmunk only visited one track station per day This is probably an unrealistic assumption, but assuming that chipmunks move through their habitats in a similar fashion across each grid and habitat type, violation of this assumption would not likely alter appreciably the estimation of relative abundances. As *T. palmeri* is the only chipmunk

found at elevations above 2500 m, tracks are easily identifiable. Density estimates from track plate were tested for correlations with population estimates from trapping with a Pearson correlation.

Recommend long-term monitoring sites and assist managing agencies in choosing the appropriate monitoring methods based on habitat type, cost and projected results.

Results from this project determined *Tamias palmeri* distribution, abundance, habitat associations, and tested the efficacy of track plates for estimating abundance. From this data a long-term monitoring plan with the appropriate monitoring sites, replication, equipment, and analyses requirements has been produced. This aspect of the study was originally designated to be in consultation with the Nevada Division of Wildlife, however NDOW was unable to participate due to personnel shortages, and therefore the USGS had accepted full responsibility of this aspect of the study. The monitoring protocols are provided in Appendix A as a separate document: *Protocols for the Monitoring of Relative Abundance of* Tamias palmeri *within the Spring Mountains, Nevada.*

RESULTS

Distribution

A comprehensive trapping effort within and beyond the known borders of *T. palmeri* habitat was completed. Forty-one two-kilometer transects were trapped around the circumference and within the Spring Mountains each year: 16 transects were trapped within the Pinyon-pine/Juniper habitat association at the lowest elevations; 14 across the Ponderosa-Pinyon pine transition zone; and five were trapped within the Ponderosa pine association. Additionally, six transects were trapped across the Bristlecone pine-treeless zone at the uppermost elevations (Figure 2). We captured 264 individual chipmunks within transects across both years including 24 within the high elevation alpine zone. Genetic analysis confirmed Palmers chipmunks were captured within a range of 2080 m to 3290 m elevation, while Panamint chipmunks were found to inhabit a range of 2000 m to 2643 m, resulting in, generally, 563 meters of elevation overlap. However the range of overlap will be dependent upon local conditions. Although *T. panamintinus* occurred up to an elevation of 2643 m, all *T. panamintinus* locations examined were within the pinyon-juniper habitat type, which occurs at these higher elevations along the western facing slopes of the Spring Mountains. Comparatively, *T. palmeri* locations were found from the highest locations sampled (above the bristlecone tree line), to within the (upper elevation extent of) pinyon-juniper association. This supports our finding, detailed subsequently, that tree cover type is an important factor explaining *T. palmeri* distribution.

Relative Population Abundance and Survivorship

A comprehensive trapping effort to determine subpopulation and survival levels of *T. palmeri* within the Spring Mountains, Nevada was completed. Forty eight trapping

grids, each encompassing a 3.6 hectare trapping area, were trapped within known *T. palmeri* habitat (Figure 3). We found an average density of 14.7 (4.1 animals per hectare) *T. palmeri* per grid (SD = 8.1, range 3.5 – 33.9). Average survival rate of individual animals across the eight day trapping period was 0.849 (SD = 0.10, range 0.601 – 1.0).

<u>Relationship between Habitat Variables and *T. palmeri* Occurrence, Abundance, and Survival Estimates</u>

Macrohabitat

Our analyses of landscape-scale variables within the Spring Mountain range permitted characterization of the fundamental niche (potential habitat) of *T. palmeri*. Logistic regression analysis indicated a strong ability to differentiate between *T. palmeri* locations and random points using the habitat variables described (Table 5) (overall model: χ^2 = 2633.15, df = 5, P < 0.0001, Nagelkerke R^2 = 0.534, 81.4% T. *palmeri* locations predicted correct). BIC values for distance to water, slope, and aspect were 546.4, 180.0, and 12.8 respectively. BIC values for the three types of land classification (White fir/limber pine, ponderosa/white fir, and pinyon pine/juniper/mountain mahogany, see Table 4 for related ReGap definitions) were 51.4, 33.7, and 50.4 respectively. The BIC values indicate all four habitat variables are strong predictors of *T. palmeri* locations. The odds ratio (exponential of the logistic regression coefficient) indicates that the probability of *T. palmeri* occurrence increases by a factor of 2.05 (95% CI = 1.068-1.254) when sampling within the white-fir forest, increases by a factor 1.84 (1.53-2.22) when within the ponderosa forest, and decreases by a factor of 0.27 (0.19-0.37) when sampling within the pinyon-pine/non-conifer woodland. Northern aspects positively contributed by a factor of 1.16 (1.07-1.25) relative to southern aspects. We also find probability of occurrence reduced by a factor of 0.18 (0.16-0.19) for every 100 m increase from permanent water sources, and reduced by a factor of 0.36 for every 10% increase in percent slope. We used deviation coding on the categorical variables of aspect and tree cover type (DeCoster 2004). All transformed variables were back-transformed before reporting. Although water sources outside approximately 100-200 m are essentially unavailable to resident chipmunks, if areas near water are serving as a source population, then probability of occurrence should diminish linearly with distance to water.

Microhabitat

An intensive small scale linear regression analysis demonstrated specific relationships between *T. palmeri* population size, survival, and the immediate habitat. Overall, including all animals captured (males, females, juveniles, adults), we found potentially causal relationships between tree and shrub density and *T. palmeri* population estimates (F = 13.045, P < 0.001, R^2 = 0.370, df = 47). Specifically, increasing density of currant berry shrubs and decreasing density of understory white fir trees contributed significantly to increasing population density of *T. palmeri* (Table 6).

Our analyses of survival found decreasing understory white fir tree density contributed to increased survival of *T. palmeri*. We further found greater population

density contributed positively to increased survival rates across the 48 grids, suggesting density dependent processes affecting *Tamias palmeri* population dynamics (F = 5.479, P = 0.007, R^2 = 0.200, df = 47) (Table 7).

