



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

2008 Annual Report

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EXECUTIVE SUMMARY

In this document we report on the Mammal Module of the Plumas-Lassen Administrative Study (PLAS). A pilot study was conducted September-November 2002, the study design was incorporated in 2003, and 2008 marked the sixth year of implementation of the study. As of the end of the 2007 field season, all of the proposed treatments have been implemented; thus, everything we report in 2008 reflect post-treatment conditions, whereas all data reported prior to 2007 reflect pre-treatment conditions.

The information provided in this report is intended to provide background information on the pre-treatment and post-treatment status of small mammals in a variety of forested habitat types, determine habitat associations of many small mammal species, particularly the principle prey of the California spotted owl (i.e., dusky-footed woodrat, *Neotoma fuscipes*; northern flying squirrel, *Glaucomys sabrinus*), and provide resource managers with important habitat attributes to manage for to ensure a sustainable mammalian community.

In 2008 Brett Jesmer succeeded Robin Innes as Project Leader of the Mammal Module of the PLAS. Robin Innes continues to develop and improve upon manuscripts initiated during their time with the PLAS, although she currently works with the U.S.D.A. Forest Service in Missoula, MT. To date, we have had three graduate students at the University of California, Davis successfully complete their graduate work with the PLAS. In 2005, Stephanie Coppeto completed her graduate work on the habitat associations of small mammals at multiple spatial scales. In 2006, Robin Innes completed her graduate work on habitat selection by dusky-footed woodrats. Jaya Smith will complete his graduate work on home range and habitat use of the northern flying squirrel in 2009.

INTRODUCTION

Small mammals play vital roles in forest ecosystems, serving as important consumers and dispersers of seeds, fruits, and fungi (Carey et al. 1999; Gunther et al. 1983; Maser and Maser 1988; Pyare and Longland 2001), and as prey for mammalian and avian predators, including many species of concern in the Sierra Nevada (e.g., California spotted owl, *Strix occidentalis occidentalis*; northern goshawk, *Accipiter gentilis*; fisher, *Martes pennanti*; and marten, *M. americana*; Carey et al. 1992; Forsman et al. 1984; Zielinski et al. 1983). Given their essential interactions with flora and fauna across multiple trophic levels (e.g., Carey et al. 1992; Forsman et al. 1984), changes in the distribution and abundance of small mammals could substantially affect the dynamics of forest communities. This makes small mammals valuable subjects for the integrative research necessary to fully understand the ecological responses of spotted owls and other species to forest management practices.

Here we report on the Mammal Module of the PLAS, one of five integrated study modules intended to evaluate land management strategies within the area covered by the Herger-Feinstein Quincy Library Group Forest Recovery Act (HFQLG) Pilot Project. Forest management practices implemented during the HFQLG Pilot Project aim to "...promote ecologic and economic health for federal lands and communities of the northern Sierra Nevada" (Title IV-HFQLG Forest Recovery Act- Sec.401). Understanding how small mammal communities respond to different forest management regimes at macrohabitat (i.e., stand-level, landscape) and microhabitat (trap-level, home range) scales would provide valuable feedback to other PLAS modules. Managers manipulate fuel loads through mechanical thinning of the forest in an effort to prevent catastrophic wildfire events and to create more suitable conditions for prescribed burning. Such management activities are becoming more frequent throughout western North America (Covington et al 1997, Dodge 1972, Long et al. 2008). Exactly how these management practices effect small mammal populations, particularly in the Sierra Nevada, is not well understood (Carey 2000, Meyers et al 2007, Suzuki and Hayes 2003). As with the current status of the Mammal Module, most studies focus on the short-term responses of small mammal communities to habitat manipulation (e.g., Carey 2000, Carey and Wilson 2001, Converse et al. 2006, Klenner and Sullivan 2003, Meyers et al. 2007). Long-term studies have the potential to record a broader range of variability in community dynamics which will lead to a greater understanding of ecosystem processes (Beche and Resh 2007); i.e. distilling natural fluctuations in population, climatic effects, and predator responses from the effects of management practices. The value of long-term studies has been exemplified in many field studies across taxa (eg. Beche and Resh 2007, Brook and Bradshaw 2006, Elias et al 2006, Jackson and Furender 2006, Pettorielli and Durant 2007, Tsuji et al 2006). When considering the goals of the HFQLG forest recovery act, the long-term study approach is most appropriate for the mammal module. We will continue to develop predictive small mammal habitat models to forecast how individual species will respond to forest management treatments and test these models by assessing the impacts of forest management treatments on long term responses of small mammal abundance and species diversity. This is done by monitoring several independent populations of small mammals for multiple years before and after forest

management treatments are applied, developing demographic profiles (e.g., survival, reproduction) of species, and obtaining detailed measurement of habitat characteristics. To sample and monitor these small mammal populations, we have established permanent (long-term grids) and temporary (land bird transects) live-trapping grids throughout the Plumas National Forest (PNF).

Key non-hibernating small mammals in the northern Sierra Nevada include the northern flying squirrel (*Glaucomys sabrinus*) and dusky-footed woodrat (*Neotoma fuscipes*). Northern flying squirrels and dusky-footed woodrats are the principle prey of the California spotted owl (Carey et al. 1992; Rosenberg et al. 2003), a species of concern in California due to its dependence upon late-seral forest ecosystems (United States Department of the Interior 2003), which are among the most highly altered ecosystems in the Sierra Nevada (Beardsley et al. 1999; Franklin and Fites-Kaufman 1996). For example, some populations of northern flying squirrel may be depressed by the intensity of spotted owl predation (Carey et al. 1992), and high woodrat biomass may reduce the area requirements of the spotted owl (Carey et al. 1990; Zabel et al. 1995). Thus, northern flying squirrels and dusky-footed woodrats are an important focus of our study module.

Northern flying squirrels are nocturnal, arboreal rodents located throughout the northern latitudes of the United States and Canada (Wells-Gosling and Heaney 1984), and frequently associated with forests with high densities of large trees (Smith et al. 2004, 2005). Northern flying squirrels act as a major dispersal agent for hypogeous fungal spores, which are important for nutrient and water uptake by host trees (Fogel 1980). Although they are typically associated with mesic northern forests, northern flying squirrels are also found throughout the Sierra Nevada where they experience a much more xeric landscape than elsewhere in their range; as a result, populations of northern flying squirrel inhabiting the Sierra Nevada may be quite different from those inhabiting the more mesic forests of Oregon, Washington, and Alaska. Specifically, northern flying squirrels may be more sensitive to moisture availability in the Sierra Nevada since this influences the distribution of truffles, their primary food source. This disjunctive distribution of food resources may drive differences in northern flying squirrel biology, suggesting that northern flying squirrels may exhibit a more clumped distribution, lower overall densities, increased competition for suitable nest trees, and larger individual home ranges; thus, northern flying squirrels in the Sierra Nevada may be affected differently by forest management practices than in other parts of their range. We are using live-trapping and radiotelemetry techniques to determine the abundance and distribution, habitat use, and home range of northern flying squirrels in the Sierra Nevada, comparing this with data from other parts of their distribution, and evaluating the effects of forest management practices on this species within the area covered by the HFQLG Pilot Project.

The dusky-footed woodrat is a nocturnal, semi-arboreal rodent found throughout northern California and Oregon that inhabits a wide variety of densely vegetated habitats, including chaparral, juniper woodland, streamside thickets, and deciduous or mixed forests with well-developed undergrowth (Carraway and Verts 1991). Dusky-footed

