Appendix C

Plumas-Lassen Area Study Module on Small Mammal Distribution, Abundance, and Habitat Relationships

Annual Report

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INTRODUCTION

Small mammals provide critical food sources for many carnivores, including the American marten, California spotted owl, and Northern goshawk. As a result, changes in small mammal abundances could have affects on many species throughout the forest. Understanding the demographics, habitat requirements, and natural fluctuations of small mammals is critical to the management of Sierra Nevada forests. Alterations in habitat structure can directly affect small mammals by increasing habitat quality allowing greater small mammal density, higher reproduction, and increased survival. In addition, changes in the spatial distribution of habitat characteristics can lead to differences in small mammal distribution patterns (e.g. more clumping).

Determining which components of the habitat are important in structuring the dynamics of small mammal populations requires close monitoring of several independent populations through multiple years combined with measuring habitat characteristics. In addition, the requirements of key prey species (woodrats and flying squirrels) must be understood in detail. In particular, daily activity and habitat use of key prey species within specific habitat types is necessary to understand the link between small mammal and predator populations.

In addition to understanding small mammal population dynamics and habitat relationships, we will investigate links between physiology and population dynamics in a key diurnal prey species. Golden-mantled ground squirrels represent a primary prey species for diurnal predators, such as the Northern goshawk. Alterations to habitat structure may affect individual fitness of small mammals by altering their ability to build fat layers in anticipation of hibernation. We will quantify fat content of golden-mantled ground squirrels throughout the year and relate that to habitat structure. The results of this aspect of the study would provide a possible link between habitat structure and population dynamics of these important prey species.

Finally, we are establishing separate collaborations with independent researchers to investigate the phylogenetic relationship between the chipmunk species living in the study site. Several of the chipmunk species are virtually identical in appearance and can only be identified by skeletal differences. As a result, we hope to find simple molecular techniques to identify species using a small of ear tissue. This will allow proper identification of the species without killing individuals being studied.

OBJECTIVES

Research objectives for the small mammal unit are to evaluate small mammal responses to different forest management practices, and model these responses in terms of demography, spatial distribution, and habitat associations. Specifically we will investigate:

1. <u>Demographic profiles of small mammal populations inhabiting a variety of habitat types</u>. We established nine semi-permanent live-trapping grids for use as experimental plots. Three sets of three experimental grids were established throughout the treatment area with each set of three grids established in a cluster. The clustered grids

consist of two grids established in known DFPZ treatment zones and will be treated with a light (grid A) or heavy (grid B) thinning treatment, and a third, control, grid (grid C) will not be treated. All grids are located in white fir dominated forest with triplicate grids located in close proximity to each other.

2. Habitat associations of small mammal populations in the northern Sierra Nevada. This was investigated using multivariate techniques to identify key habitat characteristics used by individual species of small mammals. Nine additional grids were established in various representative habitats throughout the study site. Habitat grids were established in triplicate for each habitat, and did not necessarily need to be located near other grids in the same habitat type. We measured a number of macro- and microhabitat characteristics among the habitat grids for use in determining habitat associations among small mammals inhabiting the study area. In addition, we performed fall cone counts on all trapping grids to identify annual and seasonal pattern in cone production among the major conifer species inhabiting the study area.
3. Dynamics of key spotted owl prey: dusky-footed woodrat and northern flying squirrel. Dusky-footed woodrats (*Neotoma fuscipes*) and northern flying squirrels (*Glaucomys sabrinus*) are of particular concern to forest managers, as they comprise a major portion of California spotted owl diets. We will capture and radio-collar 20 dusky-footed woodrats and perform monthly radio-telemetry throughout the season. Through the use of radio-telemetry we will identify home ranges and nest locations for both sexes and various age classes. In addition, we will capture as many flying squirrels as we can and radio-collar them for use in home range analyses.
4. Fitness correlates to forest management. Some taxa may not exhibit numerical responses to forest treatments, but the quality of individuals as prey items may be altered, with important implications for spotted owls or northern goshawk. In particular, fat deposition is critical in ground squirrels that live off these stored reserves while hibernating. We will capture and radio-collar 12 female golden-mantled ground squirrels for use in the fat analysis study. Females will be randomly assigned to one of two groups. Group one will receive a high-fat supplementary diet during the months leading into hibernation, whereas group 2 will forage normally and act as a control group. All individuals will be captured and have their mass, body composition, and overall health measured. In addition, monthly home ranges will be calculated for each individual using monthly radio-triangulation. Offspring from these 12 experimental females will be captured, radio-collared, and followed to determine the effects of maternal body condition on offspring fitness, dispersal, and home range establishment.
5. Taxonomy and classification of Sierra Nevada chipmunks. Chipmunk species in the Plumas and Lassen National Forests display considerable overlap in habitat requirements, diet, and activity. Additionally, two

species (long-eared chipmunk (*Tamias quadrimaculatus*) and Allen's chipmunk (*Tamias senex*)) overlap in appearance to such an extent that they are virtually impossible to identify without using skeletal features. We will collect representative samples of chipmunks from throughout the study site to identify species through the use of pubic bines and collect tissue samples from these known chipmunk species to develop molecular markers for non-lethal identification of chipmunk species in the future. While this is not central to the present study, we have begun to establish collaborations with chipmunk taxonomists towards better understanding the nature and distribution of these species using outside funds.

METHODS – 2004 Field Season

Demographic profiles of small mammal populations inhabiting a variety of habitat types:

Small mammal populations were sampled monthly using established trap grids. We employed a nested grid system. Sherman live traps were established in a 10 x 10 grid with 10m spacing, nested within a larger (6 x 6, with 30 m spacing) grid of Tomahawk live traps (2 traps per station). All traps were opened in the late afternoon and checked the following morning. Both Sherman and Tomahawk traps were checked soon after sunrise (AM1 session). Animals captured during the AM1 session were worked up and released. Tomahawk traps were reset following release of any animals. All Sherman traps were closed following the AM1 session to prevent deaths from heat exposure. All Tomahawk traps were checked again approximately 2 hrs following the AM1 session (AM2). Animals captured during the AM2 session were worked up and released, and all traps were then closed. All traps remained closed from 11:00 – 15:00 to prevent deaths to animals due to heat exhaustion. All traps were baited with a mixture of rolled oats, peanut butter, and sunflower seeds.

All individuals captured were weighed and measured (e.g., ear length, hind foot length), and sex and reproductive condition noted. For males, testes may either be enlarged and scrotal or reduced and abdominal; for females, the vagina may be perforate (thereby receptive) or imperforate (not receptive), the vulva may either be swollen or not, and the nipples may be enlarged and/or reddened (reflecting nursing offspring), or not. All animals were individually marked with numbered ear tags, and released at the site of capture. Total processing time for an experienced technician is generally < 2 minutes.

Population demographics will be modeled by species using program MARK. Species that do not enough individuals to generate detailed capture history will be modeled using the minimum number known alive (MNKA) parameter. Monthly survival and population densities will be modeled for each species by habitat type using the Cormack-Jolly-Seber data type in program MARK. Suitable habitat parameters, such as cone production, will be incorporated into population models and can be used to identify habitat variables that are linked to population parameters using multivariate analyses.

Habitat associations of small mammal populations:

Measurement of habitat variables on each trap grid was stratified into macro- and microhabitat characteristics and measured during the 2003 field season. Macrohabitat variables were measured at alternate trap stations on each grid, whereas microhabitat variables were measured at all trap stations on each grid. Macrohabitat was defined by forest type. Overstory vegetation was quantified in July-August 2003 using point centered quarter sampling (Mueller-Dombois and Ellenberg 1974) at 18 predetermined, stratified Tomahawk trap stations per grid. Trees sampled had a diameter-at-breast height (1.4 m) of ≥ 10cm. All macrohabitat analyses used the first capture of an individual at a forest type (thus, repeat captures were not counted). Macrohabitat variables include the identity (species), DBH, height class, and distance to the nearest tree (> 10 cm DBH) in each of four quadrants, centered on the trap station.

Microhabitat characteristics were sampled during July-August 2003. All measurements were recorded within a 1m radius (3.14 m^2) circular plot centered at every trap station. Percent cover was visually estimated for 12 ground cover variables (e.g., rocks, bare ground, forbs and grasses, litter, downed wood, shrubs, saplings; Table 1). Canopy above breast height (1.4 m) was quantified by taking a single photograph with a hemispherical lens at every trap station, and calculating percent canopy openness using Gap Light Analyzer v2 (Simon Fraser University 1999). Aspect was measured with a compass by estimating the direction water would flow from the center of a trap station and was converted to North-South (e.g., $^{-}90°$-$^{+}90°$) and West-East ($^{-}90°$-$^{+}90°$) variables. Slope was measured with a clinometer as the general decline of the substrate within each circular plot. Substrate (ground) hardness was measured as kg/cm^2 using a soil penetrometer (Pocket penetrometer, Forestry Suppliers Inc.) at four random points (one per quadrat) within each circular plot; the four measurements were averaged for a hardness value per trap station. Very thick duff layers at ≥ 50% of trapping grids (up to 15cm) made digging for true soil measurements impractical and somewhat meaningless; therefore, this metric represents a measurement of substrate (ground surface) hardness rather than true soil hardness. A non-woody perennial category was created to include species that exhibited both shrub- and forb-like characteristics yet did not fall distinctly into either category; such non-woody species include bracken fern (*Pteridium aquilinum*), thimbleberry (*Rubus parviflorus*), Prince's pine (*Chimaphila umbellata*), and snowberry (S*ymphoricarpos* sp.). Snowberry was by far the most frequently encountered of these species. Microhabitat vegetation (excluding canopy) was re-sampled in July 2004 at one fourth (n = 30) of all trap stations in six randomly chosen trapping grids representing all forest types; because no changes were documented in these metrics (paired t-tests; all $p > 0.01$), measurements recorded in 2003 were used in comparisons with small mammal data from both 2003 and 2004. All microhabitat analyses used the first capture of an individual at a given trap station (thus, repeat captures were not counted).

Total abundance (N), species richness (S) and species diversity (H') was calculated for each trapping grid. Small mammal species diversity was calculated using the Shannon-Wiener diversity index ($H' = -\sum p_i \log p_i$). We tested the null hypothesis that the mean of these metrics of community structure do not differ across forest types and sampling year using a repeated measures multivariate analysis of variance (rmMANOVA) and subsequent repeated measures analysis of variance tests (rmANOVA) on each metric. Abundance counts were square-root transformed to meet

assumptions of normality. Variances were univariate homogeneous but were not examined at the multivariate level. Because variances were univariate homogeneous and the smallest cell size was > 50% the size of the largest cell (meaning sample sizes were not extraordinarily unbalanced; Scheiner 2001), we are confident that assumptions were met within reason. Nevertheless, Pillai's trace was used to test the null hypothesis as it is considered very robust to violations of assumptions (Scheiner 2001). *Post hoc* comparisons were conducted using Scheffé test (Day and Quinn 1989) and considered significant at $\alpha = 0.05$.

There were sufficient captures of *P. maniculatus* and *Neotamias* for parametric analyses of macrohabitat associations. The null hypothesis that abundance of *P. maniculatus* and *Neotamias* did not differ across forest type and year was tested using rmMANOVA and subsequent rmANOVAs on each species. Counts of *P. maniculatus* and *Neotamias* were square-root transformed to meet assumptions of normality. All assumptions were tested as for community metrics. Pillai's trace was used to test the null hypothesis and post hoc comparisons were conducted using Scheffé test ($\alpha = 0.05$) (Day and Quinn 1989).

Six taxa were captured at < 50% of sampling grids, precluding the use of parametric tests; these species included: *Glaucomys sabrinus*, *Microtus*, *Neotoma fuscipes* (dusky-footed woodrat), *Spermophilus beecheyi* (California ground squirrel), *Spermophilus lateralis,* and *Tamiasciurus douglasii* (Douglas squirrel). Because a Wilcoxin nonparametric test documented no significant differences in abundance of these species between sample years, a Kruskal-Wallis nonparametric test was applied to species counts pooled from 2003 and 2004 to evaluate differences in abundance of each species among forest types. All macrohabitat analyses were conducted using SAS v8 (SAS Institute Inc. 2000).