Habitat Modeling

We used the six variables found significant within the macrohabitat analyses to develop a distribution-wide GIS-based resource selection function (RSF) model. We then extrapolated the model to determine potential *Tamias palmeri* habitat across the Spring Mountain range. Given the similarity of the beta values within the model, we combined the white fir and ponderosa tree type categories to simplify the RSF model and therefore ease potential management efforts. For completeness, we report these variables separately in Table 5. The logistic regression model found: RSF = (-0.037 * percent slope) + (-0.0018 * distance to permanent water sources) + (0.243 * Aspect) + (0.6412 * white fir and ponderosa combined) + (-1.133 * Pinyon pine-Juniper). Our model predicted the valley areas of (esp.) the northeastern areas of the range to have the greatest potential in terms of total area for *T. palmeri* habitat (Figure 4).

Track Plate Correlation with Population Estimates from Trapping

We tested the potential for track plates to substitute for mark-recapture methods across the Spring Mountain range. Correlation estimates between track plate numbers and population estimates were compared on 32 independent occasions within the two-year time period. We found no correlation between track plate counts and population estimates as derived from the Jolly-Seber mark recapture method (Pearson correlation 0.104, P = 0.570, N = 32).

Table 5. Landscape-scale habitat variables contributing to greater probability of occurrence of *Tamias palmeri* within the Spring Mountain range, Nevada, 2008-2009. Values are from a binary logistic regression analysis.

Habitat Variable	Beta	S.E.	Wald χ^2	Sig
Distance to permanent water sources†	-0.0018	0.00005	620.4	<0.001
Slope percent†	-0.037	0.0023	187.4	<0.001
Aspect (categorized as North or South)	0.243	0.035	40.9	<0.001
White Fir (categorical)	0.716	0.070	54.1	<0.001
Ponderosa (categorical)	0.610	0.06	40.7	<0.001
Pinyon pine-Juniper (categorical)	-1.133	0.12	57.4	<0.001

†Square root transformed, then back-transformed

Table 6. Microhabitat-scale variables significantly contributing to greater population size of *Tamias palmeri* within the Spring Mountains, Nevada, 2008-2009.

Habitat Variable	Beta	S.E.	Sig
Currant berry (*Ribes cereum*) density†	0.113	0.026	<0.001
Understory white fir (*Abies concolor*) density†	-0.110	0.03	0.001

†Square root transformed, then back-transformed

Recommend long-term monitoring sites and assist managing agencies in choosing the appropriate monitoring methods based on habitat type, cost and projected results

In Appendix A we provide a detailed monitoring protocol to assist management in creating a long-term conservation strategy for *Tamias palmeri*. We provide an overview of monitoring methods, three options for *T. palmeri* monitoring based on management objectives, sample size requirements, specific monitoring sites, monitoring itinerary, time and personnel required, materials needed, animal handling procedures, and safety considerations.

Table 7. Microhabitat-scale variables significantly contributing to greater survival rates of *Tamias palmeri* within the Spring Mountains, Nevada, 2008-2009.

Habitat Variable	Beta	S.E.	Sig
Understory white fir (*Abies concolor*) Density†	-0.0637	0.002	0.014
Tamias palmeri population density†	0.0288	0.013	0.037

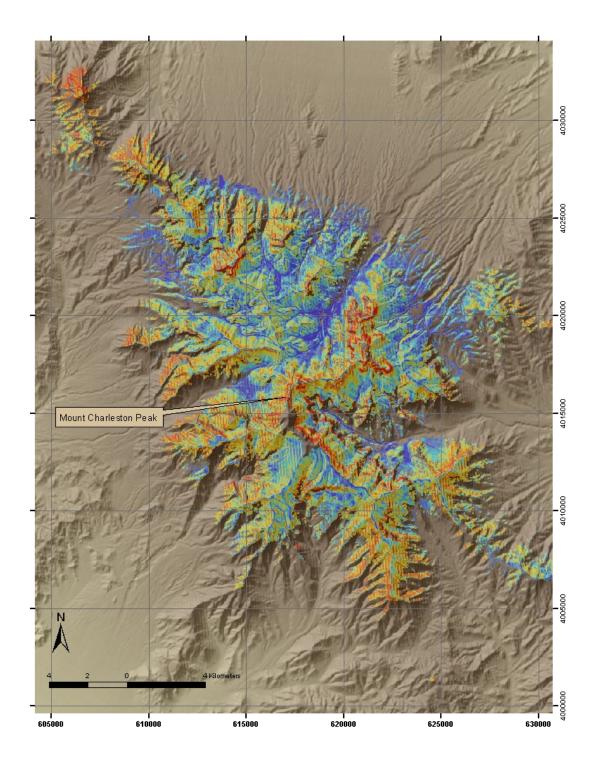† Square root transformed, then back-transformed

Figure 4. Resource selection function (RSF) predictive model of *Tamias palmeri* habitat across the Spring Mountain range, Nevada. Cooler colors are higher RSF values (greater quality habitat), warmer colors are lower values (lesser quality habitat). Brown color is beyond *T. palmeri* range, 2009.

DISCUSSION

Our study of *Tamias palmeri* ecology demonstrates that this species is a likely habitat generalist species within the parameters of relatively mature conifer forests. The species further trends toward the white-fir/limber/mixed conifer association forests, which occurs, in general, above 2600 m and below 2900 m. Beyond tree species type and composition, lower slopes, nearness to permanent water sources, and northern aspects comprise further constraints upon the likelihood of occurrence at the macrohabitat level. Within the microhabitat level of habitat use, understory tree density and shrub cover explained a significant amount of the variance of *T. palmeri* population abundance.

Distribution

With the exception of the Mount Sterling area, both species of chipmunks were captured across most of the conifer forested areas of the Spring Mountain range. Palmers chipmunks were captured at a wide elevation range from the upper pinyon-juniper association to above the bristlecone timber line. Panamint chipmunks were captured almost exclusively within the pinyon-juniper association. However there was an approximately 560 m elevation overlap between the two species occurring within the ponderosa/pinyon-juniper transition zone. This zone occurs at different elevations across the Spring Mountains, depending primarily on the respective aspect and rainfall patterns. The overlap range of the two species therefore changes with a general pattern: the widest overlap along the northeastern side and northern aspects of the range, and a narrowest overlap along the southwestern side and southern aspects.