woodrats play an important role in community dynamics. As mentioned previously, they are prey for many avian and mammalian predators, including the California spotted owl. Additionally, the availability of woodrat houses may influence species richness for small mammals, reptiles, amphibians, and invertebrates (Cranford 1982; M'Closkey et al. 1990; Merritt 1974; Vestal 1938). Thus, promoting quality habitat for the dusky-footed woodrat may provide a variety of ecological values in managed forests, for example in the form of increased biodiversity, with important consequences for forest conservation (Carey et al. 1999). We used live-trapping and radiotelemetry to determine the abundance and distribution, habitat use, and home range of dusky-footed woodrats in the Sierra Nevada, and evaluate the effects of forest management practices on this species. Specifically, our first objective was to test for an association between woodrat abundance and abundance of California black oak (*Quercus kelloggii*), an important food source (Atsatt and Ingram 1983; Cameron 1971; Meserve 1974). Our second objective was to evaluate the importance of microhabitat variables to dusky-footed woodrats at 2 levels -- placement of houses within mixed-conifer habitat, and use of houses within home ranges. Dusky-footed woodrats construct conspicuous houses on the ground using sticks, bark, and plant cuttings, and sometimes also on limbs or in cavities of trees (Fargo and Laudenslayer 1999). Given the investment involved in building, maintaining, and defending a house, we predicted that houses should be distributed such that they minimize energetic costs in movement, yet maximize individual fitness components (Manley et al. 1993), such as access to food, protection from predators, and a thermally suitable microclimate (Atsatt and Ingram 1983). Thus, we evaluated ground and tree house-site selection of houses by dusky-footed woodrats by comparing house sites with nearby random sites. Since only a subset of available houses is used by woodrats at any one time (Carey et al. 1991; Cranford 1977; Lynch et al. 1994), some houses may be more suitable than others. We evaluated house suitability by comparing characteristics of used and unused ground houses and availability and use of house trees. Because woodrats defend their house against conspecifics, subadults might be forced to settle in lower quality houses (Vestal 1938), thus, we also evaluated whether subadults selected houses differently from those selected by adults. Our third objective was to examine the spatial organization of dusky-footed woodrats. The spatial organization of a population has important implications for population dynamics, as well as the genetic structure of a population (e.g., Dunning et al. 1992; Lambin and Krebs 1991; Sugg et al 1996).

Two commonly occurring species of mice, the deer mouse (*Peromyscus maniculatus*) and the brush mouse (*Peromyscus boylii*), inhabit PNF. These species display different behavior and morphological characteristics yet both possess similar foraging habits. Due to the ubiquitous nature of deer mice, there is a great overlap in habitat affinity with the brush mouse (Jameson 1951). Deer mice are nocturnal, non-hibernating, terrestrial to semi-arboreal species, which are distributed throughout the Sierra Nevada (King 1968; Martell and Macaulay 1981; Jameson and Peters 2004) and forage on a variety of seeds, berries, insects, and hypogeous fungi. Deer mice are by far the most commonly occurring *Peromyscus* encountered within the study areas of the Mammal Module in PNF (98% of 6252 *Peromyscus* individuals captured). We will group these two similar species and herein refer to them collectively as *Peromyscus* species as is commonly done when referring to spotted owl forage in situations when more than one species of *Peromyscus* is

present. Variability among spotted owl subspecies diet and regional differences within spotted owl subspecies diet indicate foraging habits of the spotted owl may differ based on habitat and prey availabilities. Little is known of the California spotted owl diet in PNF. Diet studies of the spotted owl (*Strix occidentalis*) indicate that *Peromyscus* species are a frequently taken prey item but do not dominate the percent of biomass ingested by the spotted owl (Block et al. 2005, Bravo-Venaja 2005, Forsman et al. 2004, Rosendberg et al. 2003, Smith et al. 1999, Trailkill and Bias 1989). However, reproductive success in northern spotted owls is positively correlated with trends in *Peromyscus* abundance (Rosenburg et al. 2003), and Munton and others (2002) recorded an increase in *Peromyscus* taken during the breeding season of California spotted owls in the Sierra National Forest. Coppeto et al (2006) reported that trends of *Peromyscus* in PNF are explained primarily by forest type and year. Wilson et al (2008) further supported the findings of Coppeto et al. by correlating yearly trends, such as mean cone production, with *Peromyscus* abundance in PNF. Such factors appear to strongly influence annual *Peromyscus* abundance.

Other key small mammals include the golden-mantled ground squirrel (*Spermophilus lateralis*) and chipmunks (*Tamias* sp.), which also are important prey species of the northern goshawk, a species of increasing concern to resource managers due to the species' sensitivity to the effects of forest management. Chipmunks are forest-associated, semi-arboreal rodents that constitute a considerable portion of the small-mammal biomass in an area, making them important prey for a variety of mammalian and avian predators (Vaughan 1974). Additionally, chipmunks are important consumers and dispersers of seeds (Briggs and Vander Wall 2004; Vander Wall 1992), and may contribute to the natural regeneration of some species of plants by caching seeds (Aldous 1941). Small mammals may cache seeds beneath the layer of decaying vegetation on the forest floor, where they stand a better chance of germinating than those remaining on the surface litter (Sumner and Dixon 1953); alternatively, they may deposit seeds in underground burrows where seeds cannot establish seedlings. If soil-moisture levels have been altered due to fire, logging, or weather patterns, the ability of chipmunks to retrieve cached seeds may be reduced, thus promoting germination of a larger proportion of seeds after disturbance (Briggs and Vander Wall 2004; Vander Wall 2000). However, if chipmunks are very abundant, they can prevent normal regeneration of some plants, particularly pines, by eating their seeds, which may contribute to the generation of dense brushfields that could further hinder the return of timber (Smith and Aldous 1947, Tevis 1953). We were particularly interested in the long-eared (*T. quadrimaculatus*) and Allen's (*T. senex*) chipmunks, which occur commonly throughout PNF. These sympatric species are similar in body mass, diet, and general resource utilization, and thus are likely to compete locally. Similar species often coexist by partitioning habitat. However, detecting differences in habitat affinities is influenced by spatial scale. Our objective was to investigate the abundance, distribution, and habitat associations of the long-eared and Allen's chipmunks at three spatial scales in PNF and evaluate the affect of forest management practices on these species.

OBJECTIVES

The primary objective of the Mammal Module is to evaluate small mammal responses to different forest management practices, and to model these responses in terms of demography, spatial distribution, and habitat associations at local and landscape scales.

To meet the primary objective, we will address the following:

1. Determine small mammal habitat associations at macro- and microhabitat scales.
2. Develop demographic profiles of small mammal populations inhabiting a variety of habitat types.
3. Develop predictive small mammal habitat models, based on the results of objectives 1-2, to forecast how individual species will respond to forest management treatments.
4. Quantitatively assess the impacts of forest management treatments on small mammal abundance and species diversity.
5. Determine small mammal population trends, evaluate how populations are changing temporally, and assess the factors responsible for the observed trends.
6. Evaluate the spatial distribution (i.e., home range), social organization (i.e., home range overlap), and habitat selection (i.e., den use, house use) of the principle prey of the California spotted owl, the northern flying squirrel and dusky-footed woodrat.
7. Evaluate habitat affinities of two sympatric and semi-cryptic chipmunks, the long-eared and Allen's chipmunks, at multiple spatial scales.

MATERIALS AND METHODS

Live-trapping

Capture-recapture data obtained from the live-trapping methods described herein allow us to measure population parameters such as abundance, density, and frequency of occurrence of individual small mammal species and small mammal species richness and diversity, and permit the measurement of habitat use, availability and selection (Lancia et al. 1996, Litvaitis et al. 1996). Live-trapping methods are useful for making comparisons of small mammal communities across time, locations, habitats, and land-use treatments. We established several different live-trapping designs, each appropriate to the small mammal community or species of interest.

Long-term grids

To provide base-line information on small mammal populations inhabiting major forest types, and to quantitatively assess the impacts of forest management treatments on small mammal abundance and species diversity, we established 21 long-term grids using controls and pre- and post-treatment data. In 2007, all of the proposed treatments were implemented. All data collected between 2003 and 2006 were collected prior to any treatments to determine baseline conditions. In 2003, we established 18 permanent, live-trapping grids (Fig. 1a); we established 3 additional long-term grids in 2005. Twenty

grids consist of a 10 x 10 array of Sherman traps (Model XLK, 7.6 x 9.5 x 30.5 cm, H. B. Sherman Traps, Inc., Tallahassee, FL, USA) with 10 m spacing, nested within a larger 6 x 6 grid of 72 Tomahawk traps (Model 201, 40.6 x 12.7 x 12.7 cm, Tomahawk Live Trap, Tomahawk, WI, USA; 1 ground, 1 arboreal) with 30 m spacing (Fig. 1b). The remaining long-term grid was constrained by road configuration such that the array of Sherman traps was nested within a 4 x 9 grid of 72 Tomahawk traps (30 m trap spacing; 1 ground, 1 arboreal). Arboreal traps were placed approximately 1.5 to 2 m above the ground on a randomly-selected tree located <10 m from the grid point; arboreal traps may or may not be placed on the same tree each trapping session. Ground traps were placed within 1 m of the grid point under protective cover, such as a shrub or log, at small mammal burrow entrances, and along small mammal runways, when possible.