Repeated measures MANOVA and rmANOVAs were used to examine microhabitat associations of *Peromyscus* and *Neotamias* across microhabitat variables (n = 19) and between sample years. Counts were square-root transformed and all assumptions were addressed identically to those at the macro-scale. Again, Pillai's trace was used to test the null hypothesis that abundance did not differ across microhabitat characteristics or sample year.

Canonical correspondence analysis (CCA) using CANOCO v4.5 (ter Braak & Šmilauer 2002) was used to describe associations between abundance of small mammals (n = 8) pooled from 2003 and 2004 and all microhabitat variables. CCA is a constrained ordination that directly and simultaneously relates species composition to environmental variables, unlike unconstrained ordinations (e.g., Detrended Correspondence Analysis) that perform sequential analyses. CCA is an extension of multivariate multiple regression but is robust to moderate violations of normality assumptions (Palmer 1993, Lepš & Šmilauer 2003), performing well even with skewed species distributions (Palmer 1993). Small mammal counts were square-root transformed prior to ordination. Default options (e.g., biplot scaling focusing on inter-species distances) were used because they were appropriate for these analyses. Monte Carlo permutations (n = 500) were performed to test the significance of the contribution by each canonical axis to explanations of variation in small mammal abundance. Forward selection with unrestricted Monte Carlo permutations (n = 500) was used to determine the relative importance of each measured microhabitat variable to species abundance. Finally, the

overall ordination results were qualitatively confirmed by inspecting species-specific contour plots that illustrate the fitted values of species abundance (using Loess linear regression) and microhabitat variables in CCA space.

Dynamics of spotted owl prey taxa:

Dusky-footed woodrat:

Two primary study areas, Oasis and Gulch, were used to supplement species habitat relationships. To supplement species habitat relationships obtained from Oasis and Shrub, vegetation data was collected at 2 other study areas: Gulch and Black Oak. These study areas are located within the Meadow Valley quadrangle in Plumas National Forest, Plumas County, California, approximately 5 km north of Meadow Valley at 1300 m elevation. The study areas are indicative of the Sierra Nevada mixed-conifer forest type, which is characterized by one tree deciduous species, California black oak (*Quercus kelloggii,* QUKE), and 5 dominant conifer species: white fir (*Abies concolor,* ABCO), sugar pine (*Pinus lambertiana,* PILA), Ponderosa pine (*P. ponderosa,* PIPO), Douglas fir (*Pseudotsuga menziesii,* PSME), and incense cedar (*Calocedrus decurrens,* CADE). The understory is dense and dominated by deer brush (*Ceanothus integerrimus*).

Individual woodrats were captured and fitted with radio-collars. These individuals were followed throughout the year as access was available to identify activity patterns and specific patterns of habitat use. We captured 85 (31 fitted with radio-collars) individual dusky-footed woodrats of various ages and sexes from the two main study areas (Oasis and Shrub) in the Plumas NF.

Live-trapping was used to obtain biological information for and attach radio-collars to individual woodrats. In addition, live-trapping data will be used to determine house use patterns by individual woodrats. Two trap sessions (Session 1: Apr-Jun, Session 2: July-August), consisting of 4 consecutive trap nights each were conducted with additional trapping performed when necessary. During trap sessions, 4 Sherman live-traps were placed within 1 m of the base of all houses within the study area. Traps were baited with raw oats and sunflower seeds coated in peanut butter, set prior to sunset, and checked at sunrise. All woodrats were given eartags for identification, weighed, sexed, and, if necessary, were fitted with radio-collars (Model PD-2C, Holohil Systems Ltd.). Woodrats were lightly sedated with ketamine HCl (100mg/ml) to facilitate application of radio-collars and allowed to recover from anesthesia before release. Radio-collared individuals were released at the point of capture, immediately after transmitters were attached and biological data was obtained.

Nocturnal radio-telemetry was conducted to determine movement patterns and estimate individual home ranges. In addition, diurnal radio-telemetry was used to locate houses, determine house use, and verify trap data accuracy. During nocturnal surveys, radiolocations were determined using triangulation methods, and occurred during 10 nights each month from June to October 2004. Bearings to radio-collared animals were obtained by bisecting the angle of signal drop-offs. Technicians worked in synchronized pairs to achieve 3 (or more) directional bearings within as short a time interval as possible. Triangulation systems were tested regularly using dummy collars to ensure the accuracy of the triangulation method. Radiolocations were obtained 2-3 times per night, a

minimum of 3 hours apart to avoid location autocorrelation. The timing of nightly telemetry was varied to ensure heterogeneity in sampling effort.

Diurnal surveys utilized homing techniques. Diurnal locations for all radio-collared animals were determined once per day, 3 days per week from June to September 2004. Diurnal radiotelemetry locations were accurately (≤ 1 m) referenced using a Trimble GPS. Program *Locate II* will be used to calculate animal locations from bearing data obtained during triangulation. Animal locations were then be entered into an ArcView GIS database and plotted. Monthly minimum convex polygon (MCP) and adaptive kernel home ranges will be calculated for each individual using the animal movement extension of ArcView. We will compare home range size and overlap among sexes and age classes as well as temporally within each individual. We will also determine habitat use by these key prey species based on vegetation and forest maps obtained from the fire and vegetation modules.

Differences between the structure and composition of plants adjacent to woodrat houses and the surrounding habitat will be measured by using a matched-pair sampling design. A 4-m radius circular plot (0.005 ha) was placed around each house and random points. Random points were placed at a random distance (10-50 m) and directions (1-360°) from house center and a number of characteristics were measured: shrub density, tree and snag composition, stumps and logs, and rock and coarse woody debris cover. In addition, house-specific characteristics were measured including house length, width, height, shape, location (i.e. ground, tree), type (i.e. cavity, stick) and supporting structures.

Northern flying squirrel:

We trapped for northern flying squirrels using a combination of Sherman (Tallahasee, FL) and Tomahawk (Tomahawk, Tomahawk, WI) live traps placed on the ground or strapped to trees at a height of 1.5 m. Traps were baited with peanut butter or molasses coated rolled oats and checked in the morning. Polyfill fluff and a milk carton were provided for warmth during cold nights.

All captured individuals were weighed and measured (e.g., ear length, hind foot length), and sex and reproductive condition noted. For males, testes may either be enlarged and scrotal or reduced and abdominal; for females, the vagina may be perforate (thereby receptive) or imperforate (not receptive), the vulva may either be swollen or not, and the nipples may be enlarged and/or reddened (reflecting nursing offspring), or not. All animals were individually marked with numbered ear tags.

New individuals were anesthetized with isofluorane to facilitate the administration of a radio-collar. Following radio-collar attachment, individuals were allowed to recover form the anesthetic and were released at the site of capture. Individuals were monitored following release until they flew into a nest or cavity. The tree was marked as a potential nest tree and the animal was allowed to rest for 24-48 hrs before radio-telemetry began.

Individuals were radio-tracked during the day to find their nest trees. Each tree was marked and the location taken by GPS using UTM coordinates. Tree height, diameter at breast height (DBH), species, and condition (live, dead snag), and nest type (cavity or external nest) were measured for each nest tree.

Monthly radio-telemetry sessions were performed to determine individual location during each month. Individuals were located using the drop-off signal method of triangulation. Locations of all radio-collared individuals were determined at least three times per session for 5-8 sessions each month from May to October. Animal locations in UTM coordinates were calculated from triangulation data using program LOCATE and entered into an ArcView GIS database. The animal movement extension in ArcView was used to generate monthly home range estimates using the 95% minimum convex polygon for interspecific comparison with previously published flying squirrel home range sizes. Adaptive kernel home range analysis was also used to identify core usage for individuals during the entire field season.

Fitness correlates to forest management:

Twelve female golden-mantled ground squirrels were captured for use as experimental subjects in July of 2003 and fitted with radio-collars. Individuals were randomly assigned to control or supplemented diet treatments. Supplemental feeding began in September 2003 with all supplemental animals fed at the same date and time. Individuals in the control group were trapped at the same interval as the supplemental group, but were not provided extra food. We evaluated the effectiveness of food supplementation by comparing the slope of mass over time for control vs. supplemental groups.

Monthly measurements taken on female squirrels required that the radio-collars be removed. Immediately following anesthetization (using ketamine hydrochloride, 100 mg/ml) the rectal temperature was taken from each individual to monitor changes in body temperature. Total mass was measured to the nearest 0.1g using a portable electronic balance, and the head+body length recorded. Total body electrical conductivity (ToBEC) was measured using an EM-SCAN body composition analyzer. Following body composition analysis the radio-collar was reattached.

Locations of all females were determined at least three times per day for at least 5 days each month from July to September. Animal locations were determined using triangulation methods for radio-telemetry. Each sampling occasion was separated by 2 hours to ensure independence of samples. Three technicians were used to take 6 bearings to animal locations. Animal locations were calculated using program LOCATE (Nams 1990) and then entered into an ArcView GIS database. The animal movement extension in ArcView was used to generate monthly home range estimates using the minimum convex polygon (MCP) for interspecific comparisons with previously published home range sizes. Adaptive kernel home range analysis also was used to identify core usage for individuals during the entire field season. In addition to telemetry locations, known burrow locations were identified by homing to an individual's burrow during the late afternoon after they have settled into their burrows for the night. Locations of individuals in burrows were measured using a handheld GPS unit accurate to ca. 3m. Final burrow locations were noted to facilitate relocation of individuals following winter hibernation.

In the spring of 2004 we attempted to relocate and recapture all 12 females from the previous field season; however, only 7 were recaptured. The fate of the remaining 5 females is not known. The remaining 7 females were given new radio-collars and followed monthly until offspring became apparent in early July. Unfortunately, during the Fourth of

July weekend one of the remaining females was shot reducing our sample size to 6 females. The female was found dead on a rock with a bullet hole in its side.

Once offspring become available aboveground (mid July 2004) the remaining mothers were located early in the morning before they became active and traps were placed around the burrow. Traps were checked around 11:00 for the presence of the female squirrel and her offspring. Typically the female was captured along with a number of offspring within 2 hours of trap placement. A total of 9 offspring from 4 females were captured and used for the remainder of the experiment. Offspring were fitted with radio-collars and subjected to the same monthly cycle of measurements: overall mass, body condition, head+body length, and home range. Each offspring was marked as described above and tissue samples will be collected for possible maternity analyses. All subjects (i.e., offspring and mothers) were followed throughout the remainder of the 2004 field season (July-October) to determine home ranges; however all locations during the 2004 field season (offspring and mothers) were determined using homing and GPS position rather than triangulation. This allowed us to determine precise offspring locations and reduce the error associated with triangulation.

Van Vuren (1979) defined dispersal as "the process of leaving the natal home range before breeding and establishing a new home range." Following this definition, we measured dispersal using adaptive kernel home range estimators, as this produced two distinct home ranges for offspring, one encapsulating the burrow offspring were initially captured and one at the final place of residence before hibernation. No individuals will breed until after their first hibernation (Bartles and Thompson 1993) and so all location data for offspring is considered pre-reproductive. Dispersal distance was calculated as the linear distance between the point of initial capture (mother's burrow) and the final location for a particular individual (hibernation burrow). Dispersal direction was determined by setting all initial captures to the origin (0,0), adjusting the final location to reflect the new relative coordinates, and then solve for the angle of dispersal. Percent use by offspring of their new home range was calculated as the proportion of locations found within the new home range for each week following initial capture.

Taxonomy and classification of Sierra Nevada chipmunks:

We collected a sample of reference chipmunks from areas throughout the study site and brought them back to U. C. Davis for use in the phylogenetic study. Individuals collected were prepared as standard museum specimens (full skeleton plus skin) and tissues (e.g., liver, heart, muscle, kidney) collected for use in molecular analyses. All individuals were deposited in the Museum of Wildlife and Fish Biology at U. C. Davis.

We also collected small sections (< 1 cm) of ear pinna from all chipmunks trapped in this study to identify the distribution of closely related chipmunk species. Ear tissue was placed in cryovials containing 95% ethanol and stored in a refrigerator. Tissues from both reference and live chipmunks will be sent to the University of Idaho for molecular analysis to determine what molecular markers exist to identify chipmunk species. In addition, we will investigate whether hybridization is occurring between certain species, most notably *Tamias senex* and *T. quadrimaculatus*.