Vegetation, Water, Topographic, and Survival Associations with Relative Abundance

Vegetation Associations

Although *T. palmeri* is relatively ubiquitous across the range, it appears to be most abundant within the white fir/mixed conifer association forest. The species does not have any abundant competitors for food resources that might limit its' expansion into the lower Ponderosa pine community (*Spermophilus lateralis* has a different food strategy, *Tamias panamintinus* occurs at lower elevations, *Nucifraga Columbiana* (Clark's nutcracker) does not occur in significant numbers), and this suggests two physiological causes for the findings. *Tamias palmeri* has a narrow thermoneutral zone of 32-34ºC (Best 1994), and may be constrained by the higher temperatures found at lower elevations. Hyperthermia develops above 34ºC, and these temperatures often occur at the lower elevations in this region. High temperatures may force *T. palmeri* to seek shelter during daylight hours, and therefore foraging efficiency may decrease at lower elevations. Alternatively (or additionally), there may be a difference in the ability of *T. palmeri* to digest different conifer seed species. If the digestive microfauna within *T. palmeri* are able to digest fir seeds better than ponderosa seeds, for example, than this ability may be reflected in their distribution (Kerley et al. 2010). The ability to harvest conifer seeds also depends upon morphological and behavioral abilities. Tree height,

conifer seed cone masting levels, and processing times in hulling seed cones are different for different tree species. White-fir, ponderosa, bristlecone, and pinyon pine trees all have different seed cone types and harvesting these may result in differing foraging efficiencies. If Palmers are able to harvest white fir tree seeds more efficiently, this may further explain differences in distribution.

Given *T. palmeri's* primary food is conifer seed, greater density of masting trees would suggest greater *T. palmeri* density, in contrast to our findings. The structural component of decreasing understory tree density suggests a resource and/or predator-prey response to habitat choice. Access to resource trees requires moving across ground, and although this increases risk of predation (Creel and Christianson 2008), more open ground could increase the efficiency of foraging by allowing shorter time periods between resources. Both *T. palmeri* abundance and survival increase with decreasing understory density, suggesting an advantage to risking greater exposure to predation in order to increase efficiency in resource collection (Creel and Christianson 2008) (we assume here predation is primarily from meso-predators and birds of prey).

We found increasing survival further dependent upon increasing population size. *T. palmeri* have been observed foraging in groups, and sentry activity, where one chipmunk observes potential threats while the group feeds, has also been observed (Lowrey, pers. obs.). This warning (chirp calls, trills) and sentry behavior may contribute to greater survival under higher *T. palmeri* population densities by increasing detection of predators through increased vigilance (Carey and Moore 1986).

Permanent Water Sources

Although *T. palmeri* occurs in areas remote from permanent water, our findings indicate reduced occurrence as distance to water increases. Although is basically unavailable to resident chipmunks beyond approximately 100-200 m from a water source, areas near water sources may serve as population sources (Lowrey 2002). Therefore, probability of T. palmeri occurrence may decrease even beyond this threshold. The lack of water sources may limit the reproductive success of *Tamias* species (Heller and Poulson 1972, Hirshfeld 1975). Some *Tamias* species are physiologically constrained to particular elevations due to the inability of the species to dissipate heat through rolling and squatting behaviors (Heller and Poulson 1972). *Tamias palmeri* has been observed drinking, rolling in, and defending wet areas from conspecifics (pers. obs.), and the presence of water may allow longer foraging times during summer. Hirshfeld (1975) found lactating females and juveniles consumed more water than other *T. palmeri,* indicating the importance of water for reproduction. In addition, VanderWall (1995, 1998) found that *T. amoenus* was better able to detect seeds under wet vs. dry conditions, and greater activity (trap success) of *T. palmeri* has also been observed under wet conditions (Lowrey, unpublished data).

Slope

Like all ground dwelling species in alpine environments, *T. palmeri* must dig relatively deep burrows to survive winter weather. Over-winter survival for *T. quadrivittatus, T. umbrinus,* and *T. minimus* has been shown to be less than one-third of

the respective population estimates (Bergstrom and Hoffman 1991), suggesting increasing soil depth (and thus increasing warmth) is an important habitat variable. Kawamichi (1996) demonstrated in *T. sibricus* that juveniles selected hibernation burrows only after adults had selected theirs, further suggesting burrows may be a limiting factor to over-winter survival. Soil depth is determined largely by slope, and areas with lower slope may therefore allow *T. palmeri* to more easily find or establish burrow sites. Lower slopes have been associated with greater shrub cover within the Spring Mountain range (Lowrey 2002). The shrub *Ribes cereum* provides food resources during late summer in the form of currant berries, and groups of *T. palmeri* have been observed foraging, defending, and storing this potentially essential food resource (Lowrey, pers. obs.).

Aspect

Due to protection from the drying effects of the sun, northern aspects naturally provide greater vegetation cover within the dry regions of the northern hemisphere. This is especially the case in the Spring Mountains, where the high relief of mountains and cliffs produce areas subject to great differences in sun exposure. Southern exposed areas of this range are measurably dryer, and density of all vegetation is greatly reduced. Often, larger conifer trees, the species primary food source, are completely absent from south facing areas even at higher elevations, and ground cover is accordingly reduced. This clearly reduces food availability, cover from predators, and increases ground temperatures, all which can limit *T. palmeri* probability of occurrence.

<u>Habitat Model</u>

The resource selection function (RSF) model we provide allows managers to predict the effects of changes in habitat across the Spring Mountains on *T. palmeri* probability of occurrence. For example, our model will predict the effects of the loss of a permanent water source upon the probability of occurrence of *T. palmeri* by recalculating the RSF values based on new information. Our model improves upon the previous model (Lowrey 2002) in two important ways. The ability to calculate specific probabilities of occurrence across the range allows for more specific knowledge on both present conditions and potential effects of changes. Furthermore, the addition of tree cover type greatly improves upon the previous model from Lowrey (2002), where tree type was not included.