We trapped all long-term grids (n=21) in 2008. All grids had 120 trap stations and covered 2.25 ha (3.24 ha with a ½ inter-trap distance buffer) of contiguous forest. Arboreal Tomahawk traps were removed from all grids on August 1, 2004 because of consistently poor capture rates; however, arboreal Tomahawk traps were again used in 2005 and thereafter, and capture rates were improved by placing the trap entrance flush against the tree bole, fastening the trap more securely to the tree, and switching to a more desirable bait mixture, following Carey et al. (1991).

Prior to August 2005, all traps were baited with crimped oats and black oil sunflower seeds lightly coated in peanut butter; thereafter, traps were baited with a mixture of rolled oats, molasses, raisins, and peanut butter which was formed into a small, sticky ball (Carey et al. 1991). Small nest boxes made from waxed-paper milk cartons were placed behind the treadle in Tomahawks to minimize stress and provide thermal and protective cover (Carey et al. 1991); in addition, synthetic bedding material (nonabsorbent polyethylene batting), and natural cover (e.g., bark, moss) or cover boards, were provided as needed for thermal insulation. After the trap session was completed, bait was discarded on the ground at the grid point and all traps were removed.

The 18 long-term grids established in 2003 were placed in 5 principal forest types (Coppeto et al. 2005, 2006; these are Pub. #1 and #4). Forest types were defined by the dominant live tree species representing ≥ 70% of total tree composition, and included white fir (*Abies concolor*, n = 4), red fir (*A. magnifica*, n = 3), mixed fir (co-dominant mix of white fir and Douglas-fir, *Pseudotsuga menziesii*, n = 5), mixed conifer (n = 3), and pine-cedar (co-dominant mix of yellow pine [ponderosa pine–*Pinus ponderosa* and Jeffrey pine–*P. jeffreyi*], and incense cedar, *Calocedrus decurrens*, n = 3). In 2005, sampling grids were established in group selects located in white fir (n=2) and mixed-conifer (n=1) habitats. In an effort to more fully integrate our module with those of other research modules of the PLAS, Wilson et al. (Publication #5) used alternative forest type classes for these grids, as follows: white fir (n=9), red fir (n=3), Douglas fir (n=3), and ponderosa pine (n=3). According to this classification, the 3 group selects established in 2005 were placed within white fir habitat. Overall, PNF is dominated by white fir and Douglas fir so these forest types had proportionally more trapping grids placed within them. Common shrubs in the region include mountain rose (*Rosa woodsii*), Sierra gooseberry (*Ribes roezlii*), serviceberry (*Amelanchier utahensis*), bush chinquapin

(*Chrysolepis sempervirens*), green- and white-leaf manzanita (*Arctostaphylos patula* and *A. viscida*), mountain dogwood (*Cornus nuttallii*), mountain whitethorn and deer brush (*Ceanothus cordulatus* and *C. integerrimus*), bitter cherry (*Prunus emarginata*), willow (*Salix* spp.), Fremont silk tassel (*Garrya fremontii*), and huckleberry oak (*Quercus vaccinifolium*). Pinemat manzanita (*Arctostaphylos nevadensis*) occurred almost exclusively in red fir forests, and buck brush (*Ceanothus cuneatus*) predominantly in pine-cedar/ponderosa pine forests.

| GRID # | SITE NAME | LOCATION | FOREST TYPE AS PRESENTED IN COPPE TO ET AL. | FOREST TYPE AS PRESENTED IN WILSON ET AL. | EXPERIMENT TYPE |
|--------|-------------|------------------------|---|---|-----------------|
| 1 | BLACKOAK | SNAKE LAKE | MIXED-CONIFER | WHITE FIR | LIGHT THIN |
| 2 | BOA | SCHNEIDER CREEK | MIXED-FIR | MIXED-FIR | HABITAT |
| 3 | CABIN | MILLER FORK | WHITE FIR | WHITE FIR | CONTROL |
| 4 | DOGWOOD | LITTLE SCHNEIDER CREEK | MIXED-FIR | MIXED-FIR | HABITAT |
| 5 | GIMP | DEAN'S VALLEY | MIXED-FIR | WHITE FIR | HEAVY THIN |
| 6 | GREENBOTTOM | GRIZZLY MOUNTAIN | RED FIR | RED FIR | HABITAT |
| 7 | GULCH | BEAN CREEK | PINE-CEDAR | PINE-CEDAR | HABITAT |
| 8 | MONO | GRIZZLY MOUNTAIN | RED FIR | RED FIR | HABITAT |
| 9 | NOGO | SNAKE LAKE | MIXED-CONIFER | WHITE FIR | CONTROL |
| 10 | NONAME | DEAN'S VALLEY | WHITE FIR | WHITE FIR | LIGHT THIN |
| 11 | OASIS | BEAN CREEK | PINE-CEDAR | PINE-CEDAR | HABITAT |
| 12 | RALPH | GRIZZLY MOUNTAIN | RED FIR | RED FIR | HABITAT |
| 13 | RIPPER | MILLER FORK | WHITE FIR | WHITE FIR | HEAVY THIN |
| 14 | RUTT | SNAKE LAKE | MIXED-CONIFER | WHITE FIR | GROUP SELECT |
| 15 | STEEP | TAYLOR CREEK | MIXED-FIR | MIXED-FIR | HABITAT |
| 16 | SWARM | BEAN CREEK | PINE-CEDAR | PINE-CEDAR | HABITAT |
| 17 | TEEPEE | DEAN'S VALLEY | WHITE FIR | WHITE FIR | CONTROL |
| 18 | THICK | DEAN'S VALLEY | WHITE FIR | WHITE FIR | GROUP SELECT |
| 19 | TOAST | MILLER FORK | WHITE FIR | WHITE FIR | GROUP SELECT |
| 20 | TRIANGLE | MILLER FORK | WHITE FIR | WHITE FIR | LIGHT THIN |
| 21 | VIEW | SNAKE LAKE | MIXED-CONIFER | WHITE FIR | HEAVY THIN |

Twelve of the long-term grids were placed within the experimental management plots established by the Vegetation Module of the PLAS. These 12 study plots were placed in 3 groups (Miller Fork, Dean's Valley, and Snake Lake) of 4 study plots, consisting of 1 control plot and 3 experimental plots (1 group select plot, 1 light thin, and 1 heavy thin). The remaining 9 study plots were not established in groups. Minimum distance among long-term grids (n=21) was 1 km with the exception of 4 grids that were 700-900 m apart. Movement between grids was extremely rare; we documented a single golden-mantled ground squirrel that moved from red-fir grid #12 to red-fir grid #6 in 2006.

Long-term grids were trapped monthly (May-October) during 2003-2004 and biannually (June, Oct) during 2005-2006. We sampled once in 2007 (July-August) because logging and prescribed burn activities at treatment grids restricted sampling activities. Grids were

again sampled biannually in 2008. Trapping sessions consisted of 4 consecutive trap-nights. Sherman and Tomahawk traps were set and baited every evening just before dusk, and checked just after dawn; Sherman traps were then closed until dusk whereas Tomahawk traps were re-baited and checked again at mid-day, a minimum of 2 hours after the first trap check, at which point they were closed until dusk. This resulted in all traps remaining closed from 12:00 – 16:00, but enabled us to sample both diurnal and nocturnal species while reducing deaths that result from thermal stress during the hottest part of the day. Field technicians were thoroughly trained and rotated among grids each trapping session, to reduce the variability in capture success due to differences among technicians.

Demographic profiles.—Population demographics will be modeled by species using program MARK. Species without sufficient captures to generate detailed capture history will be modeled using the minimum number known alive (MNKA) parameter. Monthly or seasonal 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.

Northern flying squirrels

We captured and radiocollared northern flying squirrels at long-term grids, land bird transects, and at areas predicted to have moderate and high suitability for northern flying squirrels, hereafter flying squirrel transects (Fig. 3). At long-term grids and land bird transects, northern flying squirrels were collared only in areas where triangulation was feasible, which required fairly large areas of habitat with one or two roads bisecting the area. In 2004, animals were captured and radiocollared at 3 long-term study grids located in upper elevation (2,100 m) red-fir habitat. Additional transects bisecting or parallel to original transects were established during 2005-2007 to increase the area covered and increase capture success. The 3 long-term grids and intervening habitat are hereafter referred to as study site FS-1. In 2005, we established a second study site (FS-2) in mixed-conifer forest at 1,500 m elevation; in 2006 and 2007, additional transects bisecting or parallel to original transects were established. FS-2 was selected using a GIS-based northern flying squirrel habitat-relations model based on known habitat affinities of this species, and which predicted poor, moderate, and high suitability habitat for northern flying squirrels. Although we established many live-trapping transects (>10) in areas predicted to have high and moderate suitability, study site FS-2 was the only study site to yield captures where triangulation also was feasible; FS-2 was predicted to have moderate suitability for northern flying squirrels.