2004 FIELD SEASON PROGRESS AND RESULTS

The 2004 season began in February with the hiring of 8 technicians. Work began at the study site on 1 May and continued through October. Due to heavy snow, we were limited in the amount of area we could access at the beginning of the season. As a result, we began the field season by training the technicians on trapping and telemetry methods. We began trapping the grids that were established in 2003 as they became accessible. We continued pretreatment trapping of the nine experimental grids and continued a second season of trapping for the nine habitat grids. The nine experimental grids (Grids 1-9) were located in white fir dominated forests in the Snake Lake, Dean's Valley, and Waters districts. Each site was trapped on a monthly basis consisting of 5 consecutive days (4 nights) of trapping. Each night's effort comprised 100 Sherman trap-nights and 72 Tomahawk trap-nights (n = 172 trap-nights total), and each grid experienced 688 trapnights during each month of trapping. Similarly, the habitat grids were trapped on the same schedule.

Demographic profiles of small mammal populations inhabiting a variety of habitat types:

During the 2004 field season we captured and marked a total of 2,414 individuals across all species of small mammal and all sites (Table 1). A total of 123,840 trapnights were evenly distributed across all sites during two years of trapping. Predominant species in the study area include dusky-footed woodrat (*Neotoma fuscipes*), deer mice (*Peromyscus maniculatus*), long-eared and Allen's chipmunks (*Tamias quadrimaculatus* and *T. senex*), California and golden-mantled ground squirrels (*Spermophilus beecheyi* and *S. lateralis*), montane vole (*Microtus montanus*), Douglas squirrel (*Tamiasciurus douglasii*), and the northern flying squirrel (*Glaucomys sabrinus*). Incidental species captured during our trapping included shrews (*Sorex* spp.), snowshoe hare (*Lepus americanus*), long-tailed weasel (*Mustela frenata*), striped skunk (*Mephitis mephitis*), and spotted skunk (*Spilogale gracilis*).

White fir forests had the highest number of captures consisting of 1,084 unique individuals from 9 species. Red fir forests had 1,009 individuals from 8 species, and Douglas fir and ponderosa forests had 652 and 224 individuals from 9 and 6 species respectively. Species richness did not differ between white fir and Douglas fir forests and was only differentiated from red fir forests by the absence of woodrats in the red fir forest. Ponderosa pine forests, however, did not contain golden-mantled ground squirrels, Douglas squirrels, or flying squirrels.

Goodness-of-fit tests for individual encounter histories were performed by species using RELEASE and bootstrap simulation methods in program MARK. Goodness-of-fit tests were used to assess the assumption of capture homogeneity and survival. These tests indicated that significant deviations from the assumptions were found in all species. If individuals do not exhibit independence in trapability then estimated sampling variances will be underestimated, a situation called overdispersion. For example, individuals that occupy a home range centered within the trap grid will be more likely to be trapped than individuals living on the edge of the grid. This characteristic may violate the assumption of independence and will lead to overdispersion. Burnham et al. (1987)

suggested that estimation of overdispersion (c-hat) is calculated from the summation of tests 2 and 3 in the goodness-of-fit analysis. If the assumption of independence is violated, then a c-hat value of > 1.0 will be observed. Burnham et al (1987) gives a c-hat value of > 1.3 as evidence of significant overdispersion in the data. As a result, we used corrected values for c-hat to compensate for our observed overdispersion (Table 2).

Model selection identified top candidate models for each species (Table 2). A single model was chosen for both deer mice and golden mantled ground squirrels with the model for golden-mantled ground squirrel survival explained by month. Deer mouse survival was dependant on an interaction between habitat and month as well as over-winter survival and fall mean cone production (Table 2). Both species of chipmunk had survival vary by an interaction of habitat and month with over-winter survival.

Cone production varied within each forest type and between fall 2003 and fall 2004 (Figure 1). Cone production by Douglas fir did not vary greatly between the two fall cone counts and seemed to represent a constant source of seed. Production among the other tree species did differ between fall counts, however. Overall, cone production was greater in the fall of 2003 compared to fall 2004 (Figure 1). White fir cone production differed by season ($F_{2,360} = 37.49$, $P < 0.0001$) and within forest types ($F_{2,360} = 6.12$, $P = 0.002$). White fir cone production was higher in Fall 2003 (22.4 ± 2.2 cones/tree) compared to Fall 2004 (4.7 ± 1.0 cones/tree). Between forest types white fir cone production was lowest in white fir forests (9.5 ± 1.1 cones/tree), and increased in Douglas fir (26.0 ± 4.1 cones/tree) and ponderosa (43.0 ± 8.7 cones/tree) forest types. Red fir cone production also showed a seasonal effect with cone production higher in fall 2003 (71.4 ± 8.7 cones/tree) than fall 2004 (6.7 ± 6.0 cones/tree). Western white pines also produced more cones in fall 2003 (83.5 ± 11.2 cones/tree) than fall 2004 (37.1 ± 5.9 cones/tree). Sugar pines were the only species to show an interaction between season and forest type ($F_{4,335} = 3.03$, $P = 0.02$) with cone production within the Douglas fir and red fir forests being greater than those from ponderosa and white fir forests.

Ponderosa pines and Douglas firs both showed a season and forest type effect in cone production. Ponderosa pines produced cones in fall 2003 (10.2 ± 1.7 cones/tree) whereas there was virtually no cone production in fall 2004 (0.2 ± 0.1 cones/tree). Within forest types, ponderosa pines from white fir (4.8 ± 0.9 cones/tree) and ponderosa (3.8 ± 1.3 cones/tree) forest types produced similar amounts of cones, where ponderosa pines from Douglas fir forests only produced and average of 1.1 ± 0.4 cones/tree. The largest cone producer was the Douglas fir, producing 156.6 ± 15.9 cones/tree and 137.2 ± 14.5 cones/tree in fall of 2003 and 2004 respectively. Douglas fir cone production also varied by habitat ($F_{2,310} = 8.57$, $P = 0.0002$) with trees located in Douglas fir (174.5 ± 19.0 cones/tree) producing the most cones followed by those in white fir (123.6 ± 11.1 cones/tree) and ponderosa pine (73.4 ± 7.6 cones/tree) forests.

Mean monthly deer mouse densities varied both between years and between months within years (Figure 2a). Deer mouse densities were significantly lower during all of 2003 compared to 2004. A single peak was observed in deer mouse populations during 2004, suggesting a single reproductive episode. The reproductive peak occurred during June in all forest types except the Douglas fir forest which peaked in September (Figure 2a). Densities during 2003 remained below 10 individuals/ha on all sites, varying between 0.7 and 7.3 individuals/ha. However, in 2004 densities were much greater

reaching maximum densities (individuals/ha) of 86.0, 112.7, 77.4 and 65.7 in red fir, Douglas fir, white fir, and ponderosa pine forests respectively.

Although golden-mantled ground squirrels were found in both red fir and Douglas fir forests, we only captured enough individuals to provide estimates for individuals from the red fir forest. Population densities increased following hibernation from a low in May or June, peaked in September, and declined in October (Figure 3).

Two chipmunk species were found in the study sites: long-eared (*Tamias quadrimaculatus*) and Allen's (*T. senex*) chipmunks. Both species occurred in white fir, Douglas fir, and red fir forests. In 2003, long-eared chipmunks reached higher densities in red fir and Douglas fir forests than in white fir forests (Figure 4a). Populations form all three forest types peaked in September. In 2004 population levels in all three forest types remained low. Population levels in July 2004 were not assessed in white fir and Douglas fir forests because trapping did not occur during this month. Allen's chipmunks remained at lower densities compared to long-eared chipmunks, except during September 2004 when populations of Allen's chipmunks reached high densities (Figure 4b). Although Allen's chipmunks peaked during September 2004, there was considerable variation among the densities.

Deer mouse survival varied by forest type with those inhabiting white fir forests remaining at moderate levels (0.48 – 0.71) until fall 2004 when survival decreased (Figure 2b). Deer mouse survival followed a similar pattern in the remaining three forest types. Survival decreased throughout 2003 reaching a low in September 2003. The best fit model used a single survival value for deer mice in all forest types indicating that the probability of survival did not differ by forest type during winter. However, following winter survival did differ. Deer mouse survival from white fir forests remained near 0.60 whereas deer mice from Douglas fir and ponderosa forests declined. Red fir forests were not trapped until June due to snow cover, but mice from this forest type also showed an initial decrease in survival (July and August 2004) followed by an increase in fall (September and October).

Golden-mantled ground squirrel survival was only measured in red fir forests. Survival remained near or above 0.50 throughout the study (Figure 3b). Survival rates followed similar patterns throughout both years, increasing from August to September before dropping again in October. Although survival was not estimated for June 2003, June 2004 showed the greatest survival rate (0.79).

Survival among long-eared chipmunks did not differ between forest types, and remained above 0.50 for all of 2003 (Figure 5a). Winter survival did not differ between forest types and was estimated to be 0.94. Survival rates returned to their previous vales following winter. Allen's chipmunk did not show a difference in survival by habitat type during 2003, however, chipmunks from Douglas fir forests and red fir forests had decreased survival during early summer (May and June; Figure 5b). Survival remained high in red fir forests, but decreased in chipmunks from Douglas fir and white fir forests during late fall 2004. Survival estimates could not be determined for July 2004 in either chipmunk species because trapping did not occur at that time.

<u>Habitat associations of small mammal populations</u>:

A total of 464 small mammals were captured 1201 times during July-September 2003. With equivalent trapping effort, 1647 small mammals were captured 4204 times during May-August 2004 representing a 355% and 350% increase in individuals and total captures, respectively. Chipmunks (*Neotamias*) comprised 49% of individuals in 2003 while deer mice (*Peromyscus maniculatus*) increased from 2003 by nearly nine-fold and comprised 69% of individuals in 2004. It was unclear if these abundance values represented unusually low numbers for 2003 or high counts for 2004. Studies of small mammals in similar Sierra habitats are rare but may suggest that small mammal abundance is similar to that found in 2004. For comparable trapping effort in the neighboring Lassen National Forest, Waters and Zabel (1998) captured similar counts of small mammals (n = 1700). However, unlike the small mammal fauna found in the Plumas National Forest, few deer mice (n = 70) contributed to their captures. Two late and severe winter storms in 2003 may have contributed to low capture success in that year. Incidental captures included Trowbridge's shrew (*Sorex trowbridgii*), snowshoe hare (*Lepus americanus*), long-tailed weasel (*Mustela frenata*), western spotted skunk (*Spilogale gracilis*), and striped skunk (*Mephitis mephitis*).

Forest Structure

Previous logging and fire history are not well documented for these trapping grids but the general vegetative structure indicated active fire suppression and silvicultural practices. For example, mixed fir, white fir, and mixed conifer forests generally were characterized by high tree density (440 m^2/ha, 512 m^2/ha and 645 m^2/ha, respectively), fairly closed canopies (mean openness 12%, 11%, and 11%, respectively), deep duff layers (up to 15cm), and heavy fuel and litter loads. Three of the five mixed fir sites had comparably more patchy canopies and heterogeneous understories characterized by high shrub cover and richness and highest cover of all forest types by non-woody perennials (i.e. *Symphoricarpos*). Pine-cedar and red fir forests generally had more open stand structure (178 m^2/ha and 166 m^2/ha, respectively) with comparably open canopies (mean openness 40% and 47%, respectively) and high cover by rocks, exposed soils, and live shrubs. However, shrubs in pine forests were spatially clumped whereas those in red fir comprised a ground cover. One trapping grid in pine-cedar forest likely experienced a fire in 1970 yet was structurally indistinguishable from other pine-cedar trapping grids.

