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 will establish nine semi-permanent live-trapping grids for use as experimental plots. Three sets of three experimental grids will be established throughout the treatment area with each set of three grids established in a cluster. The clustered grids

will consist of a 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 will be 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 will be investigated using multivariate techniques to identify key habitat characteristics used by individual species of small mammals. Nine additional grids will be established in various representative habitats throughout the study site. Habitat grids will be established in triplicate for each habitat. Habitat grids do not necessarily need to be located near other grids in the same habitat type. We will measure 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 will perform 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.
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.
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 – 2003 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. All Sherman traps were closed during the day to prevent deaths from heat exposure. All Tomahawk traps were checked periodically throughout the day (ca. every 3 hr) to capture diurnal species, but were also be closed from 11:00 – 15:00 to prevent deaths to animals. 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* or another appropriate computer program. Monthly survival and population densities will be modeled for each species on each site. These parameters can then 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 the grid was stratified into macro- and microhabitat characteristics. Macrohabitat variables were measured at alternate trap stations on each grid, whereas microhabitat variables were measured at all trap stations on each grid. 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 variables were measured in 2-m diameter circles centered on each trap station. Within each circle we recorded percent cover by bare ground, rock, litter, forbs, shrubs, mats (prostrate plant species), small trees (< 2m height), and downed woody debris (branches, small logs, and large logs).

In addition to macro- and microhabitat characteristics, numerous physical characteristics of the trap grids were measured. We recorded slope, aspect, and percent canopy openness at each of the 120 major trap stations (e.g., Tomahawk stations) on each gird. Canopy openness was recorded by taking a photograph using a hemispherical lens; photographs were taken at breast height and later analyzed using the computer program, *Gap Light Analyzer 2.0*. Finally, soil hardness was measured once in four equal quadrants at each trap point.

All habitat variables will be checked for colinearity using a principal components analysis at the sampling point level. Variables exhibiting colinearity will be eliminated from further analyses. All remaining variables will be tested for normality of variances and used in a multiple regression to determine which habitat variables significantly explain small mammal distribution. Significant habitat variables will be used to generate grid and habitat level values for use in developing habitat relationship models for all small mammal species. Habitat models will be developed for habitat use vs. availability and to identify patterns of distribution based on habitat characteristics associated with specific forest types. Finally, the effects of edge and other habitat characteristics will be investigated with respect to the probability of capture for each species.

Dynamics of spotted owl prey taxa:

To supplement species habitat relationships, individual woodrats were captured and fitted with radio-collars. These individuals were followed throughout the year as access is available to identify activity patterns and specific patterns of habitat use. We captured and collared 20 individual dusky-footed woodrats of various ages and sexes to follow throughout the study, and located nests and houses to determine the habitat type important for key prey habitation. Activity patterns and habitat use were determined using radio-telemetry and triangulation methods, with telemetry performed on a monthly basis throughout the season with a minimum of 5 days of telemetry per animal. A minimum of 3 independent locations was recorded for each animal during a single day of telemetry.

Program *Locate II* will used to calculate animal locations from bearing data obtained during triangulation. Animal locations will then be entered into an ArcView GIS database and plotted. Monthly minimum convex polygon 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.

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 a radio-collar. 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 three times per day for 5 days each month from July to September. Animal locations were determined using triangulation methods for radio-telemetry. Animal locations were calculated 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 minimum convex polygon for interspecific comparisons with previously published home range sizes. Adaptive kernel home range analyses will also be used to identify core usage for individuals during the entire field season.

Taxonomy and classification of Sierra Nevada chipmunks:

We collected a sample of reference chipmunks from areas throughout the study site and braught 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*.

2003 FIELD SEASON PROGRESS AND RESULTS

The 2003 season began in February with the hiring of 6 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, new trapping grids were established from May through June, and regular trapping began in July. For logistic and experimental design reasons all but three (Grids 10, 11, and 16) of trap grids from the 2002 season were abandoned. The addition of a new experiment requiring nine semi-permanent trap grids and the need to sample a number of representative habitat types required us to establish new trap grids for the remaining 15 grids (Table 1). Nine experimental grids (Grids 1-9) were established 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