We established flying squirrel transects primarily along riparian areas, due to the importance of this habitat type to northern flying squirrels (Meyer and North 2005). If habitat, road configuration, and topography were suitable, we used a live-trapping grid (i.e., several parallel transects) to maximize the number of captures. We used a combination of Sherman and Tomahawk traps, typically 1 Sherman and 2 Tomahawk (1 ground, 1 arboreal) traps, spaced 40-50 m apart. Sherman and Tomahawk traps were set

and baited every evening just before dusk, and checked with the same schedule as our long-term trapping grids. As indicated above, we changed out trapping bait and protocol for flying squirrels in August 2005.

Dusky-footed woodrats

We established four study sites (WR1 – WR4, 1,450–1,750 m elevation; Fig. 2) in early-seral forest (30–40 years post-logging), representative of Sierra Nevada westside mixed-conifer forest type and characterized by California black oak, sugar pine (*Pinus lambertiana*), yellow pine, white fir, Douglas fir, and incense cedar. All study sites had a brushy understory consisting primarily of deer brush, buck brush, and mountain whitethorn, with lesser coverage by greenleaf and whiteleaf manzanita and mountain dogwood. Each study site included 2–4 habitat types, which varied in composition of overstory and understory dominants, canopy closure, and aspect. Habitat type was defined by GIS data layers provided by the USDA, Forest Service. WR-1 and WR-2 had moderately sloping topography, whereas WR-3 and WR-4 had mixed terrain or undulating topography. Because woodrat activities extended somewhat into adjacent habitats, we trapped woodrats at all houses located within approximately 3 home range diameters (ca. 180 m—Cranford 1977, Lynch et al. 1994, Sakai and Noon 1997) of each study site to ensure that all woodrats potentially influencing the spatial structure at each study site were identified. Historic logging activities and fire suppression practices contributed to heterogeneity within study sites, with abundant dead wood as well as shrubby gaps interspersed with patches of closed canopy forest. Recent (<5 yr) management activities (e.g., prescribed burns, logging) have created open understory and overstory conditions in areas between study sites. Study sites lay 1.2–2.8 km apart, and no woodrats were recorded moving between study sites.

We systematically searched for woodrat houses in the spring and fall of 2004–2006 by walking overlapping belt transects that covered each study site. In addition, woodrat houses were opportunistically located at all study sites during a concurrent radiotelemetry study of woodrat movements. Each house was marked and its location mapped (≤ 1 m) using a GPS unit (Trimble Navigation, Ltd., Sunnyvale, California; GeoExplorer, GeoXT), and volume was estimated as a cone using measurements of length, width, and height.

Woodrats are active year-round, but our study was limited to the snow-free period (May–October). We documented house use by livetrapping in the spring (May–June) and late summer–early fall (August–September) of 2004–2006 with 4 Sherman live-traps (H.B. Sherman Traps, Inc., Tallahassee, Florida; $7.6 \times 9.5 \times 30.5$ cm) set at the base of each house for 4 consecutive nights; longer trapping efforts (>4 consecutive nights) do not yield higher success (Carey et al. 1999; Laudenslayer and Fargo 1997; Willy 1992). Traps were baited with raw oats and sunflower seeds coated with peanut butter and opened at dusk and checked at dawn. Synthetic batting was provided for thermal insulation. Traps were set at all houses within each study site.

Chipmunks

Chipmunk species in PNF display considerable overlap in habitat requirements, diet, and activity. Both long-eared and Allen's chipmunks are captured frequently in our live-trapping efforts. These species overlap greatly in external characteristics and consequently can be challenging to identify in the field (Clawson et al. 1994; Gannon and Forbes 1995). To date, the only sure means to identify some individuals appears to be with skeletal features, which are obtained only by sacrificing animals. We collected a sample of reference chipmunks throughout PNF by salvaging trap mortalities at long-term grids as well as euthanizing a small portion of animals from land bird transects (≤ 3 chipmunks per census transect). To avoid affecting capture-recapture data, animals were only collected on the last day of the trapping session. All specimens were frozen and submitted to the University of California, Davis, Museum of Wildlife and Fish Biology, where they have been prepared as standard museum specimens (full skeleton plus skin) and tissues (e.g., liver, heart, muscle, and kidney) have been preserved for use in molecular analyses. We have collaborated with Dr. Jack Sullivan (University of Idaho) to develop molecular markers for non-lethal identification of chipmunk species in the future. We are collecting tissue samples (small sections (< 1 mm) of ear pinna, frozen in 95% ethanol) from all chipmunks captured at long-term grids and land bird transects. During 2005-2008, we recorded the presence of six external morphological characteristics that have been suggested to visually distinguish between the two species. These are: ear patch size and color; face stripe color and curvature; length and shape of the ear; and body color. We will use these data to determine characteristics that reliably distinguish these species in the field, thereby allowing us to proceed with analyses of habitat use.

Animal handling

Captured animals were transferred to a mesh handling bag, identified to species, individually marked with numbered Monel ear tags (National Band & Tag Co., Newport, Kentucky), weighed, aged, measured (e.g., ear length, hind foot length), examined for reproductive status, and released at the point of capture. Total processing time for an experienced technician was generally < 2 minutes. Reproductive condition for males was noted as either scrotal (enlarged and scrotal testes) or non-scrotal (reduced and abdominal testes); for females, the vagina was noted as either perforate (thereby receptive) or imperforate (not receptive), the vulva as either swollen or not, and the animal as lactating (nipples were enlarged and/or reddened, reflecting nursing offspring), or not. Animals were aged based upon a combination of weight, pelage (juvenile: gray, subadult: intermediate, and adult: brown), and reproductive condition (juvenile/subadult: nonreproductive, adult female: pregnant/lactating, and adult male: scrotal).

At initial capture, a tissue sample was collected from each animal. Tissue samples were collected by snipping the terminal 1 mm of ear tissue using sterile surgical scissors and placing the tissue in a cryovial with 95% ethanol. Samples were placed in a freezer for long-term storage. Prior to 2006, we collected tissue samples from dusky-footed woodrats and chipmunks. In 2006, we collected tissue samples from all captured animals. In 2007, we collected tissue samples from chipmunks and northern flying

squirrels. During the field season of 2008 tissue samples were collected from chipmunks only.

Any trap mortality, including incidental trap deaths, is thoroughly documented, and specimens are frozen and submitted to the University of California, Davis, Museum of Wildlife and Fish Biology, in accordance with the permitting requirements of the California Department of Fish and Game. All field work and handling procedures are approved by the University of California, Davis Animal Use and Care Administrative Advisory Committee protocol (#10394), and meet guidelines recommended by the American Society of Mammalogists (Animal Care and Use Committee 1998; Gannon et al. 2007).

Radiotelemetry

Movement data obtained from the radiotelemetry methods described herein allow us to measure home range, movement patterns, and social organization of individuals, permit the detailed measurement of habitat use and selection, and document the location and frequency of use of denning, nesting, and resting sites (Lancia et al. 1996, Litvaitis et al. 1996). Radiotelemetry methods are useful for making comparisons of small mammal movements and space use across time, locations, habitats, and land-use treatments. We applied radiocollars to a subset of dusky-footed woodrats and northern flying squirrels and radiolocated them during daytime resting activities and at night during foraging activities.

Radiotransmitter application

During 2003-2006, we applied radio transmitters to northern flying squirrels and dusky-footed woodrats. In 2007 only northern flying squirrels were radiotagged. A 4.0 g collar-type radio transmitter (Holohil Systems Ltd., Model PD-2C) was placed on the neck of individuals. Woodrats were lightly sedated with ketamine hydrochloride (100mg/ml) injected into the thigh muscle to facilitate application of radio-collars. Prior to being released at the point of capture, woodrats were allowed to fully recover from anesthesia (4-5 hours). Northern flying squirrels were not anesthetized prior to radiocollaring in earlier years; however in 2007, the use of anesthesia was implemented to avoid handling-related stress and mortality. A mild anesthetic plane was achieved by administering 0.8-1.0ml of a low concentration mixture of ketamine hydrochloride (100mg/ml) and xylazine (100mg/ml) (1.4mg ketamine, 0.06 mg xylazine) in a saline solution. Flying squirrels were then released after application of the radiocollar and full recovery at their point of capture. Radiotelemetry activities of newly collared individuals were initiated after a 24-hour acclimation period succeeding their release.