Macrohabitat Associations

Small mammal abundance (N), species richness (S), and diversity (H') were significantly different across forest types (rmMANOVA; Pillai's trace = 1.06, $F_{12,78}$ = 3.58, $P = 0.0003$) and between sample years (rmMANOVA; Pillai's trace = 0.79, $F_{3,24}$ = 29.68, $P < 0.00001$). Overall, forest type and sample year explained 84% of the variation in mean abundance (rmANOVA; $F_{3,24}$ = 14.86, $P < 0.0001$), 49% of variation in mean species richness (rmANOVA; $F_{3,24}$ = 2.72, $P = 0.0223$), and 31% of variation in diversity (rmANOVA; $F_{3,24} = 1.32$, $P = 0.2765$). Results of rmANOVAs revealed that mean abundance and richness differed significantly across forest types and abundance increased significantly between sample years. *A posteriori* multiple comparisons showed that red fir forests had significantly greater mean abundance of small mammals than any other forest type (Scheffé, $P < 0.05$; Figure 6a) and greater mean species richness than all types but mixed fir (Scheffé, $P < 0.05$; Figure 6b).

Abundance of *Peromyscus* and *Neotamias* differed significantly among forest types (rmMANOVA; Pillai's trace = 0.73, $F_{8,52}$ = 3.78, P = 0.0015) and between sample years (rmMANOVA; Pillai's trace=0.91, $F_{2,25}$ = 133.57, P < 0.0001). There was a strong trend towards a forest type x year interaction (rmMANOVA; Pillai's trace = 0.48, $F_{8,52}$ = 2.06, P = 0.0568) likely because of high captures of deer mice in 2004. Overall, forest type and sample year explained 93% of variation in abundance of *Peromyscus* (rmANOVA; F = 36.52, P < 0.0001) and 67% of variation in *Neotamias* (rmANOVA; F = 5.78, P = 0.0002). Results of rmANOVAs indicated that abundance of *Peromyscus* was influenced significantly by forest type, year, and forest type x year interaction and abundance of *Neotamias* was influenced significantly by forest type. *A posteriori* multiple comparisons revealed a clear preference by *Peromyscus* for red fir, white fir, and mixed fir sites over mixed conifer and pine-cedar forests (Scheffé, P < 0.05; Figure 6c). Macrohabitat affinities of *Neotamias* were similar to *Peromyscus* but more narrowly focused with preferences for red fir and white fir sites over all other types (Scheffé, P < 0.05; Figure 6d).

Kruskal-Wallis nonparametric analyses suggested that abundance for *G. sabrinus*, *Microtus, N. fuscipes, S. beecheyi,* and *S. lateralis* were significantly influenced by forest type (Figure 7). For example, *G. sabrinus* (χ^2_4 = 13.615, P = 0.0086), *Microtus* (χ^2_4 = 21.43, P = 0.0003) and *S. lateralis* (χ^2_4 = 28.04, P<0.0001) were found almost exclusively in red fir forests. In contrast, *N. fuscipes* (χ^2_4 = 11.61, P = 0.0205) and *S. beecheyi* (χ^2_4 = 16.62, P = 0.0023) were associated primarily with pine-cedar and mixed fir forests but only rarely in mixed conifer forests. *Tamiasciurus* abundance was low and not significantly different among forest types (χ^2_4 = 5.07, P = 0.28).

Microhabitat Associations

Results of rmMANOVA revealed that local abundance of *Peromyscus* and *Neotamias* differed significantly across 14 of 19 microhabitat variables. Overall, microhabitat variables and sample year explained 69% of variation in local (i.e. trap-scale) abundance of *Peromyscus* (rmANOVA; F_{2405} = 1.75, P < 0.0001) and 70% of variation in local abundance of *Neotamias* (rmANOVA; F_{2405} = 1.83, P < 0.0001).

CCA of microhabitat associations was based on 4503 individuals (samples) captured at 1424 trap stations (Figure 8). The first two canonical axes cumulatively explained a large proportion (71%) of the variation in local abundance of small mammals. The first canonical axis alone explained more variation (53%) than axes 2, 3, and 4 combined (37%) and was positively correlated with canopy openness, cover by live shrubs, and shrub species richness. Despite a significant amount of variation in small mammal local abundance explained by the first canonical axis (Monte Carlo Permutation test; F = 66.091, P = 0.002), axes two and three each also contributed significantly to explanations of community variation (Monte Carlo Permutation test; F = 22.216, P = 0.002 and F = 18.370, P = 0.002, respectively) but were comparably less correlated with microhabitat characteristics. Forward selection included the following variables (at $P \leq 0.05$) in the final model explaining overall small mammal abundance: cover by rocks, bare ground, branches, large logs, live shrubs, and percent canopy openness, shrub richness, substrate hardness, slope, and south-facing aspects.

CCA described diverse microhabitat affinities for many species (Figure 8). For example, *G. sabrinus*, *S. lateralis*, and *Microtus* exhibited strong microhabitat

preferences for open canopy, high cover by shrubs, bare ground, and rocks; these characteristics dominate the understories of red fir forests where the three species reached their highest abundance. *Neotamias* was captured across many microhabitats but affinities were best described by high shrub cover and richness, open canopies, bare ground, rocks, large logs and south-facing aspects, characteristics associated predominantly with red fir forests but also representative of mixed fir forest understories. Local captures of *N. fuscipes, S. beecheyi,* and *T. douglasii* were not restricted to narrow microhabitats; rather, these species exhibited broader affinities for similar microhabitat features. The location of *Peromyscus* in the center of CCA space likely is artifactual since this species was found at 99% of trap stations used in analyses and over half of all analyzed trap stations were located in closed canopy forests (left side of figure). Inspection of a species-specific contour plot reveals that while *Peromyscus* is associated with all measured microhabitat variables (no zero values); this species reached the highest abundance in traps characterized by open canopy and cover by live shrubs, rocks, and bare ground.

Dynamics of spotted owl prey taxa:

Dusky-footed woodrats:

In 2004, we captured and placed radio-collars on 31 individual woodrats, consisting of 18 females and 13 males. Of these, we recaptured 6 individuals from the 2003 field season. Work continued in the Oasis study area (where the 6 individuals were recaptured) and a second study site, Shrub, was established to replicate woodrat work. Both Shrub and Oasis were located in ponderosa pine forests. We captured 36 and 49 individuals in the Oasis (10 adult males, 11 juvenile males, 7 adult females, and 9 juvenile females) and Shrub (5 adult males, 15 juvenile males, 15 adult females, and 14 juvenile females) study sites. Telemetry began in late June and continued until the beginning of October.

We located 109 woodrat houses at Oasis and 104 at Shrub. Most woodrat houses were located on the ground (Oasis, 77%; Shrub 76%), but many were also located in tree and snag cavities or on the limbs of live trees (Oasis, 23%, Shrub, 24%). Woodrat houses were found in a variety of structures ranging from cavities in stumps and logs to stick houses constructed to heights of 2 m. Thirty-six percent and 54% of houses were utilized diurnally by radio-collared woodrats at Oasis and Shrub, respectively.

We will continue to analyze the location data obtained from 2004 telemetry and expect to generate a viable home range for most, if not all, woodrats studied during the 2004 field season. In addition, we will analyze the vegetation and woodrat house data to begin understanding the relationship between woodrat house use and availability and habitat preference for woodrats.

Northern flying squirrels:

We captured 6 northern flying squirrels consisting of 3 males and 3 females (Table 3). All individuals but two, M2 and F2, were of adult size and coloration. We attempted to place radio-collars on all individuals, however only 3 individuals (M1, M3, and F3) survived long enough to produce enough locations for use in calculating home ranges. Three other radiocollared flying squirrels were either predated within a week of

release (M2), died from exposure to a night-time thunderstorm (F2), or died during handling (F1). Radio-tracking of M1 stopped after 7 July 2004 because the collar never moved from the top of a tree indicating the squirrel had lost its collar or had been predated. Squirrels M3 and F3 were tracked until October snowfall made it impossible to get to the study site.

Although telemetry could not be performed on all individuals, nest trees were located for 5 individuals (Table 4). Only 2 external nests were used by flying squirrels in this study area, with the remainder of nests consisting of cavities drilled by woodpeckers. Both external nests were found in live trees: one in a red fir (*Abies magnifica*) and one in a sugar pine (*Pinus lambertiana*). Of the cavity nests, one was in a live western white pine (*Pinus monticola*), four in solid, well formed snags, and one in a decayed snag. All snags consisted of the trunk of a dead red fir ranging from 6.4-19.3 m in height and a diameter at breast height (DBH) of 44.0-57.3 cm. The decayed snag was a small red fir 4.9 m in height with a DBH of 22.3 cm and was in an advanced stage of decay.

Three viable home ranges were generated from the data obtained from flying squirrels M1, M3 and F3 (Figure 9). The home ranges from these three individuals were located in the same general area (Taylor Rock). Minimum convex polygon home ranges were calculated from 95% of the locations and generated home ranges from 26.1 to 83.4 ha (Table 3). However, MCP home ranges can be inflated due to outlying points. As a result, 95% kernel home ranges were calculated to better reflect the actual usage of the home range (Figure 9). Kernel home ranges were calculated to be 23.0, 39.8, and 63.4 ha for flying squirrels M1, M3, and F3 respectively (Table 3). The home ranges of M3 and F3 showed considerable overlap. The only female captured had the largest home range, whereas the two males had similarly sized home ranges that were approximately half the size of the female.

Fitness correlates to forest management:

Maternal body mass decreased following emergence from hibernation until August when lactation was completed (Figure 10). Following August, both experimental groups increased in mass until females entered hibernation in early October. Supplemental feeding began on September 1, 2003, and was followed by a divergence in control and supplemental mean mass (Figure 10), although the proportion of fat found in females did not differ between treatment groups ($F_{4,27} = 0.76$, $P = 0.56$). The slopes of mass gain for August - October showed a strong trend towards distinct trajectories (control, $\beta = 14.56$; supplemental $\beta = 42.49$; $F_{1,18} = 3.25$, $P = 0.08$). No significant difference in total mass was observed between the two groups at the start of the experiment. Although supplemental females gained mass at a greater rate than control females, the rate at which both groups increased the proportion of fat did not differ (control $\beta = 4.8$; supplemental $\beta = 4.0$; $F_{1,18} = 1.83$, $P = 0.19$). Supplemental females exhibited less variation in the rate of mass gain ($r^2 = 0.73$) compared to control females ($r^2 = 0.11$). A similar, but less pronounced, trend was observed in the rate of body fat accumulation ($r^2 = 0.36$ control; $r^2 = 0.50$ supplemental).

As expected, maternal home range size for the two treatment groups did not differ during any of the months studied (Figure 11). Although supplemental feeding could induce a shift to a smaller home range in fed females, the timing of feeding coincided with the time of year when female home ranges already are at their smallest. However, we did detect a temporal change in maternal home ranges ($F_{4,31} = 3.89$, $P = 0.005$). In 2004,

female home range size increased from emergence, peaking in July and then declined until females entered hibernation. Home range size was smallest during June and September, ranging from 0.64-0.86 ha, when females were emerging and entering hibernation respectively and were largest (1.49 – 2.22 ha) during July when energetic demands from lactation were greatest (Figure 11).

Offspring emerged from their natal burrows in mid- to late- July. Nine offspring (4 males, 5 females) from four mothers were radio-collared and released. Of these, one control female, likely was predated while the remainder survived the summer and entered hibernation. The predated female was found a considerable distance away with the collar showing signs of distress (i.e. chew marks).

Offspring from supplemental mothers grew at a significantly greater rate than those from control mothers (linear regression, slope 34.9 vs. 7.26 respectively; $F_{1,12} = 4.14$, $P = 0.06$; Figure 10). In addition, the rate of fat development also was greater for offspring from supplemental mothers (linear regression, slope 9.66 vs. 2.24 respectively; $F_{1,11} = 4.62$, $P = 0.05$; Figure 10). Mean percent fat that supplemental and control offspring reached before hibernation was 19.1% and 9.3% respectively.

Dispersing juveniles quickly established new home ranges at various distances from their natal home range. Dispersal distance was greater for supplemented males than control males ($F_{1,5} = 9.13$, $P = 0.03$; Figure 12). Although control females tended to disperse farther than supplemental females, this was not significantly different. Most dispersing offspring moved to the northwest. One supplemental male dispersed to the northeast while two females moved west. No clear pattern was observed with regard to treatment or sex differences in dispersal direction.