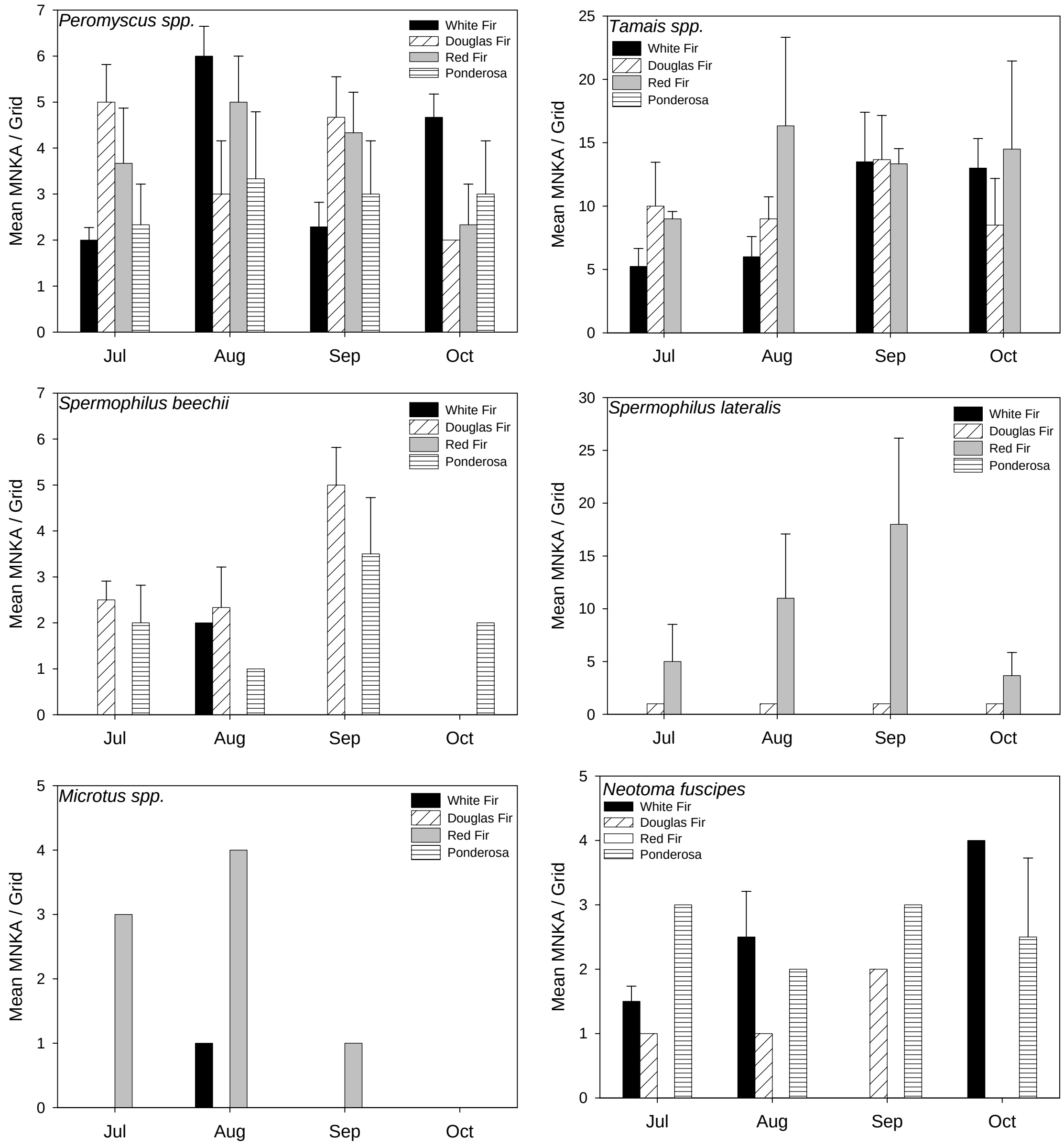

Figure 1. Mean minimum number of individuals known to be alive (MNKA) sampled in each of four forest types. Error bars represent standard error.

trap-nights total), and each grid experienced 688 trapnights during each month of trapping.

<u>Demographic profiles of small mammal populations inhabiting a variety of habitat types</u>:

During the 2003 field season we captured and marked a total of 555 individuals across all species of small mammal and all sites (Table 1). Predominant species in the study area include dusky-footed woodrat (*Neotoma fuscipes*), brush and deer mice (*Peromyscus boylii* and *P. maniculatus*), chipmunks (*Tamias* spp.), 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*).

The distribution of small mammals across the major habitat types is shown in Figure 1. Woodrats were found in significantly greater numbers ($F_{3,70} = 4.41$, $P = 0.007$) in ponderosa pine forests (1.13 ± 0.38 individuals/grid) compared to Douglas fir (0.27 ± 0.15 individuals/grid), and were completely missing from red and white fir forests. Similarly, voles differed across habitat types ($F_{3,70} = 5.52$, $P = 0.002$) with voles only found in red fir (0.6 ± 0.3 individuals/grid) and white fir (0.02 ± 0.02 individuals/grid) forests. Deer mice (*Peromyscus* spp.) were found in all four forest types; however their abundance differed between each forest type. *Peromyscus* abundance was 2.47 ± 0.59, 2.33 ± 0.51, 3.07 ± 0.58, and 1.51 ± 0.26 individuals/grid in Douglas fir, ponderosa pine, red fir, and white fir respectively. California ground squirrels showed an interaction between month and habitat ($F_{12,70} = 2.91$, $P < 0.002$; Fig 1). Although golden-mantled ground squirrels were found occasionally in Douglas fir forests, they occurred almost exclusively in red fir. Abundance of golden-mantled ground squirrels varied through the season by habitat and month ($F_{12,70} = 2.00$, $P = 0.04$), peaking in August and September, then dropping off in October as individuals began to hibernate (Fig. 1). Flying squirrels showed a pattern similar to golden-mantled ground squirrels and were predominantly found in red fir forests. However, the low number of captures makes identification of any patterns in abundance impossible. Characteristic of all sites was high temporal variability in abundance.