Homing

To document the location and frequency of use of denning, nesting, and resting sites we used homing techniques. For northern flying squirrels, diurnal locations were determined once per day, sporadically in 2003-2005 and 1-2 days per week in 2006, and 1 day per week in 2007. For dusky-footed woodrats, diurnal locations were determined once per day, sporadically in 2003 and 3 days per week in 2004 and 2005, and 1-2 days per week

in 2006. Locations were marked and accurately (≤ 1 m) mapped using a Trimble GPS unit.

Triangulation

Nocturnal telemetry sessions using triangulation techniques occurred during 5 nights per month in 2003 and 8-10 nights per month during 2004-2007. We used a Yagi[®] antenna and a hand-held radiotelemetry receiver (Model R-1000, Communications Specialists, Orange, CA, USA) to obtain the location of radiocollared animals. Compass bearings for the radio-collared animal were obtained by using a hand-held compass and bisecting the signal drop-offs. Fixed telemetry stations, mapped to within 1 m accuracy using a Trimble GPS unit were located remotely from the transmitter's position to avoid disturbance of the radio-tagged animal. Technicians worked in synchronized teams to achieve 3-6 directional bearings within as short of a time interval as possible (typically <10 minutes). Radiolocations were obtained for each animal 2-3 times per night at a minimum of 2.5 hours and 2 hours apart for dusky-footed woodrats and northern flying squirrels, respectively, to avoid serial correlation (Swihart and Slade 1988, Taulman and Smith 2004). The timing of nightly telemetry was varied from dusk until dawn to ensure that radiolocations were sampled at different times of activity. To reduce the error due to differences among field technicians, technicians were thoroughly trained and rotated among stations and study sites each radiotelemetry session. To ensure the accuracy of the triangulation method, triangulation systems were tested each night during regular radiotelemetry activities using 1-2 "dummy" collars placed within each study area; technicians did not know dummy collar locations, and the dummy collars were moved once per week. To assess bearing error rates, dummy collar locations were determined through triangulation and compared to their actual location previously mapped with a Trimble GPS unit.

Program Locate III (Nams 2006) was used to calculate northern flying squirrel locations from bearing data obtained during triangulation. We used several criteria to evaluate bearing data and determine animal locations. These included convergence of bearings, presence of outliers, number of bearings (≥ 4), and signal quality. Signal quality was reported for each reading as good, intermediate, or poor by technicians during triangulation. All poor readings were excluded from analysis. Bounce was an issue that contributed to error. To address this issue, we removed the two most divergent bearings until no fewer than 4 bearings were used for triangulation. This was possible because in 2007 we typically took 6 simultaneous bearings for each animal. Accepted locations were analyzed in Ranges VI. We estimated home range (95%) and core range (50%) using the Minimum Convex Polygons (MCP) (Mohr 1947) and Fixed Kernel (FK) methods (Kenward 2001).

Home range analysis

Northern flying squirrels.--To help describe home range area and identify important habitat features for the northern flying squirrel, we employed the use of radiotelemetry. Using simultaneous bearings (triangulation), a pinpoint of an animal's location may be achieved (see Fuller et al. 2005). Data-points generated from triangulation were subsequently further scrutinized. To determine if a stable home range was reached through incremental area analysis, data-points were added to a home range

in the order in which they were collected until an asymptote was observed (for example, see Fig. 24). Home ranges stabilized after an average of 34 points were collected. This was used to justify using data from flying squirrels that had fewer than 50 locations for kernel analysis.

We then constructed home range models using RangesVI (Kenward et al. 2003). One such model used is the minimum convex polygon (MCP- Mohr 1947) method (Fig. 22). In this model, a home range can be defined by drawing lines that connect the outermost points to form a contained area. The second model generates a home range using kernel densities. The fixed kernel (FK- Worton 1989) method uses a utilization distribution, or focal point of activity to define the home range (Fig. 23). This added characteristic weighs areas with a high density of points more heavily than areas with fewer points to generate “core use areas” (Silverman 1986, Worton 1989). Sampling in the core use area reveals which areas within a home range are important to the northern flying squirrel with respect to habitat type. Both 95% FK and 95% MCP home range models were generated for 2006 and 2007 (Table 6). Mean home range area across both years was 8.85 +/- 1.03 hectares (95% MCP) and 11.00 +/- 1.51 hectares (95% kernel). MCP was reported to compare with previous studies, and kernel estimators will be used for all subsequent analyses. Additionally, core use areas were generated using a 50% kernel estimator.

Home ranges are currently being used to determine habitat preference of the flying squirrel through the implementation of compositional analysis (Aebischer et al. 1993). Compositional analysis tests for differences between use and availability of habitat. A two-scaled approach is used; the broad scale compares the study area (availability) to the home range of each animal (use), and a second and finer scale comparison utilizes the home range (availability) and points within the home range (use). Statistical tests in compositional analysis use Multivariate Analysis of Variance (MANOVA) to compare the proportions of available habitat to the proportions of used habitat (Aebischer et al. 1993).

Dusky-footed woodrats.— Radiotelemetry techniques were employed to determine the space use of woodrats during 2004 to 2006 at study sites WR-1 and WR-2 (Fig. 2). We used the maximum-likelihood estimator method (Lenth 1981) in the software program Locate III (Nams 2006) to estimate locations and error ellipses for triangulations. We excluded all triangulations for which >50% of bearings received a rank of low confidence. Locations ≥ 1 km from the station to the transmitter also were excluded (Schmutz and White 1990). We used RangesIV (Kenward et al. 2003) to calculate incremental area analysis, home range, core area, and overlap among individuals. All analyses used a combination of nocturnal movement locations and diurnal locations obtained from trapping and homing. Because a given woodrat was often found multiple times at 1 house, we used only 1 diurnal location per house to avoid biasing core area estimates towards house locations, resulting in about 80% of locations being nocturnal.

MCP and FK methods were used to calculate home range and core area. MCP home range (95%) and core area (50%) were calculated using the arithmetic mean (Nams 2006). Incremental plots of home range size versus number of locations were inspected

for each individual using Ranges6 to check that the range area reached an asymptote; if an asymptote was not observed, then that individual was excluded from further analysis (Kenward 2001). We found that a minimum of 16 (mean=24.5±1.3) locations was required to reach an asymptote in home range area using MCP. In addition, woodrats that were radiocollared for <30 days were also excluded because of the short duration. Application of these criteria resulted in the exclusion of 12 collared woodrats (2 in 2004; 7 in 2005; 2 in 2006), all of which appeared to have been killed by predators shortly after collaring. In addition, 5 collared woodrats (2 in 2004; 3 in 2005; 0 in 2006) were excluded from analyses because they were transient or resided outside of the study areas. Fixed kernel volume contours (95% home range, 50% core area) were calculated utilizing the least-squares cross-validation method in Ranges6 for those animals with ≥30 locations (Seaman et al. 1999, Millspaugh et al. 2006); application of this criteria resulted in the exclusion of 17 additional individuals for FK analyses.

We calculated an index of overlap (OI; Minta 1992), with possible values ranging from 0 (no overlap) to 1 (100% overlap). For each study site and year, we calculated OI for home ranges and core areas for each male-male, male-female, and female-female pair. We only included woodrats whose home ranges overlapped with ≥1 other home range. All overlap calculations were based on MCP home ranges and core areas, rather than FK, because we did not want to exclude any potentially interacting individuals from overlap calculations, and to facilitate comparison with previous studies (e.g., McEachern 2005).

We assessed synchronous and asynchronous sharing and successive occupancy of houses by all radiocollared woodrats based on diurnal locations, when woodrats are inactive within their houses. Duration of house sharing was determined by assuming sharing occurred between successive radiolocations. We examined placement of houses within core areas using FK because it relies on probability distributions, which indicate areas of intense use (Seaman and Powell 1996).

All statistical tests were performed using JMP IN 5.1.2 (SAS Institute 2004) and significance was set at $\alpha=0.05$ and Bonferroni-corrected for multiple comparisons, when appropriate. Only 10% of woodrats were radiocollared for two consecutive years, thus we considered data from different years to be different samples. Differences among groups were analyzed using analysis of variance (ANOVA) after transformation to meet assumptions of normality (Kutner et al. 2005). The Wilcoxon rank scores test was used to test for differences between groups when data could not be transformed to meet assumptions of normality.