The modeled distribution of favorable habitat characteristics predicts several areas of greater probability of occurrence of *T. palmeri* across the Spring Mountains. The Lee, Macks, MacFarland, and Deer Creek Canyon areas appear especially suited for *T. palmeri* conservation efforts (Figure 4). Whether areas predicted as high quality comprise source populations is unknown, however the consistency of our findings of higher population densities incorporating white fir areas of low slopes and northern aspects near water strongly suggests incorporating these regions into conservation planning actions. The model is necessarily restricted by the quality of data included, and the reliability of the tree type model from ReGAP created some false positives of areas predicted to be of high quality which in actuality was not. The areas at the northernmost extent of the

Spring Range, especially at the northwestern edge, are unlikely high quality *T. palmeri* habitat. However these are minor problems overall, and we believe this modeling approach useful in the conservation strategy of *T. palmeri*.

Track Plates

Although the potential of estimating population size through non-invasive techniques is a commendable goal, we found track plates to be uncorrelated with our population estimates of *T. palmeri*. Track plates within this habitat were labor intensive, requiring not only the traps, but the track plates, contact paper, chalk, alcohol, etc. Re-chalking, removing, storing, and replacing contact paper, and resetting the track plates was also labor intensive in this remote environment. The potential for animals to visit many track stations, thus biasing the results, was impossible to account for using our methods. We find track plates for this species to be a good indicator of occurrence, though not a reliable indicator of relative abundance.

CONCLUSION

Tamias palmeri are an integral part of the Spring Mountain range, and therefore comprise a major ecological component of the southwestern sky-island ecosystem. Long-term conservation strategy of this important species must include consistent monitoring of population parameters, conservation of areas important to long-term persistence, and protection from detrimental effects arising from human activity. Monitoring should include long-term commitments to collecting population abundance, survival rates, and if possible, recruitment rates or juvenile survival. Our study found several aspects of *T. palmeri* ecology that will assist managers and researchers conserve this important species. The relatively mature white fir/mixed conifer association is clearly an important habitat type for both population density and survival rates. Permanent water sources also contribute positively to probability of occurrence, and this presents serious challenges to managers as these same areas are also popular with recreationist. Our habitat model provides a basis for establishing long-term monitoring sites, and the significant habitat variables found provide focus for new research objectives. Furthermore, the habitat model allows the prediction of areas of *T. palmeri*/human conflict, effects of permanent water source loss, and delineates *T. palmeri* habitat areas most susceptible to detrimental human effects such as the feral cats and accidental fire.

RECOMMENDATIONS

We recommend using the included long-term monitoring protocol within areas that are representative of important *T. palmeri* habitat based on our research and modeling efforts. Although several options are available to management, conservation of a species begins with knowledge of their abundance and survival. No conservation plan is valid without knowledge of how a species' ability to reproduce is related to habitat. Therefore, a monitoring plan based on detecting these parameters is a necessary first step

to conservation. We recommend a grid-based approach, rather than a transect-based approach, to determine these parameters. Transect-based methods are as labor intensive as grid-based, however the resulting data from transects is severely limited and, beyond determining occurrence, are of little value to wildlife managers. This monitoring protocol allows for many questions to be addressed: recreation; urban encroachment; distribution; importance of water sources; etc., since these potential impacts are generally best answered in terms of population abundance and survival. An excellent opportunity exists within the Spring Mountain range for managers to support essential research on effects of human activities (recreation, feral cats, urbanization, etc.), source-sink and predator-prey dynamics, and density dependent processes using *Tamias palmeri* as a model species. Overlap between areas predicted to be of greater *T. palmeri* occurrence and areas of high public use are especially suited for further research. We suggest that areas within wilderness areas be made more accessible to qualified researchers, especially when research results would provide for continued conservation of this unique region. Although wilderness areas are created to conserve species such as *Tamias palmeri*, no conservation is possible without the understanding of population dynamics, habitat relationships, and the effects of human activities. Finally, an improved digital vegetation model of the Spring Mountain range is greatly needed to improve model fit, and therefore increase prediction accuracy of all species of concern within the Spring Mountain Range.

ACKNOWLEDGEMENTS

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APPENDIX A: Protocols for the Monitoring of Relative Abundance of *Tamias palmeri* in the Spring Mountains National Recreation Area, Nevada.

Final Report: DRAFT

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Multiple Species Habitat Conservation Plan

WESTERN ECOLOGICAL RESEARCH CENTER

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INTRODUCTION

The importance of wildlife monitoring to ascertain population viability cannot be overemphasized (Boddicker et al. 2002, Morrison et al. 2006). Projecting population size, density, distribution, and rates of change is impossible without a consistent estimation of population parameters (Morrison et al. 2006). Monitoring, therefore, must be an integral part of any wildlife conservation plan. A population maintains viability through recruitment of new individuals via reproduction and immigration, and a detected decrease in abundance over space or time could signal one or more environmental stressors indicating threats to the population viability of the species of concern.

The most practical way for managers to estimate the viability of natural populations therefore is the monitoring of changes in relative abundance across space and time (Gibbs 2000). The measurement of relative abundance allows comparison of different management strategies across and/or between areas, and is therefore sufficient for most management needs.

Finally, there are strong legal reasons to monitor accurately the status of wildlife populations. For species that are endangered, threatened, or of concern, the legal basis for monitoring is especially acute. The requirements upon federal, regional, and local agencies from acts such as the National Environmental Policy Act (NEPA), the Endangered Species Act (ESA), and in Clark County, the Multiple Species Habitat Conservation Plan (MSHCP) are significant in terms of cost, personnel, and other resources. Failing to properly comply with these requirements can inflate costs beyond any reasonable budget, and may delay the implementation of needed management practices necessary for conservation.

Although this protocol can be modified to monitor any small mammal population found on the Spring Mountain range, this specific protocol is designed for the Palmers chipmunk (*Tamias palmeri*), a small mammal within the Spring Mountains of southern Nevada. We provide an overview of monitoring methods, three options for *T. palmeri* monitoring based on management objectives, sample size requirements, specific monitoring sites, monitoring itinerary, time and personnel required, materials needed, animal handling procedures, and safety considerations.