Offspring dispersal tended to follow one of two patterns. Some offspring conducted a few short forays into the new area before moving completely to the new home range, whereas others remained in their natal home range while making numerous forays to their new home range before finally moving; these patterns were not clearly related to gender or experimental treatment.

First-year home ranges consisted of two unique non-overlapping areas: a natal home range and a dispersed home range. The natal home range was centered around the natal burrow, whereas the dispersed home range was centered near the area where they entered hibernation. Although sample sizes were too small to allow comparisons between sex and treatment groups for both natal and dispersed home range size there was a trend for dispersed home ranges to be larger than natal home ranges for supplemental males and smaller for control males.

The proportion of usage between natal and dispersed home ranges was similar among both sexes and treatments so data were combined (Figure 13). Individuals remained close to their natal home range during the first 3 weeks following initial capture, and increased the amount of time spent in their dispersed home range during weeks 3 - 7. By week 8 (20 September to 4 October), all offspring had dispersed to their new home range and all individuals had entered hibernation by 11 October 2004.

<u>Taxonomy and classification of Sierra Nevada chipmunks</u>:

We have collected 241 (2003 field season) and 353 (2004 field season) tissue samples from live, free-living chipmunks in the study area, and have collected and

prepared 5 reference chipmunks. All tissue samples have been labeled and sent to the University of Idaho for analysis.

COLLABORATION WITH OTHER MODULES

We have initiated collaborative efforts with the vegetation module as well as the fire and fuels module, and will establish collaborative efforts with the spotted owl module over the next year. We have completed rigorous vegetation sampling on all trap grids for use with small mammal habitat associations. Vegetation data were collected in conjunction with the vegetation and fire and fuels modules. The vegetation module has also established a number of weather stations within the mammal trap grids to coordinate specific climate data with our grids. In addition, we will benefit from the remote sensing analyses of the fire and fuels team. Finally, we will initiate a study of California spotted owl diet by working with the spotted owl crew to collect and analyze pellets collected from spotted owl nests throughout the year. Results of our woodrat study will directly benefit the spotted owl module in their development of prey models within the Sierra Nevada. The results of the small mammal study will be available for any of the other modules to use, and will be of particular benefit to the spotted owl team.

CONCLUISONS

The 2004 calendar year marked the second full year of data collection. We continued to trap all 18 grids that were trapped in 2003. We have now completed two years of pretreatment data on the nine experimental grids. We have also added a second year of trapping on the nine habitat grids. We anticipate that the thinning treatments will occur sometime in 2005 and allow us to trap for 2-5 years (2006-2010) of post treatment seasons. We have used the two years of habitat data to identify patterns in the demography of small mammals inhabiting the four habitat types we studied, and have generated a paper that will be published in a peer-review journal on this aspect of the project.

With the budget forecast for 2006, we plan to continue trapping on the nine experimental grids to obtain a third year of pretreatment data, or if the thinning treatments occur then we will begin post treatment data collection. Thinning on the treatment grids will begin as early as spring 2005, but is likely to not be done until fall 2005 or spring 2006. We will evaluate the need to keep the nine habitat grids over the winter of 2003-2004 and will establish new grids as deemed necessary. We will also reevaluate the need to continue trapping the nine habitat grids and may drop them from our study in order to allocate more resources to finding flying squirrels.

In an effort to increase our flying squirrel sample size we will change our workforce to include 6 technicians that will continue to monitor the normal set of trapping grids and perform woodrat telemetry, however for the 2005 field season we will hire 2 technicians, preferably with flying squirrel experience, to trap exclusively for flying squirrels and perform the needed telemetry on these animals. We will continue to trap and follow flying squirrels in various habitats throughout the Plumas National Forest.

We will return to the woodrat site and capture new and recapture woodrats from last field season to continue to monitor their activities and habitat use through a second year. We will also continue to study golden-mantled ground squirrel dispersal and home range establishment. We have enough tissue samples from chipmunks and will not continue collecting these from wild chipmunks. Additional studies may be added as opportunities present themselves and may include a descriptive study of the chipmunk species in the study area and the rate of fat development in chipmunks from different forest types.

Forest managers will benefit from these data in being able to more accurately predict the responses of small mammals to forest treatments, and to relate these to the population dynamics of important predator species such as northern goshawk, California spotted owl, and American marten. We have begun to publish the data obtained and expect to continue publishing through the next year. Articles have been submitted for publication to the following journals: Ecology Letters and Journal of Mammalogy (see publishing section below) and we expect to submit additional articles to the Journal of Mammalogy. We expect publication of data to continue into the 2005 field season and to include articles in peer-reviewed journals on the following subjects:

1. Habitat relationships of small mammals in the northern Sierra Nevada.
2. Northern flying squirrel home range size and structure.
3. Characteristics of woodrat house use.
4. Woodrat home range size and structure.
5. Genetic structure and hybridization of *Tamias* species in the Sierra/Cascade interface.

PUBLICATIONS

Wilson, J. A., D. A. Kelt, D, H, Van Vuren, and M. Johnson. Submitted. Effects of maternal body condition on offspring dispersal in Golden-Mantled Ground Squirrels (*Spermophilus lateralis*). Ecology Letters.

Wilson, J. A., D. A. Kelt, D, H, Van Vuren, and M. Johnson. Submitted. Population dynamics of small mammals inhabiting four forest types in the northern Sierra Nevada. Journal of Mammalogy.

Copetto, S. A. 2005. Habitat associations of small mammals at two spatial scales in the northern Sierra Nevada, California. M.S. Thesis, University of California, Davis.

PRESENTATIONS

Data from the 2003 – 2004 field seasons will be used in the development of 2-3 presentations to the 2005 annual meeting of the American Society of Mammmalogists in Springfield, Missouri. We anticipate giving presentations on 1. Population dynamics of small mammals in the Plumas NF, 2. Habitat associations of small mammals in the Plumas NF, 3. Woodrat home range structure and nest use, and 4. Golden-mantled ground squirrel body composition and offspring fitness. In addition, the golden-mantled

ground squirrel presentation may also be given at the Ninth International Mammal Conference in Sapporo, Japan.

PERSONNEL

Fieldwork was coordinated by James A. Wilson, postdoctoral fellow at the University of California, Davis. Principal investigators for the small mammal module are Doug Kelt and Dirk VanVuren, Dept. of Wildlife, Fish, & Conservation Biology, University of California, Davis, and Mike Johnson, John Muir Institute of the Environment, University of California, Davis. Fieldwork in 2004 was conducted by James A. Wilson, Stephanie Coppeto, Robin Jenkins, Jolene Csakany, Geoffrey Palmer, Rebecca LeChalk, Regina Wassen, Sean Connelly, Devon DeJesus, Anna Derrick, and Jennifer Gold.

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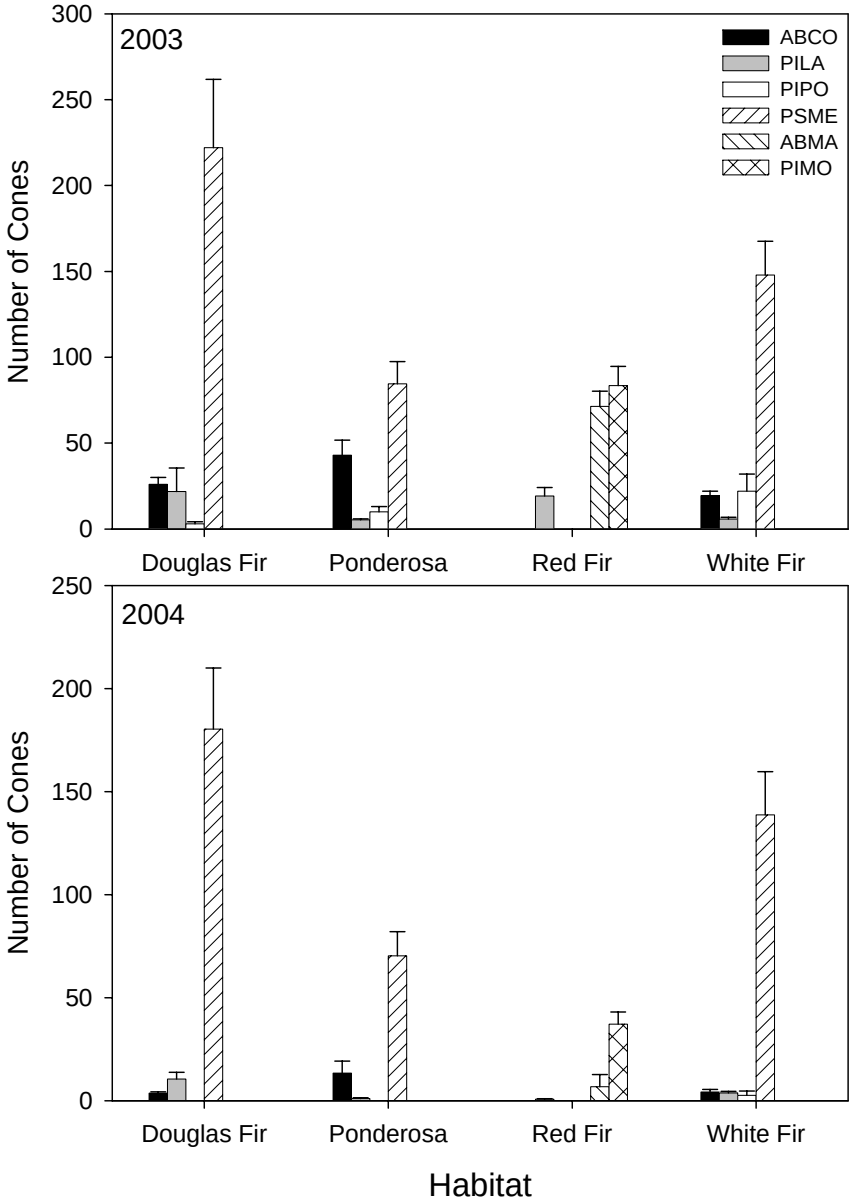


Figure 1. Mean cone production by species for fall 2003 and 2004. Tree species measured are white fir (*Abies concolor*; ABCO), sugar pine (*Pinus lambertiana*; PILA), ponderosa pine (*P. ponderosa*; PIPO), Douglas fir (*Pseudotsuga menziesii*; PSME). Red fir (*A. magnifica*; ABMA), and western white pine (*P. monticola*; PIMO).