Vegetation

Long-term grids

Coppeto et al. (Publications #1 and #4) provides a detailed analysis of the macro- and microhabitat associations of the full compliment of small mammal communities within 18 long-term grids established within 5 habitat types in PNF during 2003-2004. A subset of the data that Stephanie A. Coppeto collected represents pre-treatment vegetation conditions within the 9 of the 12 experimental grids. In 2008 the Mammal Module staff

conducted a full resample of the 12 experimental grids. By strictly adhering to the macro- and microhabitat vegetation sampling protocols developed in Coppeto et al. (2006) we are able to fully analyze the effects of different forest management practices performed in PNF on the short-term responses of small mammal communities, vegetative cover, and their associations.

Vegetation Sampling. — In order to investigate immediate short-term responses of small mammal abundance in the fuel reduction treatments of the PNF, we systematically sampled for 23 micro and 27 macrohabitat variables within the experimental grids during the 2008 field season. 1440- 1 meter radius (3.14m^2) ground cover plots, 216 point centered quarter plots, and 1440 canopy photos, with generous help from the vegetation module, were collected. The suite (Table 1.) of microhabitat variables were collected using ocular estimations of vegetative cover in a layered fashion at or below breast height (1.4 meters) at each trap station ($n=120$) within a grid. Any understory vegetation occurring above breast height was sampled as canopy cover and included in a photo analysis. Canopy cover data was collected using a Nikon® digital camera affixed with a hemispherical lens mounted on an adjustable tripod and analyzed using Gap Light Analyzer, Version 2.0 (Frazer et al. 2000). The assemblage totaled 1.4 meters in height. Point centered quarter tree sampling was conducted in a stratified manner within each grid ($n=18$). The nearest tree (≥ 10 cm. diameter at breast height (DBH)) in each quadrant was sampled. Species, slope, aspect, distance, DBH, and height of each individual were collected. Slope was determined through the use of a clinometer, aspect with the use of a compass, distance using a transect tape, and DBH through the use of a pre-calculated DBH tape. Heights were determined by first training technicians, offsite, for ocular estimation. This was accomplished by measuring tree heights using a clinometer and meter tape and having technicians estimate heights prior to revealing actual tree heights to them. Tree heights were placed into five meter interval groups.

Cone Counts.—To evaluate the effects of conifer seed production on small mammal abundance, we measured cone production during fall of 2003, 2004, 2006, 2007, and 2008 using 10 randomly selected individual trees of each species on each long-term grid. For this we selected mature dominant or codominant trees with pointed crowns, as tall as or taller than the surrounding canopy, sufficiently far apart that their crowns did not touch. For grids with <10 individual trees of a given species, additional trees were found as close to the grid as possible (<500 m). The same trees were counted in each year within the same 2-wk period to prevent confounding temporal factors. Counting was performed by standing at a distance of ≥ 1.5 x the tree height and visually counting cones using binoculars. For each tree we recorded tree height, diameter at breast height (DBH), species, and crown class. Temporal differences in cone production were determined using repeated measures analysis of variance (rmANOVA) with year, habitat type, and species as treatments, and individually counted trees as the repeated measure.

Northern flying squirrels

Den use.—We documented northern flying squirrel den locations during homing activities, and a number of measurements were taken at these dens to determine the

micro-habitat preferences of flying squirrels. These data were used to test for tree use versus availability. DBH, species, condition (live tree, snag), den height, and type (cavity or external) of each den tree were recorded. We measured habitat characteristics at den locations and paired random points. Den plots were centered on the den tree, and paired with a plot whose outer edge intersected the outer edge of the den plot. All trees ≥ 10 cm DBH within an 18 m radius (0.1 ha) were measured and species recorded. Additionally, decay characteristics (fungi present, cavities) were noted and epiphyte loads estimated according to the methods of Bakker and Hastings (2002) to see if northern flying squirrels showed any preferential selection of den trees within sites. All trees < 10 cm DBH were tallied. Estimates were taken of ground cover to the nearest percent. Dominant over- and understory trees were recorded as well. Spherical densiometers were used to take canopy measurements in a randomly selected direction at the edge of the plot, with 3 successive measurements at 90° from the first. Canopy readings were also taken at the plot center. Two randomly chosen transects were used to estimate coarse woody debris. Degree of decay, length, diameter at both ends, and species were recorded. All woody debris ≥ 10 cm diameter at the largest end were measured and recorded. Percent slope at each site was estimated using a clinometer. In 2006, 38 flying squirrel dens and paired comparison plots had measurements taken. In 2007, measurements were taken at 40 dens and comparison plots.

Dusky-footed woodrats

Tree house characteristics and use.— We examined tree house characteristics and use during 2004 to 2006 at 2 study sites WR-1 and WR-2 (Fig. 3). Ground houses were those located on the soil surface or on downed wood. Tree houses were characterized as either built within a tree cavity or externally on limbs. For all tree houses, we recorded whether the tree was alive or a snag and the species of live trees. We measured diameter at breast height (dbh; cm) of a random sample of the trees in which houses were found (88% and 83% of house trees at study sites 1 and 2, respectively). We determined tree availability by counting all trees and snags (≥ 5 cm dbh) in randomly located, 4-m radius circular plots (72 at site 1, 77 at site 2), and recorded tree and snag characteristics for each plot. We based house use analyses on radiotelemetry locations during the daytime period of inactivity determined using homing. For each woodrat, we calculated the proportion of radio locations occurring at each house type (ground or tree), then averaged across individuals and years by sex. We tested for differences in tree house use between sexes each month using the Wilcoxon rank scores test. Because we found no difference in proportional availability and use of houses between sites, results from the 2 study sites were combined for all analyses.

RESULTS AND DISCUSSION

We have been making steady progress towards our objectives. In 2008, we completed several projects. In addition to successfully completing an extensive (1 May-1 October) field season, our study module has produced quality peer-reviewed publications and other products. In 2008, we had 2 manuscripts in publication, 1 manuscript in press, and several more in preparatory stages. We have chosen to present the abstracts of our published, submitted, or in preparation manuscripts herein as a representation of the work that we have completed to date.

2008 Field Season

During the 2008 field season we marked a total of 543 individuals over 1103 captures of 9 species. Predominant species in the study area were deer mice, brush mice, long-eared and Allen's chipmunks, California ground squirrels (*Spermophilus beecheyi*), golden-mantled ground squirrels, Douglas squirrels (*Tamiasciurus douglasii*), long-tailed voles (*Microtus longicaudus*), California red-backed vole (*Clethrionomys californicus*), and northern flying squirrels. Incidental mammals captured included shrews (*Sorex* sp.), striped skunk (*Mephitis mephitis*), snowshoe hare (*Lepus americanus*), and western gray squirrels (*Sciurus griseus*).

In 2008, abundance of *Peromyscus* sp. and *Tamias* sp. fell from levels observed in 2007 (Fig. 9 and 11 respectively). We noticed a marked increase in capture rate of northern flying squirrels at long-term grids in 2005, 2006, 2007, and 2008 (Fig. 13). However, during this time woodrat abundance at long-term grids steadily declined steadily (Fig. 15), and no woodrats were captured in 2008. The 2008 field season represents our first full year of post-treatment data collection. Trends in abundance of *Peromyscus* sp., *Tamias* sp., northern flying squirrel, and dusky-footed woodrat within treatment plots have mimicked trends observed within control plots (Fig. 10, 12, 14, and 16 respectively). Year continues to be a strong determining factor in small mammal abundance (e.g., Fig. 17). Long term monitoring of the experimental plots should distill the effects of treatment from the effects of year. Across all years sampled, biomass of PNF small mammal communities was greatest within red fir habitat (Fig. 18). Large abundances of large small mammal species, such as golden mantled ground squirrels and chipmunks, accounted for 42% and 49%, respectively, of the biomass in red fir habitat which contained 24% -36% greater total biomass than other forest types sampled (Table 3). Total biomass of key California spotted owl prey species was greatest in mixed fir habitat (Fig. 19) by 4%-8% over other forest types (Table 4). However, during 2008, in pine-cedar forest type all northern flying squirrels were captured on grid #7 in a gulch consisting of a mixed fir habitat. An increase in overall abundance trends of larger species, such as chipmunks and northern flying squirrels, has been observed (Fig. 8) and assumedly contributed significantly to the marked increase in biomass observed in all experimental plots post treatment (Table 5). Light thin and heavy thin plots increased at similar proportions to control sites. Conversely, group select sites exhibited a 30% increase in biomass compared to control plots. However, 75% of group select site biomass was contributed from a single white fir habitat site, "Toast" (grid #19) (Fig. 20). Figure 21 illustrates community abundance of closely clustered groups of control and experimental plots. The "Miller Fork" group, which contains group select "Toast", displayed 52% greater abundance in 2008 than group clusters "Dean's Valley" and "Snake Lake". The skew in 2008 group cluster abundances could explain a great deal of the marked increase in abundance and biomass in group selection plots.