An Overview of Monitoring Methods

Monitoring of changes in the relative abundance of natural populations can be performed via a count of individuals, or some other form of indirect estimation (Hopkins and Kennedy 2004). Taking a census based on visual observation of individuals is normally not feasible for most wild populations of small mammals (e.g., rodents, rabbits, insectivores). Visual observation is difficult since these mammals either rarely occurs in sufficient numbers to make this technique feasible, or activity patterns make the counting of individuals extremely difficult. Therefore, correlates of actual abundance, or indices that track changes in relative abundance, are used almost exclusively in small mammal population monitoring (Caughley 1977, Gibbs et al. 1998, Hopkins and Kennedy 2004). Indices of relative abundance are appropriate for addressing most questions regarding

changes over time or across landscapes (Foresman and Pearson 1998, Kurki et al. 1998). These indices are based on the assumption that a fixed amount of searching effort will always locate a fixed proportion of the population. This implies that the index is proportional to the actual abundance, and the rate of proportionality between the relative index and actual abundance remains constant (or mathematically tractable using a model) as actual population sizes change.

Trapping data have been used to answer questions about wildlife populations for many decades (Le Cren 1965). Trapping is a direct counting method and is therefore preferred to other indices when a census is not possible. Mark-recapture trapping techniques are the most common, have been well studied as to their precision and accuracy, and are classified into those suitable for either closed or open populations (Amstrup et al. 2005). In mark-recapture studies, each animal is uniquely marked and released back into the population creating a complete capture history by the end of the study. Alternatives to mark-recapture methods, such as batch marking, where animals are not uniquely marked, do not provide unique capture histories and should be avoided, except perhaps for use in Lincoln-Peterson single sample techniques (Otis et al. 1978). Enumeration methods, otherwise known as 'minimum number known alive' counting methods, are biased towards underestimation of population sizes, do not allow for error estimation and therefore are also not recommended (Nichols and Pollock 1983).

Open vs. Closed Population Models

An open population model assumes that population size is fluctuating naturally (e.g., through immigration and emigration between a local and adjacent populations), while closed population models assume an unchanging number of animals over the trapping period (Amstrup et al. 2005). The closed population model is commonly used to estimate small mammal population sizes (Greenwood et al. 1985, Menkens and Anderson 1988). Because closed population models do not allow for fluctuation in population size during a sampling session, they are normally conducted over short periods of time (3-5 days). The most common of these is the Schnabel method (Schnabel 1938). This method is based on the assumption that each individual has an equal probability of capture, but that these probabilities can vary across sampling times (time heterogeneity). Closed population models are thought to be robust against random movement into or out of the trapping area (Kendall 1999). Closed population models are biased, however, if capture probabilities of individuals are heterogeneous, e.g. trap-happy or trap-shy animals in the population (Huggins 2001).

Open populations allow for changes in population size during the trapping period, and therefore is more realistic than closed models. The Jolly-Seber model is the most common open population estimator (Jolly 1965, Seber 1965). This model can be used to estimate population size but also, unlike the closed models, survival and number joining the population (births or immigration). The additional ability of the open population model to estimate survival rates is important. Comparisons of survival rates may lead to more direct inference than abundance alone about the importance of a particular habitat, and both researchers and managers have begun to emphasize this approach (Lebreton et al. 1992).

OBJECTIVES

Any agency or researcher considering expending the effort to monitor changes in abundance for a wild species over time and space should consider the level of precision required, reliability, and cost of acquiring the estimates. A monitoring protocol is needed that is flexible, reliable, cost effective, and designed to estimate abundance at the level of precision necessary for wildlife managers. Our objectives for the habitat protocol are to: 1) Recommend long-term monitoring sites based on results from the study: *Palmers Chipmunk (*Tamias palmeri*) Ecology and Monitoring protocols in the Spring Mountains National recreation Area, Nevada.* (Lowrey and Longshore 2010) and the Master of Science thesis research of Christopher Lowrey (2002); and 2) Develop monitoring options (toolbox) based on cost, habitat types, and specific management objectives. We strongly emphasize that the future concerns and/or questions that may arise in regards this species are the purview of the management. This protocol is designed to be adjustable to address many concerns: recreation, urban encroachment, loss of water sources, effects of fire, etc., however not all possibilities can be covered in a single document. A protocol that provides for very specific questions is of little use once conditions or different concerns arise. Therefore, the methods given are purposely generalized to allow managers to adjust for future needs. Furthermore, the frequency of monitoring is also adjustable to management needs. However based on T. palmeris' range of variability in terms of abundance and survival and our expert opinion, we strongly recommend no longer than 3-5 years between monitoring efforts for this important species.

All management plans have properties that can be stated as falsifiable hypotheses, and this protocol can be easily modified to address specific hypotheses about the ecology and conservation of *Tamias palmeri*. This protocol will create the empirical data necessary to address important questions concerning the viability and status of this species, and acquiring these data within the framework of a working hypothesis is strongly recommended. Furthermore, the isolated nature of the species habitat, relative abundance, and the fact that *T. palmeri* it is a primary prey source as well as a seed disperser across the range, makes this species well suited to address many questions of sky-island ecology.

METHODS

This monitoring protocol has been designed to detect changes in relative abundances and survival rates of *Tamias palmeri* in the Spring Mountain Range in southern Nevada. We provide three options for managers to establish long-term monitoring sites based on habitat type, cost, and expected results. The quality and limitations of results obtained from any population and habitat study is based primarily on project design and sample size. We used the population size variance estimates from the present study (Lowrey and Longshore 2010) to estimate the number of trapping grids (sample size) necessary for each option using the following formula: $N = (Z^* \theta / m)^2$ where N is the sample size necessary; Z* is the statistical constant 1.96 for 95%

confidence and 1.64 for 90% confidence; θ is the variance across all abundance estimates derived from the present study of *T. palmeri* (Lowrey and Longshore 2010); and m is the margin of error which is equal to Z* (θ/ √n) where n is the original sample size used in the present study (Moore and McCabe 1999).

We assume managers are concerned with the effects of human activity upon *T. palmeri* population size and survival, and have designed these options to address these concerns. However we stress that the protocols are easily modified to address ecological considerations such as differences across riparian areas or effects of burned areas as well. We assign human activities into two categories in terms of greater and lesser impact upon the environment. For example, high recreation (campgrounds, picnic areas) and low recreation areas (wilderness, off-trail areas). The specific levels and type of human activities are to be determined by the management agencies responsible for *T. palmeri* conservation within the Spring Mountains.