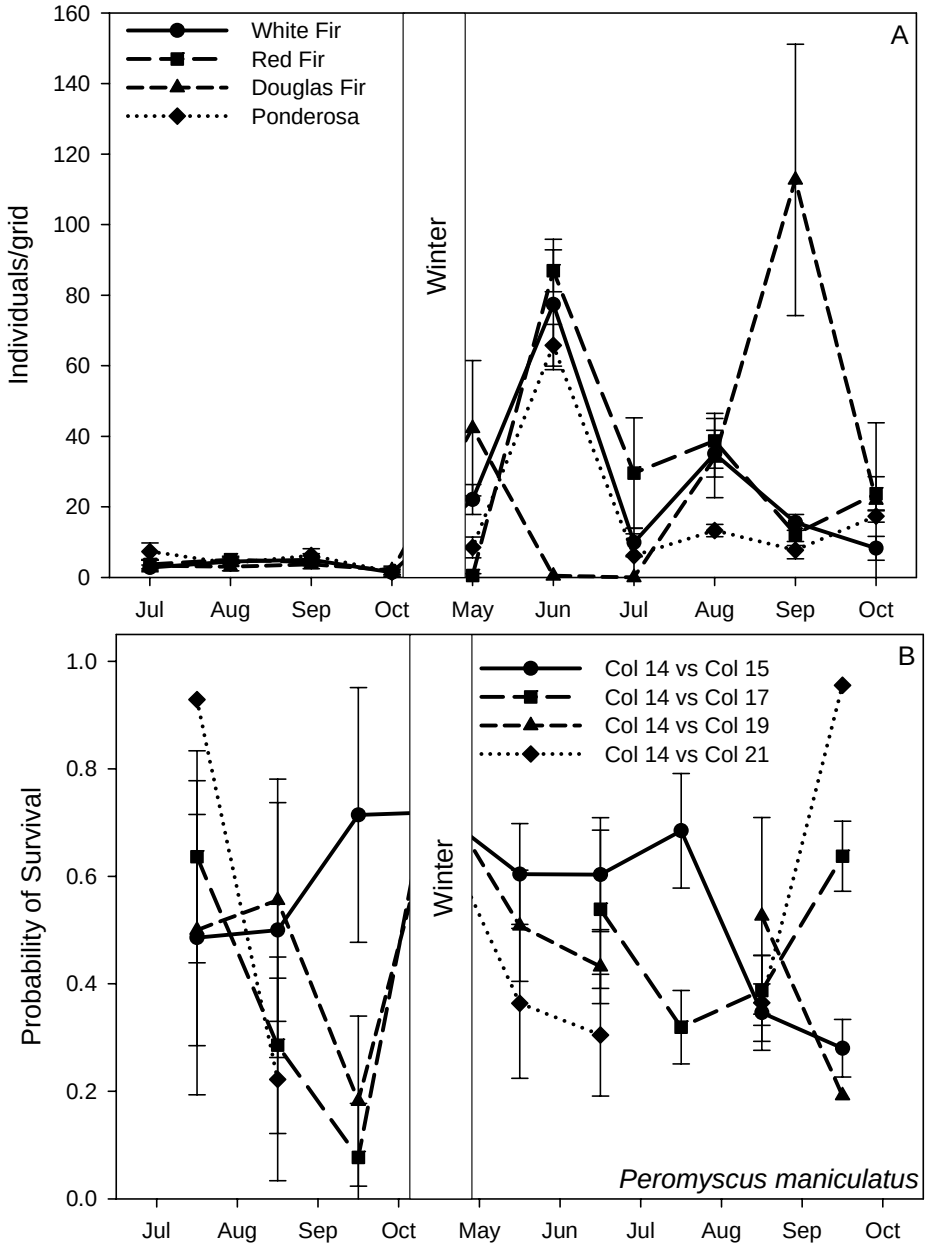


Figure 2. Mean monthly density (A) and survival (B) of deer mouse (*Peromyscus maniculatus*) populations inhabiting four forest types in the northern Sierra Nevada: white fir, Douglas fir, red fir, and Ponderosa pine. Population estimates were obtained using live recapture data and program MARK. Populations were monitored from June 2003 to October 2004.

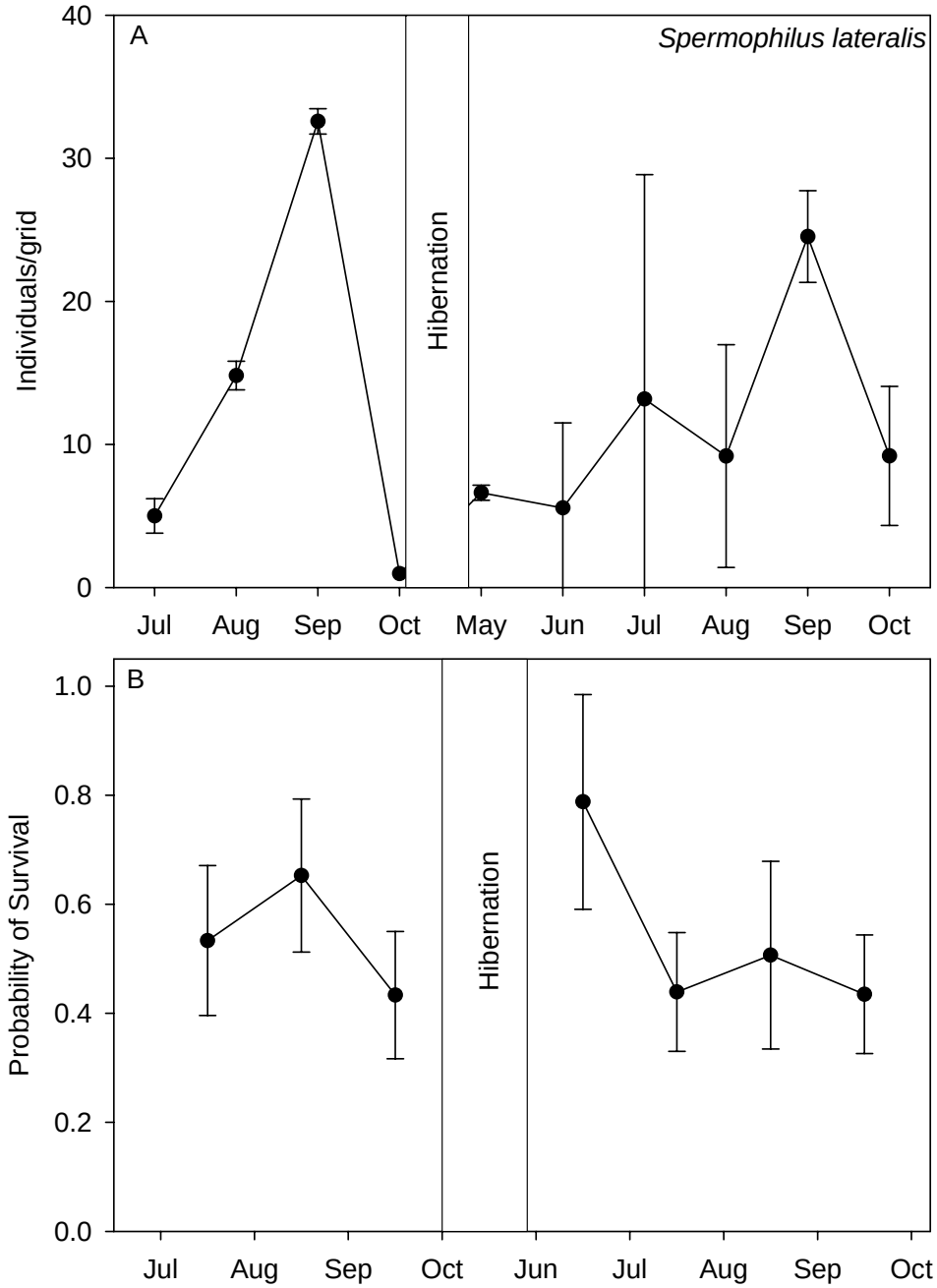


Figure 3. Mean monthly density (A) and survival (B) of golden-mantled ground squirrel (*Spermophilus lateralis*) populations inhabiting red fir forests in the northern Sierra Nevada. Population estimates were obtained using live recapture data and program MARK. Populations were monitored from June 2003 to October 2004.

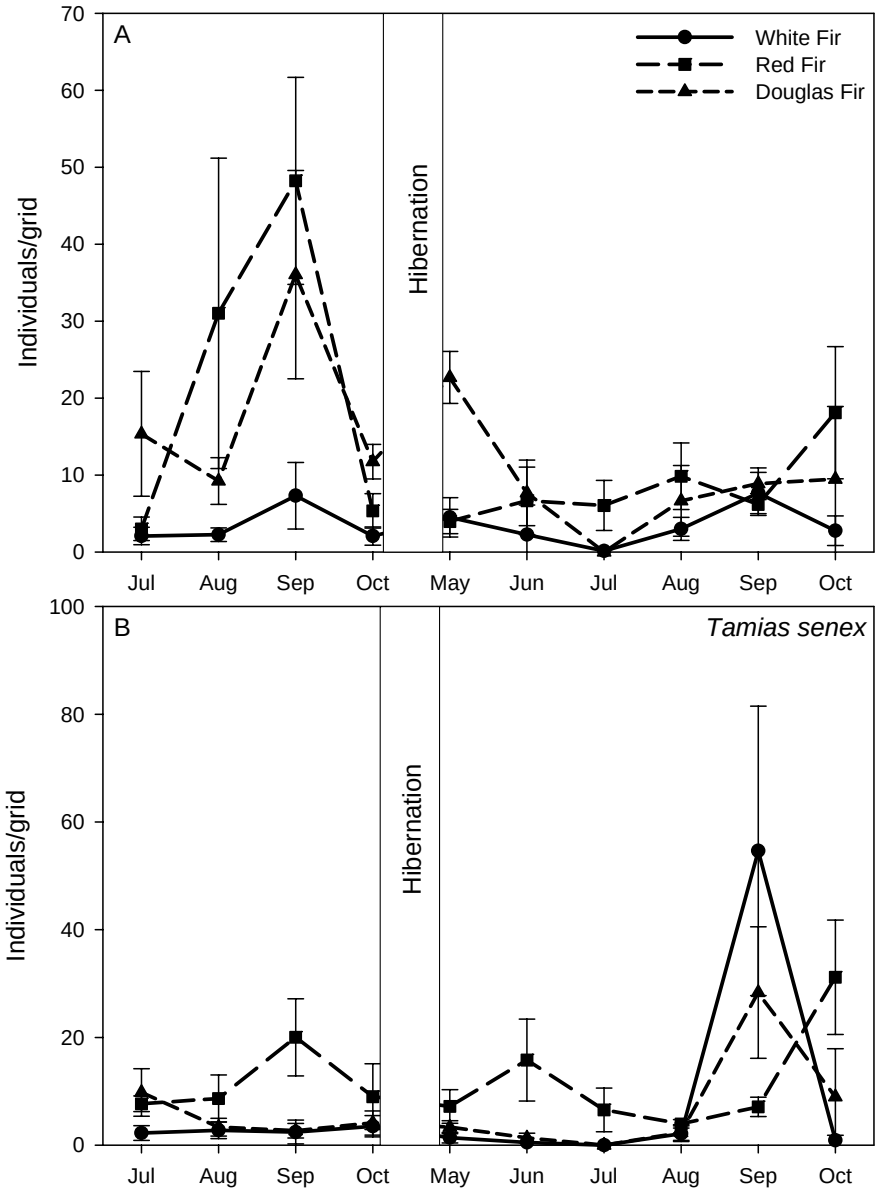


Figure 4. Mean monthly density of (A) long-eared chipmunk (*Neotamias quadrimaculatus*) and (B) Allen's chipmunk (*N. senex*) populations inhabiting three forest types in the northern Sierra Nevada: white fir, Douglas fir, and red fir. Population estimates were obtained using live recapture data and program MARK. Populations were monitored from June 2003 to October 2004.