Long-term grids

One of our objectives for the long-term grid data is to determine small mammal habitat associations at macro- and microhabitat scales (Objective #1). We have examined this at our long-term grids and include this summary herein (Publications #1 and #4). Another objective for our long-term grid data was to determine small mammal population trends,

evaluate how populations are changing temporally, and assess the factors responsible for the observed trends (Objective #5). We have documented the dynamics of small mammal abundance at long-term grids since 2003, and we have currently evaluated trends using data from 2003-2004, and include this summary herein (Publication #8). In 2007, the planned treatments were implemented and data on small mammals were collected immediately after the treatments were completed. During the 2008 field season we collected the first full year of post-treatment data. We will analyze data obtained at long-term grids pre-treatment (2003-2006) and post-treatment (2007-funding availability) to assess the impacts of forests management treatments on small mammal abundance and species diversity (Objective #4).

Publications #1 and #4: Habitat associations of small mammals at two spatial scales in the northern Sierra Nevada

Effective management strategies require an understanding of the spatial scale at which fauna use their habitat. Towards this end, small mammals were sampled in the northern Sierra Nevada, California, over 2 years (2003-2004) at 18 live-trapping grids among 5 forest types (Fig. 1a). Macrohabitats were defined by overstory tree composition, and 19 microhabitat variables were measured at all trap stations (Table 1). Macrohabitat and year explained 93% of variation in abundance of deer mice (*Peromyscus maniculatus*), whereas 69% was explained by microhabitat and year. Variation in abundance of *Tamias* sp. (long-eared and Allen's chipmunk) was slightly better explained by microhabitat and year (70%) than by macrohabitat and year (67%). Red fir forests supported significantly more mice and chipmunks than mixed conifer and pine-cedar forests, and more chipmunks than mixed fir forests. Five of 6 uncommon species were significantly associated with macrohabitat type; golden-mantled ground squirrels, northern flying squirrels, and *Microtus* sp. (long-tailed vole—*M. longicaudus*; Mountain vole—*M. montanus*) were captured almost exclusively in red fir forests, whereas dusky-footed woodrats and California ground squirrels were found in pine-cedar, mixed fir, and mixed-conifer forests. The first 2 axes of a canonical correspondence analysis on microhabitat variables explained 71% of variation in combined small mammal abundance. Microhabitat associations varied among species but were driven primarily by canopy openness, shrub cover, and shrub richness. Although much of the small mammal fauna appeared to select habitat at both spatial scales studied, CCA using macrohabitat as a covariate revealed that microhabitat explained much less of the variation in small mammal abundance than did macrohabitat. Still, the strongest scale of association may be species-dependent and hierarchical in nature.

Publication #8: Population dynamics of small mammals in relation to cone production in four forest types in the northern Sierra Nevada

We studied the small mammal assemblage in 4 forest types (white fir, red fir, Douglas fir, and ponderosa pine) in the Sierra Nevada of California for 2 consecutive field seasons (2003-2004). We also assessed cone production by dominant conifer species in both years. Cone production was greater overall in fall 2003, but varied within forest type and between conifer species (Fig. 4). Parallel to this, mean maximum densities of deer mice increased in 2004 (from 0.7 - 7.3 ind./ha to 65.7 - 112.7 ind./ha; Fig. 5). Numbers of golden-mantled ground squirrels were similar in both years, and displayed the typical

pattern of a hibernating species, with low densities in May (6.6 ± 0.2), peak densities in September ($24.5 - 32.5$ ind./ha), and declines in October (9.2 ± 4.8 ; Fig. 6). Long-eared chipmunks reached higher densities in red fir (48.2 ± 13.4 ind./ha) and Douglas-fir forests (36.0 ± 13.5 ind./ha) than in white fir forests (7.6 ± 2.7 ind./ha), and all populations peaked in September. Allen's chipmunk remained at lower densities than long-eared chipmunks except during September 2004, when populations of the former reached high densities (54.6 ± 26.8 ind./ha; Fig. 7). Survival of deer mice was dependant on an interaction between forest type and month with additive effects of winter and 2003 fall mean cone production. Golden-mantled ground squirrel survival varied by month whereas survival in both species of chipmunk varied by an interaction of forest type and month + winter (Table 2). Dusky-footed woodrats were present at lower elevations and reached greatest densities in ponderosa pine forests. Northern flying squirrels were uncommonly captured and found predominantly in red fir forests.

Publication #9: Trapping rodents in a cautious world: the effects of disinfectants on trap success.

Recommendations for hantavirus prevention include disinfecting traps that have captured small mammals. However, the potential effects of disinfection on small mammal trappability have not been thoroughly investigated. We conducted an experiment to compare the effects of 2 disinfectants (Lysol and household bleach) on trappability of 3 small mammal species (deer mice, chipmunks, and golden-mantled ground squirrels). We established triplicate trap grids in 2 forest types (red fir and mixed conifer), each consisting of a 6 x 6 array of Sherman live traps placed at 10 m intervals. Traps were given 1 of 3 treatments: control (water), Lysol, or bleach; and were placed such that the 3 treatments alternated in a regular pattern. Traps were run for 4 consecutive nights with application of each treatment daily. We found a difference in the trappability of deer mice between years; however we did not detect a statistically significant difference in trappability due to disinfection for any of the 3 study species. Within deer mice, disinfectant effects on capture probability were not supported by model selection in Program MARK. These results indicate that although populations may fluctuate temporally and spatially, trap disinfection does not have a significant effect on small mammal trappability.

Northern flying squirrels

We have captured and radiotracked northern flying squirrels since 2004 in an effort to evaluate the abundance and distribution, habitat use, and home range of this important species (Objective #6). We have examined data from 2004-2005 and include this summary herein (Publication #7). We continued these efforts during 2006 and 2007 to increase our sample size and improve our statistical power; 2007 marks the final year of northern flying squirrel radiotracking. Data from 2006 and 2007 will be included in an additional publication (Publication #3).

Publication #7: Home range and activity of northern flying squirrels in the northern Sierra Nevada

We studied the northern flying squirrel in PNF using radiotelemetry. Fourteen northern flying squirrels from 2 forest types (mixed conifer and red fir) were fitted with radiocollars and provided sufficient locations for home range analysis. We used 95% adaptive kernel and 95% minimum convex polygon (MCP) analysis to determine home ranges. No sex differences and no differences in forest type were observed for home range size. Mean kernel home range size was 25.7 ha for all squirrels. Mean distance to the nearest nest tree did not vary throughout the night; however, females tended to travel greater distances from nest trees.

Publication #3: Home range and habitat selection of northern flying squirrels in the northern Sierra Nevada

Average home range size for northern flying squirrels during 2006 using 95% Minimum Convex Polygon (MCP) was $9.12 \text{ ha} \pm 2.41$ and using 95% Fixed Kernel (FK) was $13.89 \text{ ha} \pm 4.18$. In 2007, average home range size for northern flying squirrels using 95% MCP was $8.73 \text{ ha} \pm 1.13$ and using 95% FK was $9.83 \text{ ha} \pm 1.32$. Mean home range size across years (2006-2007) using 95% MCP is $8.84 \text{ ha} \pm 1.02$ and 10.99 ± 1.51 using FK. Each year, females were larger than males (2006: $\bar{x}_{\text{fem}} = 122.2 \text{ g}$, $\bar{x}_{\text{male}} = 102.0 \text{ g}$; $P < 0.0001$; 2007: $\bar{x}_{\text{fem}} = 129.7 \text{ g}$, $\bar{x}_{\text{male}} = 103.6 \text{ g}$; $P = 0.0039$); however, home ranges of females and males were similar ($P = 0.41$).