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

All macro- and microhabitat measurements were taken on all trap grids during the 2003 field season. These data have been entered into a spreadsheet and will be analyzed during spring and summer of 2004.

<u>Dynamics of spotted owl prey taxa</u>:

We have captured and placed radio-collars on 20 individual woodrats, consisting of 11 females and 9 males. All woodrats were captured in the same general area and were found in ponderosa pine forest. Telemetry began in late July and continued until the beginning of October. All triangulation data has been entered into spreadsheets and is ready to determine animal locations. All animal locations will be calculated during February of 2004 and will be entered into ArcView before the start of the 2004 field season. In addition, monthly home ranges will also be calculated prior to the 2004 field season.

A total of 71 woodrat houses were found in the telemetry study area. Woodrat houses consisted of a variety of structures ranging from cavities in stumps and logs (n = 12 houses) to stick houses (n = 59) constructed to heights of 2-3 m. Vegetation characteristics were measured for each house and will be used to identify patterns in house use in relation to habitat characteristics.

Fitness correlates to forest management:

Twelve females were captured in July and monitored throughout the year. All females survived the season and have entered hibernation, and are expected to emerge in ca. April 2004. Females were subsequently captured in July and early August 2003 and all monthly measurements were taken as available.

Body mass fluctuated throughout the season, with an initial decrease likely associated with lactation (Fig. 2). Following August, both experimental groups increased in mass. Supplemental feeding began on September 1, 2003, and was followed by a divergence in control and supplemental mean mass (Fig. 2). Because only one individual per treatment was captured in October the full relationship between the experimental groups is not available; the marked divergence between the two individuals captured, however, strongly supports our contention that supplemental feeding was successful. Indeed, when data for August and September are compared (Fig. 3), it is apparent that the mass of control and supplemental animals showed a trend towards distinct trajectories, with slopes for mass gain from August to September being β = 14.56 and 42.49 respectively. The difference between these slopes was significant ($F_{1,18} = 3.25$, $P \approx 0.08$). No significant difference in total mass was observed between the two groups at the start of the experiment. The results of this analysis suggest that the dietary supplementation was successful in increasing the rate of fat reserve development, although the difference in mass between the two treatment groups is expected to be greatest in the spring following emergence from hibernation. As expected, maternal home range size for the two treatment groups did not differ during any of the

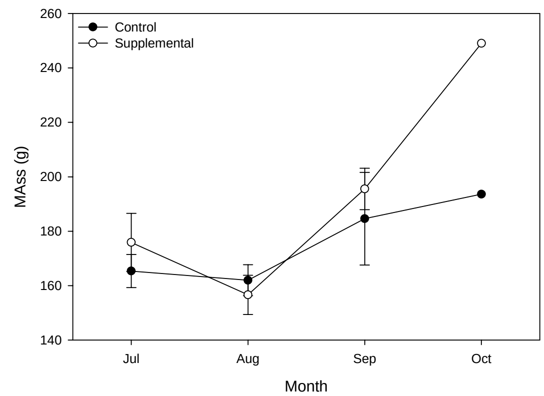

Fig. 2. Mean mass of female golden-mantled ground squirrels fed a control diet (solid) or a diet supplemented with black oil sunflower seeds (open). Error bars represent standard error, no error bars are present for October because only one individual from each group was captured. No statistics were performed using October captures.

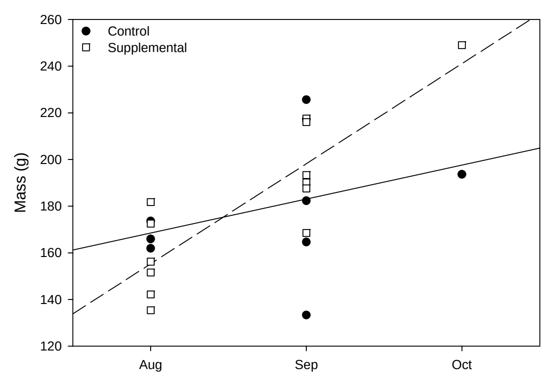

Figure 3. Mass of female golden-mantled ground squirrels fed a control (solid circles and lin) of fat supplemented (open circles, dashed) diet. Slope of mass gain was greater in supplemented females ($F_{1,18}$ = 3.25, P = 0.08).

months studied, and decreased in size following July when energetic demands from lactation are greatest (Fig. 4).