The first monitoring option (option 1) provides for a scientifically rigorous evaluation of *T. palmeri* ecology, population estimates, survival, and their relationships to human activities throughout the range. This option will detect a 15% change in population size with 90% confidence. The second option (option 2), provides for a moderately rigorous evaluation, including a comparative study between areas of differing levels of human activity, and will detect a 20% change. Option 3 will allow for a basic comparative evaluation between areas, and will detect a 28% change in population density. Monitoring efforts should begin no earlier than June and should end no later than late August to avoid cool weather inhibiting capture rates. All trapping/animal handling methods should follow the protocols within this document.

Option 1: When management objectives demand broad-scale monitoring of *T. palmeri* ecology and potential threats to the population, we recommend population density and survival estimates across different habitat types and levels of human related threats (i.e. recreation use, urbanization categories, feral cat levels, etc.). Option 1 allows for the evaluation of two levels of human activity across two different areas within each year. In order to evaluate two different levels of human activity (ex. recreation and non-recreation) across two different habitat types (ex. riparian and non-riparian) with a 90% confidence level and a margin of error of 2 animals (approximately 15% of the average population estimate), no less than 10 trapping grids should be placed in each "treatment' type (Table 1). This option will require 40 trapping grids. Suggested locations (approximate) of grids are given in Table 1. Final locations should be determined by recent human activity and stream flow levels. Dominant tree species type, slope, and distance to permanent water sources should be kept as continuous as possible within each habitat type of interest. For example all, or at least the majority, of the grids should have the same dominant tree species (ex. white-fir), and those area categorized as non-riparian should be at least 400 m from water sources. All habitat variables measured in the present study (see subsequent vegetation protocol) should also be measured immediately before or after the trapping sessions. Given the slow rate of vegetation change in these areas, these measurements may not have to be replicated each year. Grids for this option should be trapped simultaneously if possible. However given the short duration of the active season, relaxing this requirement would not likely diminish the validity of the results. However, if fewer grids are to be trapped simultaneously, the treatments (see Table 1) must be equally represented. Splitting the replicates across two years, for example 20 and

20, is also allowed if a test for differences between years is conducted on the resulting data. We believe this should be considered the best option for long-term monitoring of *T. palmeri* habitat use, population size, survival rates, and potential effects of human activity.

Option 2: When management is willing to accept detection of population size and survival changes at a less precise level, we recommend population and survival estimates between *T. palmeri* populations occurring across different levels of human related threats. The difference in using option 2 vs. option 1 is that two levels of human activity may be measured within only one habitat type. For example, all recreation and non-recreation areas should be in either riparian or non-riparian areas, not both. Like option 1, option 2 can detect differences in population and survival rates in relation to human activity, however this option is only able to detect these differences with a lower degree of precision. Also as in option 1, the treatments (i.e. recreation levels, urbanization categories, etc.) may be changed to suit other questions managers have. For example, riparian and non-riparian areas may also be compared with this option. As with all monitoring programs, care should be taken to control as many variables as possible. In order to determine two different levels of recreation with a 90% confidence level and a margin of error of 3 animals (approximately 20% of the average population estimate), estimates from at least eight grids per treatment (total of 16 grids) will be needed. As the number of replicate grids is diminished, greater attention must be made to avoid disrupting influences within the trapping areas. For example, areas where feral cats are known to occur should be avoided (unless this is the focus), and recreation levels must be monitored more closely to avoid outlier effects such as a very large recreationist group in only one campground during the trapping effort (or alternatively, a campground thought to be open that is closed).

Option 3: This final option reflects the very minimum we believe necessary to maintain a continuous monitoring effort on *T. palmeri* abundance in specific areas, and should only be used when management objectives require only limited information on Palmers chipmunk population and survival. The difference in using option 3 is that population levels and survival rates can only be compared between years, not between levels of human activity within the same year. We recommend at least 10 grids be trapped each year within areas believed to be important to *T. palmeri* (Table 1). As with the other options, grid trapping protocols should follow the methods outlined in the trapping protocol. Grids should be trapped simultaneously. Grids should also be within the same dominant vegetation type, preferably the white-fir association. This minimum number of grids does not allow for the replication necessary to address questions about differences between areas or habitat types. However, long-term repeated monitoring of the same well-chosen locations will allow relative abundance and survival estimates that will be useful for identifying limited long-term population trends.

Time and Personnel Required

The three different options provided in this protocol obviously require different levels of time, personnel, and costs. Several protocols are similarly required for all options, however. All options require a minimum of four 5-day weeks of trapping effort, and the timing of the effort should occur during the height of the active season, which is between

late June and late August. Two of these weeks should occur consecutively (with a two day break in between each week) in late June or July and the other two weeks should occur consecutively in August. Table 2 provides an example of a trapping itinerary which can be modified to fit all three options. Although the dates shown may be adjusted due to weather and/or logistical constraints, trapping should continue through their timetables of two and five days, respectively.

Table 1. Recommended areas for monitoring *Tamias palmeri* density and survival rates, testing for differences between habitat types, and testing for effects of human activity. Spring Mountains, Nevada. 2010.

Habitat and Recreation Level Activity*	Number of grids**	Easting	Northing
Riparian: High recreation levels			
Deer Creek†	2	623900	4019400
Mack Canyon	3	618700	4023900
Carpenter Canyon	3	613350	4011040
Upper Kyle Canyon	2	618897	4015100
Riparian: Low recreation levels			
Clark Canyon	2	613630	4019950
North Fork Deer Creek	3	622390	4019800
Upper Mummy Spring	2	622800	4018160
MacFarland Canyon†	3	616070	4022400
Non-riparian: High recreation			
Lee Canyon†	2	618660	4019900
Lee Canyon campground	4	617800	4018900
Lower Kyle Canyon†	2	620500	4014000
Lower Kyle Canyon campgrounds	2	625047	4013930
Non-riparian: Low recreation			
MacFarland Canyon†	4	616315	4022300
Upper Lee Canyon	3	617800	4017700
Trail Canyon (away from trail)	1	620500	4016000
Upper Rainbow Canyon†	2	623070	4012300

* Recreation levels to be determined by USFS or other agency.