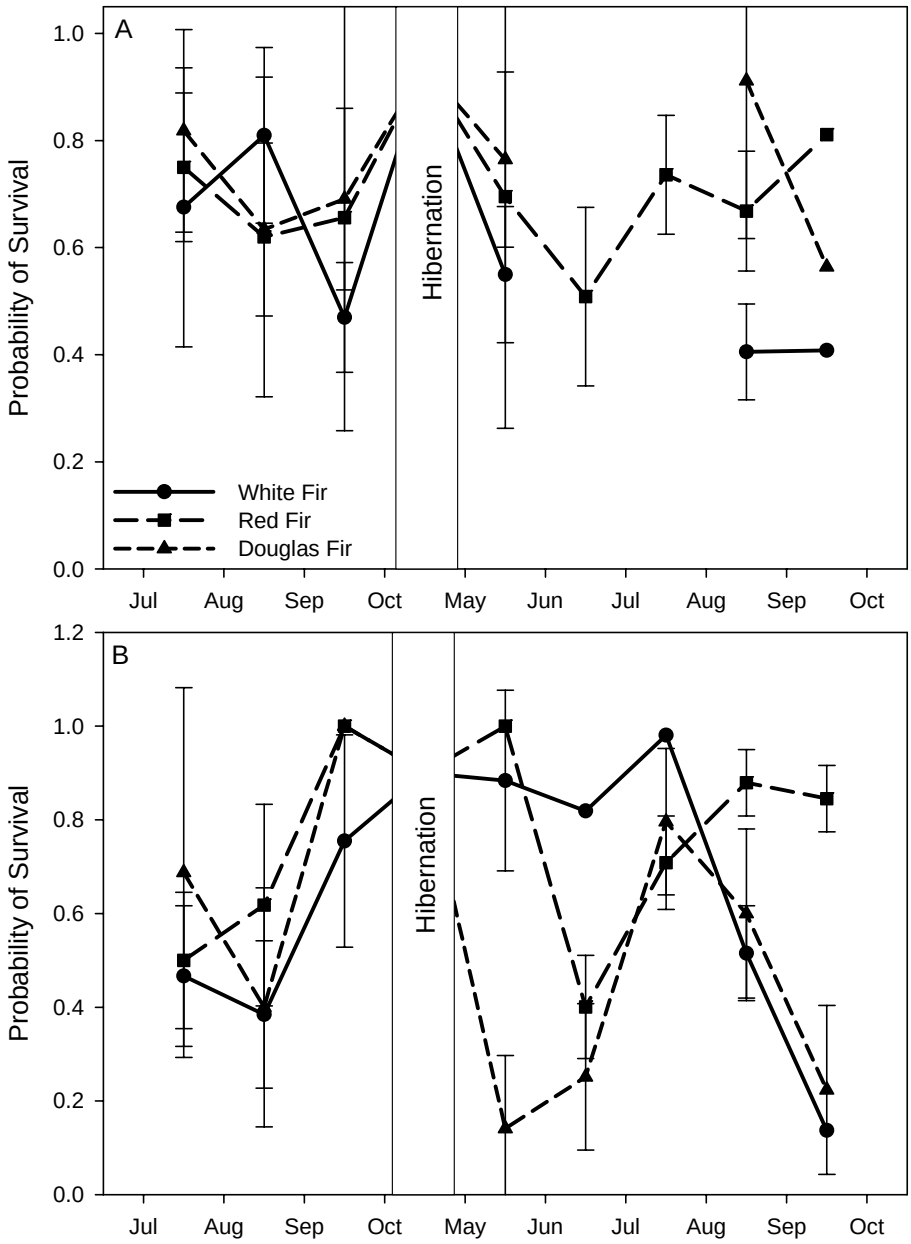


Figure 5. Mean monthly survival of (A) long-eared chipmunk (*Neotamias quadrimaculatus*) and (B) Allen's chipmunk (*N. senex*) populations inhabiting three forest types in the northern Sierra Nevada: white fir, Douglas fir, and red fir. Population estimates were obtained using live recapture data and program MARK. Populations were monitored from June 2003 to October 2004.

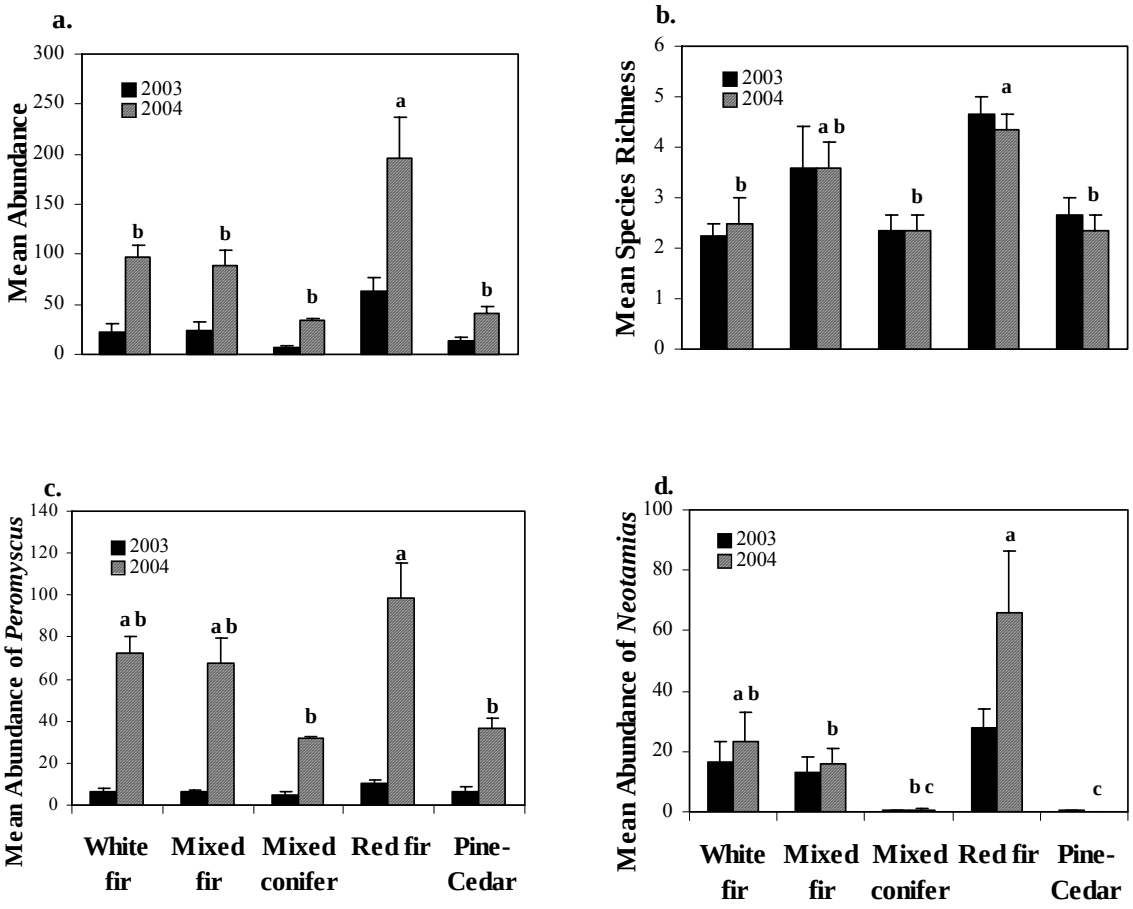


Figure 6. Differences in (A) mean abundance of all small mammals (N), (B) species richness (S), (C) abundance of *Peromyscus maniculatus* and (D) abundance of *Neotamias* among forest types in 2003 and 2004. Columns with the same letter are not significantly different (Scheffé, $P < 0.05$).

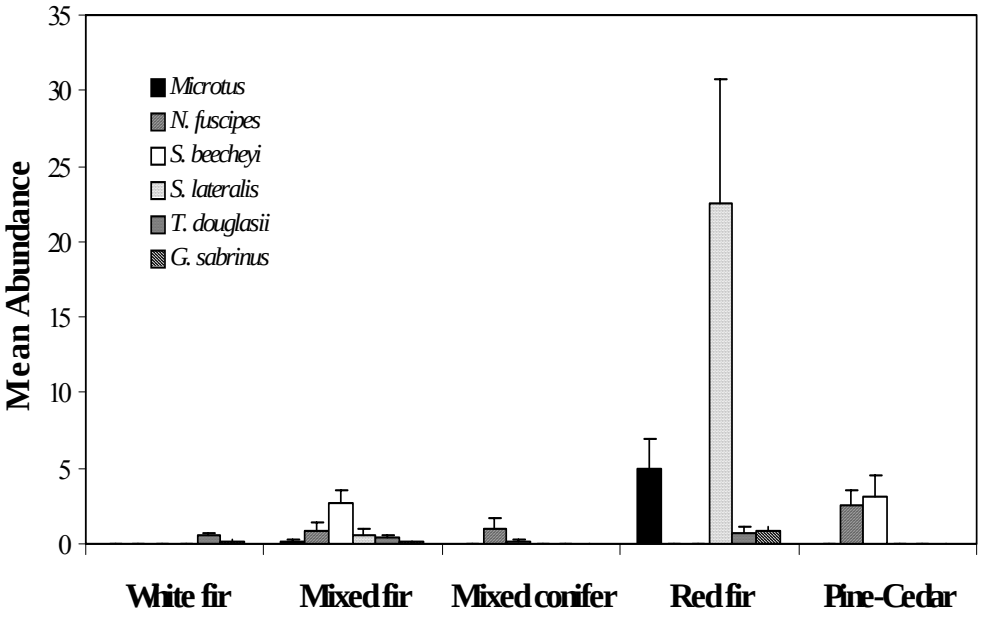
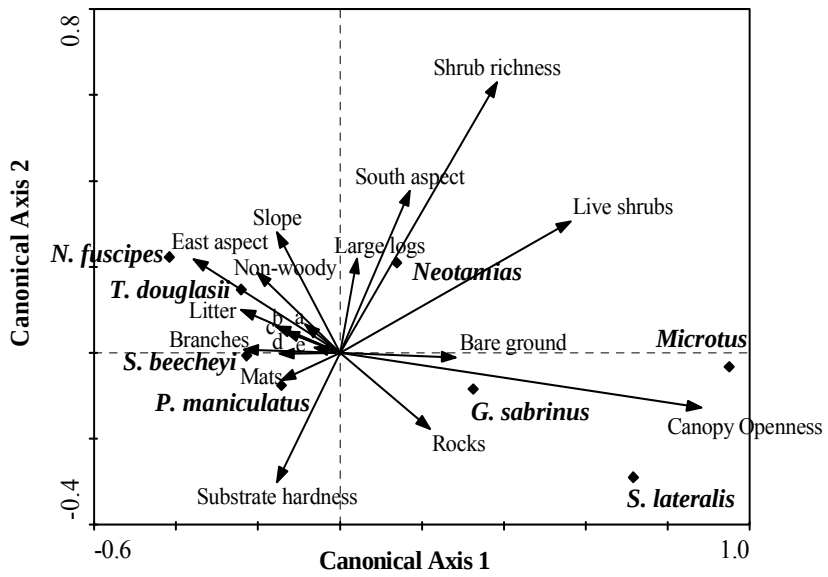


Figure 7. Mean abundance (for 2003 and 2004) of voles (*Microtus*), dusky-footed woodrats (*Neotoma fuscipes*), California ground squirrels (*Spermophilus beecheyi*), golden-mantled ground squirrels (*S. lateralis*), Douglas squirrels (*Tamiasciuris douglasii*), and northern flying squirrels (*Glaucomys sabrinus*) in five forest types (white fir, mixed fir, mixed conifer, red fir, pine-cedar).



a. Dead shrubs; b. Forbs and grasses; c. Saplings; d. Sapling richness; e. Small logs

Figure 8. Canonical correspondence analysis biplot of small mammal trap-scale abundances and microhabitat variables. Length of vector represents strength of correlation with canonical axes.

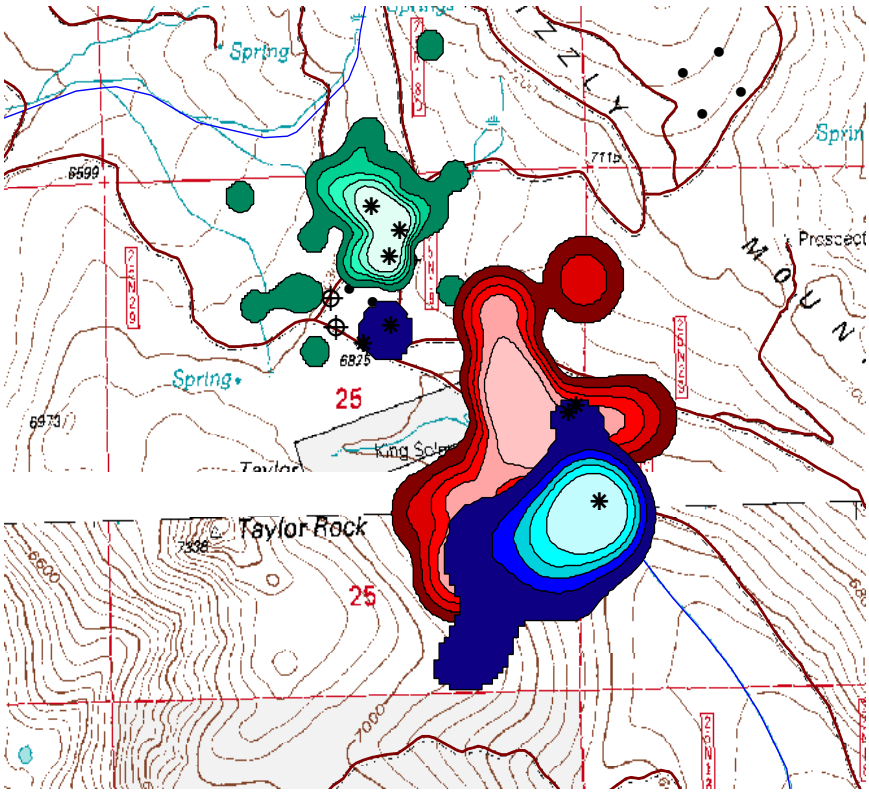


Figure 9. Home range of three (2 males, 1 female) individual northern flying squirrels (*Glaucomys sabrinus*) in red fir forests. Home ranges represent the results of adaptive kernel analyses and show frequency of use with lighter shades representing areas of higher use. Nest trees are shown by asterisks.