We will initiate our sampling efforts in April 2004, and intend to capture all marked adults as well as their offspring. Of particular interest will be the relative success of treatment and control offspring, their ability to garner resources for their first independent winter, and their productivity as yearling mothers.

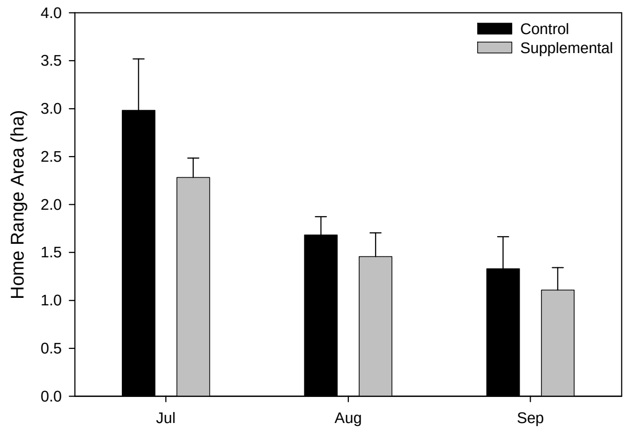

Figure 4. Home range size in hectares (ha) for female golden-mantled ground squirrels allowed to forage naturally (control, n=6) or fed a high fat supplemental diet in addition to natural foraging (supplemental, n=6).

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

To date we have collected 241 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 stored and are ready to be sent to the University of Idaho for analysis.

COLLABORATION WITH OTHER MODULES

We have initiated collaborative efforts with the vegetation, and fire and fuels modules, 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 was 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 2003 calendar year marked the first full year of data collection. We began the field season by establishing semi-permanent trap grids for use in an experiment on the effects of thinning strategies on small mammals, vegetation, and fire behavior. We established 9 trap grids for use in the experiment and 9 additional grids for use in developing habitat models for small mammals.

With the budget forecast for 2004, we plan to continue trapping on the nine experimental grids to obtain a second year of pretreatment data. Thinning on the treatment grids will begin as early as fall 2004, but is likely to not be done until 2005. 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. One concern to be addressed early in the 2004 field season will be to find and capture 20 individual flying squirrels for use in radio-telemetry studies. 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 monitor female golden-mantled ground squirrels from last year and additionally monitor their offspring during the upcoming field season. We will continue to take tissue samples from newly captured chipmunks on all sites for use in genetic analyses. All samples of chipmunk tissue will be sent to the University of Idaho for molecular analyses during the spring and summer of 2004.

The methods we have developed for this project have been tested in the 2003 season, and they appear suitable for developing a large and significant dataset on the abundance, distribution, activity, phylogenetic relationship, and physiology of small mammals in the Sierra Nevada. 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 expect publication of data to begin following the 2004 field season and to include articles in peer reviewed on the following subjects:

1. Habitat relationships of small mammals in the northern Sierra Nevada.
2. Distribution and abundance of small mammals in the northern Sierra Nevada.
3. Northern flying squirrel home range size and structure.
4. Characteristics of woodrat house use.
5. Woodrat home range size and structure.
6. Effects of fat on offspring fitness in golden-mantled ground squirrels.
7. Genetic structure and hybridization of *Tamias* species in the Sierra/Cascade interface.

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 2003 was conducted by James A. Wilson, Meghan Gilbart, Dave Smith, Robin Jenkins, Camila Morcos, Aviva Goldman, Kevin Marsee, Rachel Kussow, and John Katz.

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Table 1. Total individuals captured by genera on 12 sites in the Plumas/Lassen National Forests. Number of trapnights for each site were Barrel (6), Bear Holler (6), Beesting (5), Buck (5), Cedar (5), Greenbottom (9), Gulch (5), Lassen (16), Loop (16), Soloman's Meadow (9), Steep (9), and Trippin Falls (9).

Site	Elevation (m)	*Tamias*	*Spermophilus*	*Peromyscus*	*Tamiasciurus*	*Neotoma*	*Glaucomys*	*Microtus*	Total
Barrel	1310			4	2				6
Bear Holler	1305				2		1		3
Bee Sting	1660	20		1					21
Buck	1609	9		28					37
Cedar	1362			6					6
Green Bottom	2109	149	21	14				1	185
Gulch	1499	9		4	2	4			19
Lassen	1930	185	4	99					288
Loop	1695	72	18	95	4		1		190
Soloman's Meadow	2000	4	3	18				28	53
Steep	1563	69	2	19	11			1	102
Trippin Falls	1295			25		3			28