** Number of grids and locations are approximate.

† Suggested areas for basic population monitoring.

For option 1, time, personnel, and costs will depend upon if and how the 40 grids are separated across time. In order to trap 40 grids simultaneously, no less than 14 persons would be required to trap in the field for a minimum of four 5-day weeks. These

requirements would be reduced by half each year if trapping effort is distributed across a two year period (20 grids each year).

Option 2 demands a 16 grid effort, and this would require no less than 8 persons to trap in the field for four 5-day weeks. Which research questions are addressed, whether riparian areas, recreation areas, or another focus, would determine the specifics of the logistics necessary to fulfill the protocols. If recreation areas are the focus, for example, then costs may be minimized by the close juxtaposition of potential trapping sites (but see minimum distance requirements in the trapping protocol).

Option 3 is the least demanding option in terms of personnel requirements and costs. However, depending on management requirements, the limited scope of data collected and therefore limited inference from that data may outweigh the cost effectiveness of this design. That being said, this option will provide basic analyses of population and survival of the chosen sites. To implement a simultaneous 10-grid survey required for option 3, no less than 5 persons would be necessary to trap in the field for four 5-day weeks.

Statistical evaluation of the resulting data must be provided for all options. Data analyses will take one experienced person 5-8 days including data entry. Computer software designed specifically to calculate wildlife population densities and survival parameters is highly recommended. Software programs *Ecological Methodology* or *MARK* are very inexpensive and can make the necessary estimations. Specific statistical analyses suggestions for data collected under this protocol are given in the methods section.

Table 2. An example itinerary for *Tamias palmeri* trapping protocols. Spring Mountains, Neada. 2010.

Month/Day (approximate)	Activity	Time of activity
6/28-30	Place traps in field	All day
7/1-5	Trapping	Twice/day
7/8-12	Trapping	Twice/day
8/4-6	Place traps in field	All day
8/8-12	Trapping	Twice/day
8/15-19	Trapping	Twice/day
8/21-30	Vegetation data collection	All day
9/1-8	Data entry/Statistical analyses	All day

Trapping Design

Traps are to be laid out in rectangular trapping grids. Grids must be at least 400 m apart to maintain independence. Each trapping grids consist of 5 parallel lines of 8 traps each for a total of 40 traps for each grid. Each line is 30 m apart. Lines of traps are to be as straight as possible. Traps are spaced 30 m apart to create a rectangular grid 210 m x 120 m. This configuration gives an effective trapping area of 3.6 hectares. Traps must be

completely protected from sunlight by covering the traps with forest litter or other means for the entire day to prevent death of chipmunks from exposure. Any cover placed on the traps cannot be so heavy as to distort the trap shape and thus cause the trap to malfunction. Traps should be baited with approximately 1 gram of a dry oatmeal and peanut butter mix and provided with 2 cotton balls (as protection against cold). Traps are to be opened in the late afternoon on the day before the first trapping day. Traps are to be left open for 24 hours throughout each trapping session. All traps are to be checked twice per day. Check all traps once just after sunrise and once late in the afternoon. The trapping site should be vacated of personnel as long as possible during the daylight hours to prevent disturbing animal movements.

Materials Required

Materials shown are for option 1: Includes simultaneous trapping of all grids. Effort may be split across two years, halving the requirements. Materials required for option 2 and 3 are similar except for quantities.

- 1600 small mammal traps (40 grids x 40 traps). Collapsible aluminum Sherman traps 25 cm x 9 cm x 8 cm with galvanized steel doors are recommended (H.B. Sherman Live Trap Company).
- Approximately 4000 small mammal ear tags (size 1, Monel) (National Band and Tag company). This amount will likely last several years.
- Fourteen (1 per person) ear tag applicators (National Band and Tag Company).
- Approximately 3000 cotton balls
- Approximately 10 kg of dry oats.
- Fourteen 100 g hand-held scales with a clip on the end.
- Fourteen 300 g hand-held scales with a clip on the end (for *Spermophilus lateralis*, and *S. variegatus*).
- Clear plastic bags to hold the animals while weighing.
- Three pairs of tight fitting gloves approximately 2-3 mm thick for each person.

Handling Captured Animals

There are 4 species of mammal most likely to be captured at these locations, *T. palmeri*, *Spermophilus lateralis*, *S. vareigatus* (infrequent), and *Peromyscus maniculatus* (nocturnal). The most common are *T. palmeri*, which are easily identified by their striped face. This species is not likely to bite. However juveniles are less predictable so a pair of tight fitting gloves is recommended. Before removing the animal from the trap, place the ear tag in the applicator and close the applicator just enough to hold the tag in place. Be careful not to squeeze the applicator such that the ear tag closes before your ready to place it in the ear. If you do prematurely close the tag, do not try to re-open the same tag., throw it away and start again with a new tag. Have the weighing scale within reach. Place the clear plastic bag tightly over one end of the trap and hold with one hand. Leave enough room in the bag for the animal to run into. Keep your other hand outside the bag, and open the trap door by pushing the bottom of the door back with your finger. Often an

animal must be forced out of the trap by mildly shaking the trap with the open door facing down. Once the animal is in the bag, quickly remove the trap and close the bag to prevent escape. Weigh the animal inside the bag by clipping the scale to the closed bag. Coax the animal into a corner of the bag and pin it gently between one hand and the ground so it cannot move. Come in behind the animal with the other hand inside the bag and grasp firmly the loose skin on the dorsal side at the base of the skull. Remove the animal from the bag. Determine the animals age (juvenile or adult) and sex (The procedure for determining age and sex follows). To place the tag in the ear, hold the animal gently against the ground, place the applicator with the ear tag as deeply into the ear as possible, squeeze the applicator closed quickly and completely. The animal will squirm a little so keep a good grip. When finished, release the animal.