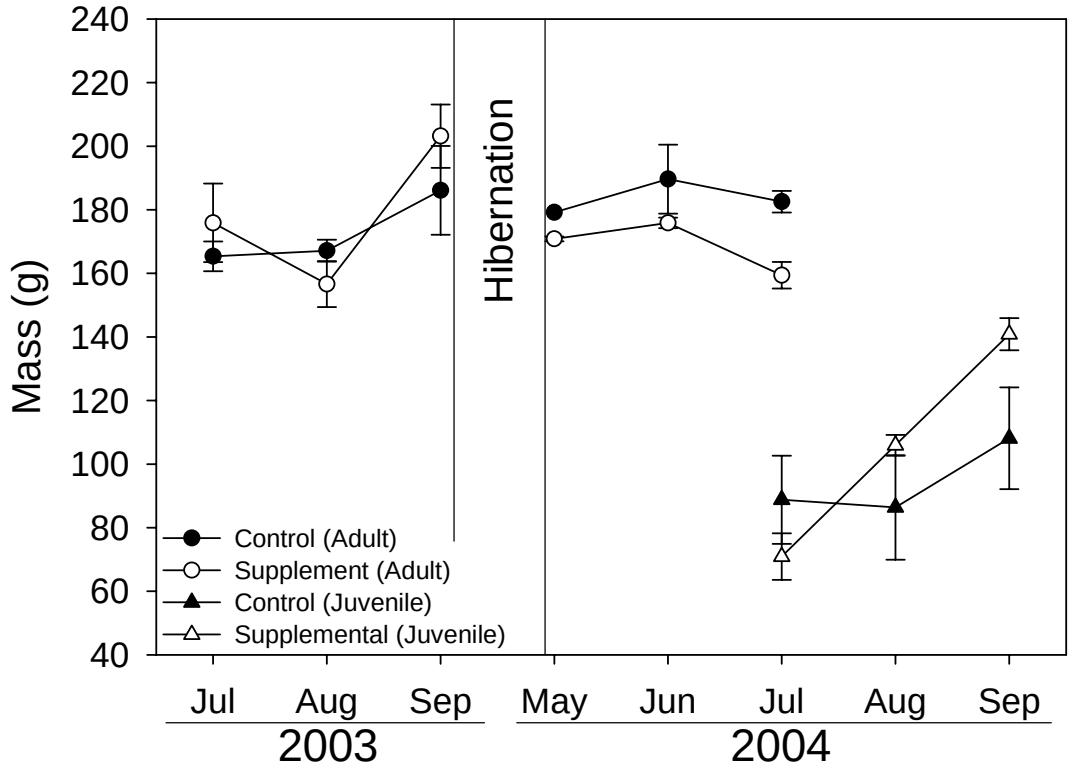


Figure 10. Mass of female (mother) golden-mantled ground squirrels and their offspring through the 2003 – 2004 field seasons. All squirrels enter hibernation during early October and Emerge following snowmelt in mid May.

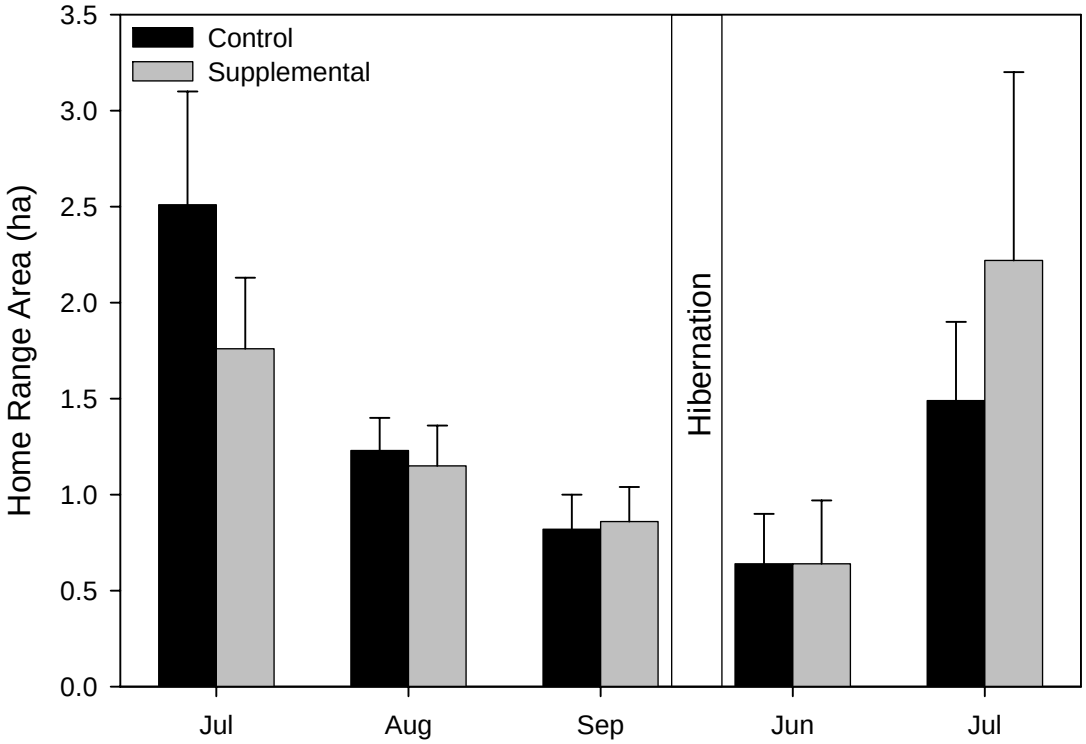


Figure 11. Maternal home range size (ha) measured using minimum convex polygon methods in ArcView. Error bars represent standard errors.

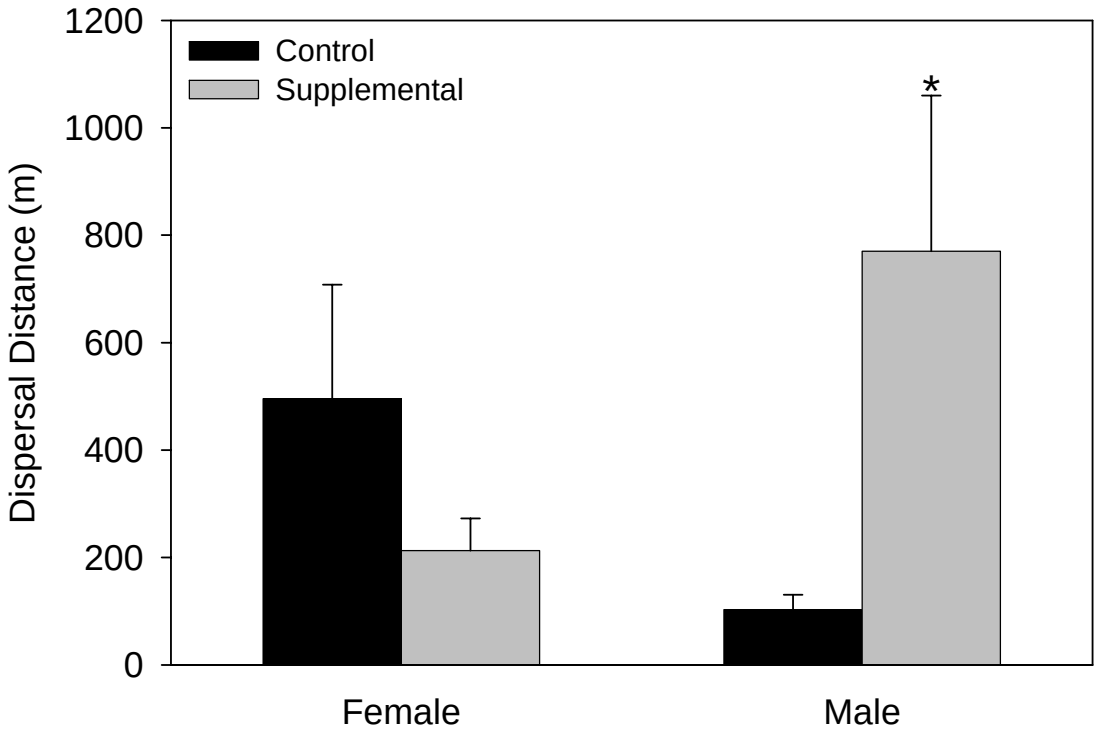


Figure 12. Dispersal distance (m), measured as the distance between location of first capture and location of hibernation, of male and female offspring from each treatment group. Treatments were applied to mothers only.

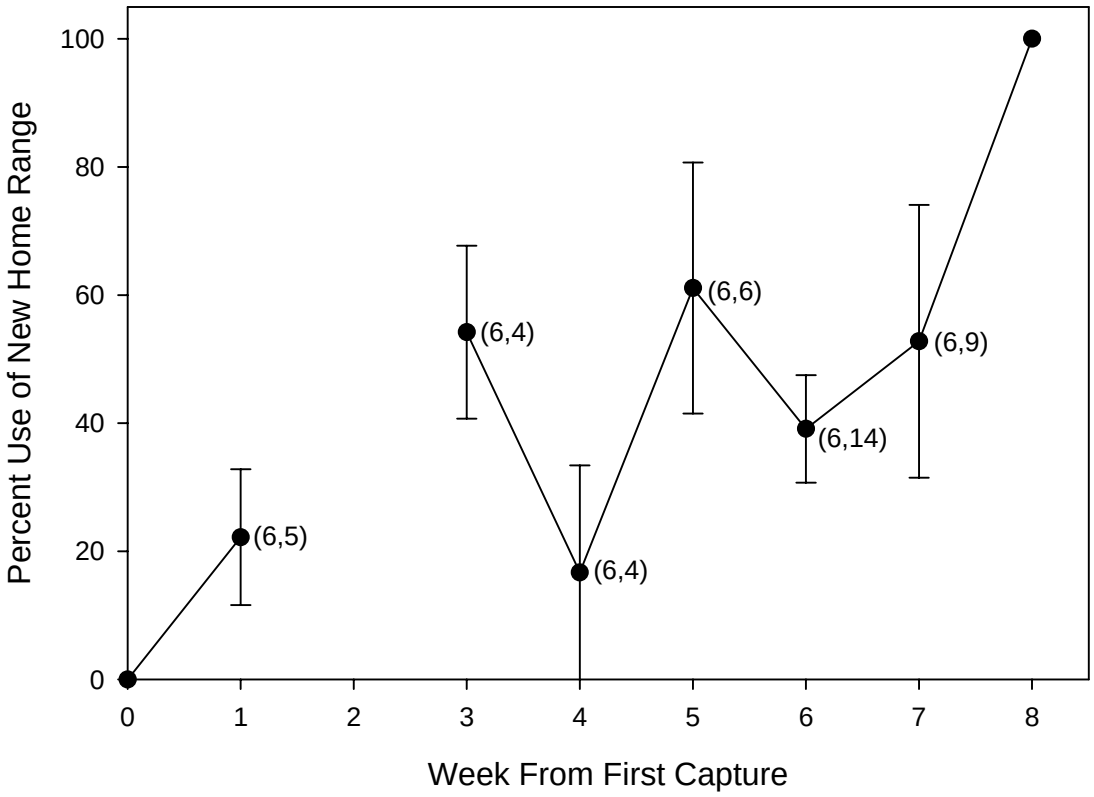


Figure 13. Proportion of use between the natal home range and the dispersed home range by offspring during the weeks following initial capture. Locations were not taken during week two. All offspring were captured between 26 July and 8 August 2004 and the initial capture date was counted as time zero. Numbers next to symbols represent number of (individuals, days) used to calculate percent use