It must be emphasized that capturing and handling is very stressful to the animal, and death can occur from stress myopathy even after release. Therefore it is essential that the tagging procedure be carried out as quickly as possible. Avoid talking loudly, excessive movement, and work with the animal in the shade. Once the animal has been removed from the trap, the tagging process should only take about 2-3 minutes.

The animals' sex can be determined by looking at the position of the ureter relative to the anus. If the ureter is directly adjacent to the anus the animal is a female. If the ureter is anterior to the anus (approx. $\geq$ 1cm. space between on adults) the animal is a male. The animal's age is best determined by weight or sexual condition early in the season. Juveniles generally weigh < 45g before mid-July. From June through mid-July, swollen nipples can usually identify adult females, and swollen testes can usually identify adult males. Juveniles begin to catch up to the adults in weight in late July, and sexual condition of adults also diminishes about this time. Therefore age identification late in the season requires the use of other factors. Juveniles generally have more gray fur especially on the chest and belly and their fur in general is not as brightly colored or as thick. Juveniles generally have a thinner body shape, and their head is proportionally larger than their bodies relative to adults.

Another species one is likely to capture in these areas is the golden-mantled ground squirrel (*Spermophilus lateralis*). Managers may want to measure the population levels of this species in order to find potential interactions, competition, or other relative parameters relative to *T. Palmeri* ecology. *S. lateralis* is considerably larger (up to ≈300g) and more aggressive than *T. palmeri*. Gloves are strongly recommended, as this species is likely to bite given the opportunity. Follow the same procedure as for T. palmeri to tag and weigh *S. lateralis* except that the larger 300 g scale is needed to weigh this species. The procedure for determining age and sex of *S. lateralis* is similar to that for *T. palmeri*.

The other common species is the nocturnal deer mouse (*Peromyscus maniculatus*). If population sizes of this species are of interest they must also be ear tagged. Follow the procedures outlined above. If this species is not of interest then release the animal by opening the door on one end of the trap and allow the animal to escape. Be aware that the deer mouse is the primary reservoir of the sin nombre hantavirus strain in North America and therefore that appropriate handling procedures must be followed (guidelines can be found in a document provided by the American Society of Mammalogists; www.mammalsociety.org/committees/index.asp).

Handling Recaptured Animals

Recaptured animals must also be handled in order to re-weigh the animal and read the ear tag number. Care must be taken in reading the ear tag as the numbers are very small and mistakes will lead to a loss of data. The date of each capture and exact location (trap number) of the animal is also needed. Be sure to differentiate between initial captures and recaptures.

Trapping Analyses

Densities from trapping data should be calculated using the Jolly-Seber capture-recapture method for open populations (Amstrup et al. 2005). We recommend either the Ecological Methodology (Exeter Software Co., Setauket, N.Y.) or the program MARK computing software (available online at http://warnercnr.colostate.edu/~gwhite/mark). As in any project there are options for analyses, however we recommend an analyses of variance (ANOVA) for determining differences in population size/survival between areas of interest, habitat types, human activity levels, or years (Sokal and Rohlf 1995).

Vegetation and Topographic Data Collection

Vegetation species composition, structure, and topographical variables should be measured within eight-meter radius plots centered on each trap (40 traps per grid) within each grid. Suggested variables are given in Table 3. We define downed logs as >0.5 m in diameter and >2 m in length and shrubs as species > 0.25 m and < 2.0 m. Overstory (trees > 10 m in height) and understory (trees < 10 m in height) should measured as separate categories. Percent tree, shrub, and forest litter cover can be estimated by standing at 20 systematically placed points within each plot and looking straight up (canopy) and down (shrub, litter) through a 20 cm long by 3 cm diameter tube. Derived percent cover by counting the number of times the canopy (or shrubs) covered the line of sight (hits) and dividing that number by 20 (total) (modified from Dueser and Shugart 1978). Tree heights can be measured with a hypsometer. Water source locations, either wet ground or open water, should also documented. Slope, aspect, and distance to water variables should be measured with a GIS. Record all trails or other structures within the plots. All spatial data, including trap, track plate, grid, transect, water source locations, and vegetation plot locations should be recorded with a GPS unit. Data should be collected using identical coordinate and datum systems to prevent mapping errors.

Table 3. Suggested habitat variables to measure for the Palmers' chipmunk monitoring protocol within the Spring Mountains, Nevada. 2008-2009.

Habitat Variables Measured	
Tree* percent cover	Downed logs density (#/plot, #/grid)
Tree density (#/plot, #/grid)	Large rock density (> 1 m diam) (#/plot, #/grid)
Tree height (m)	Forest litter percent cover
Shrub† percent cover	Aspect (categorical, 1=N, -1=S)
Shrub density (#/plot, #/grid)	Distance to water (m)
Snag density (#/plot, #/grid)	Slope percent

* 8 species of tree measured
† 3 species of shrub measured

<u>Safety Considerations</u>

Rodents are known carriers of disease. Known diseases carried by rodents likely to be captured in the Spring Mountains include rabies, plague, and hantavirus. Rabies can be transmitted only by bite from an infected species. Plague is carried by fleas and ticks which are carried by the rodents, and is transmitted to humans by flea and tick bites. Hantavirus is carried in the feces and urine of deer mice (Peromyscus maniculatus) and is transmitted to humans by inhaling the dried feces or urine of this animal.

Safety practices are recommended to help prevent the transmission of diseases from animals to humans (zoonotic diseases). Rabies vaccinations are available and recommended to prevent acquiring this disease. If the researcher is bitten in any case, post-exposure vaccinations must take place immediately. Prevent flea and tick bites by using insect repellent and wearing long pants and long sleeves. If a bite takes place, antibiotics are available. Prevention of hantavirus is facilitated by keeping the face away from traps to prevent inhalation of feces particles. Researchers should not touch their hands to their face after handling animals and/or traps. Hands should be washed frequently with an anti-bacterial solution while trapping. Traps should be wrapped in plastic while being stored or transported in an enclosed vehicle or office. Transmission of hantavirus is an extremely rare event. However there is no vaccine and exposure may result in death. These disease prevention recommendations are not to be considered comprehensive. For comprehensive prevention recommendations contact the Center for Disease Control.

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