Most dens ($n=53$) were located in cavities (49%), but some were external stick nests located on the limbs of trees (12%); 39% could not be identified because they were not visible to the observer. Preliminary results obtained using 53 dens and 53 paired random plots indicate that dens were distributed amongst various tree species and size classes. Most den trees were located in white fir (28%) and California black oak (26%; Table 7). However, comparison of use and availability indicate that California black oak may be used preferentially for den sites (Fig. 25). Many den trees were located in large sawtimber ($\geq 53.4 \text{ cm dbh}$, 44%), but poletimber (10-27.9 cm dbh, 35%) and small sawtimber (28-53.3 cm dbh, 21%) were also used. Comparison of use and availability indicate that northern flying squirrels are using larger trees than those available (Table 7).

Dusky-footed woodrats

We have captured and radiotracked dusky-footed woodrats since 2003 in an effort to evaluate the abundance and distribution, habitat use, and home range of this important species (Objective #6). To date, we have examined vegetation data obtained during 2004-2005 and include this summary herein (Publications #2, #5, and #6). In 2007, we prepared a manuscript on the spatial organization of dusky-footed woodrats (Publication #11). The 2006 field season marked the final year of data collection, so that we might focus our efforts on northern flying squirrel ecology during 2007 and analyze data obtained on woodrats from previous years.

Publication #2 and #5: Habitat selection by dusky-footed woodrats in managed mixed-conifer forest of the northern Sierra Nevada

Dusky-footed woodrats are important components of forest communities, including serving as a primary prey of the California spotted owl, a species of concern in California. We examined the macro- and microhabitat associations of the dusky-footed woodrat at 4 study sites within mixed-conifer forest of the northern Sierra Nevada, California, during 2003–2005. We investigated the importance of California black oak as a macrohabitat component for woodrats, and we examined microhabitat selection at 2 levels, house location and house use, by comparing house-site ($n = 144$) characteristics to random sites ($n = 144$) and characteristics of used and unused houses, respectively. We found a strong trend towards a positive relationship between woodrat density and large (≥ 33 cm diameter at breast height) oak density, suggesting that large oaks are an important macrohabitat component for woodrats, probably because of their value as a food resource. At the microhabitat scale, house location was strongly influenced by the presence of large (≥ 30 cm diameter at root collar) stumps, but also by abundance of logs, steeper slopes, and lack of bare ground and mat-forming shrub cover. Houses used by adults were not distinguishable from unused houses on the basis of microhabitat variables, suggesting that woodrats make decisions about microhabitat conditions at the time a house is built. Adult and subadult woodrats selected houses with different microhabitat characteristics, but this pattern was not consistent between years. In 2005, adults chose larger houses that were characterized by more logs and less pole timber, but we detected no such differences in 2004. Dusky-footed woodrats in the northern Sierra Nevada would benefit from management techniques that promote the growth and retention of large California black oaks and create abundant dead wood within a stand.

Publication #6: Characteristics and use of tree houses by dusky-footed woodrats in managed mixed-conifer forest of the northern Sierra Nevada

Dusky-footed woodrats are important components of forest communities, including serving as a primary prey of the California spotted owl, a species of concern in California. Because previous studies have focused on the more “typical” ground houses, little is known about tree houses, perhaps because their inconspicuous nature makes them difficult to locate (Fargo and Laudenslayer 1999). Our objective was to describe locations of tree houses and determine if dusky-footed woodrats used these houses preferentially.

Most houses ($n=252$) were located on the ground (58%), but many were also located in cavities of trees or snags (27%) or on the limbs of live trees (15%). Three houses were located aerially in shrubs (hence neither ground nor tree), and were excluded from analyses. Tree houses were located primarily in white fir, Douglas-fir, California black oak, and snags (Table 8). Comparison of use and availability suggests that white fir were preferred as locations for houses constructed on limbs. White fir were mostly smaller, understory trees with splayed branches suitable for supporting the woody debris used in house construction. Large California black oaks and snags were strongly preferred as sites for cavity houses, probably because their size and tendency to decay resulted in formation of cavities of sufficient size for constructing houses.

Individual woodrats used as many as 3 tree houses and 8 ground houses, and use of tree houses was common, with 70% of males and 73% of females using at least 1 tree house. We expected that tree houses might provide increased protection from predation, because houses on the ground were vulnerable to destruction by black bears, or provide better access to arboreal food sources. However, woodrats did not spend more time at tree houses than expected on the basis of availability (Table 9). Among tree houses, cavity locations seemed preferred to limb locations when compared with availability, perhaps because cavity locations were more protected, and there was some evidence that females used cavity locations more frequently than did males (Table 9). Use of tree houses increased during the late summer with a peak in October (Fig. 26), possibly because mast availability in the fall increased arboreal foraging opportunities. Females used tree houses more frequently than did males during June ($Z = -2.13$, $P = 0.032$) and July ($Z = -0.222$, $P = 0.026$), coincident with the time of reproduction, perhaps because tree houses offer enhanced protection for unweaned offspring.

Our results suggest that tree houses are a prevalent and frequently used resource for dusky-footed woodrats in mixed-conifer forest of the northern Sierra Nevada. Tree house use is most prevalent during late summer and fall, and large California black oaks and snags are the most important forest elements for tree house location because of the protected sites provided by their cavities.

Publication #11: Spatial organization of dusky-footed woodrats in managed mixed-conifer forest of the northern Sierra Nevada

We studied the spatial organization of dusky-footed woodrats (*Neotoma fuscipes*) in mixed-conifer forest of the northern Sierra Nevada, California by radiotracking 63 adult woodrats at 2 study sites (Fig. 2.) during May–Oct, 2004–2006. Home range and core area estimates differed between study sites, but they were within the range reported elsewhere; variability in home range size was explained in part by density (Table 10.). Woodrat home ranges overlapped with multiple neighboring woodrats (Fig. 27.), both same-sex and opposite-sex, suggesting that foraging areas were shared. However, core areas showed little overlap between same-sex neighbors. Woodrats occupied multiple houses and frequently moved among them, and sharing of houses (either simultaneously or nonsimultaneously) with neighboring woodrats was common but occurred mostly between male-female pairs (Fig. 28.). Females typically shared their core area and houses with 1 male, whereas males shared core areas and houses with multiple females; further, males moved more than females. Our results suggest that dusky-footed woodrats are semi-territorial, maintaining near-exclusive use of their core area and houses against same-sex conspecifics, and that the mating system likely is polygynous.

Golden-mantled ground squirrels

We captured and radiotracked golden-mantled ground squirrels during 2003–2005. Data analysis and manuscript preparation took place in 2009; no additional data has been collected since 2005. The following summary (Publication #8) represents the culmination of this work.

Publication #8: Spatial-organization and dispersal of golden-mantled ground squirrels (*Spermophilus lateralis*): questioning asociality in a small spermophiline.

Social-organization and dispersal patterns indicate that *Spermophilus lateralis* exhibit single family female kin clustering rather than complete asociality. A great deal of home range overlap (FK- mean IO 0.31 ± 0.20 SD, range 0.00-0.69; MCP- mean IO 0.28 ± 0.22 , range 0.00-0.81) and core area territoriality (FK- mean IO 0.03 ± 0.08 SD, range 0.00-0.43; MCP- mean IO 0.01 ± 0.03 , range 0.00-0.17) is observed. 40% of juveniles remained philopatric in their first year. Juvenile males dispersed more often (75%) whereas juvenile females tended to remain philopatric (62%). Dimorphic dispersal behavior in a population where males are dispersing further and more often than females results in increased female kin proximity, or “clustering”, promoting social interaction. Further clarification of kin and non-kin spatial organization and interaction will be necessary to determine whether *S. lateralis* should truly be placed at Michener’s (1983) social grade of 1-“asocial” or 2-“single family female kin clusters”.

Chipmunks

We have live-trapped chipmunks at long-term grids, land bird grids, and flying squirrel transects since 2003. One of our objectives was to evaluate the habitat affinities of 2 species found commonly in PNF, long-eared and Allen’s chipmunks, using data obtained from long-term grids during 2003-2004 (Objective #8). The following (Publication #10) is a summary of these results.

Publication #10: A multiple spatial scale perspective of the habitat affinities of sympatric long-eared and Allen’s chipmunks.

Sympatric species that are similar in body mass, diet, and general resource utilization are likely to compete locally. Similar species often coexist by partitioning habitat. However, detecting differences in habitat affinities is influenced by spatial scale. We investigated the habitat associations of two ecologically similar chipmunk species – the long-eared chipmunk and the Allen’s chipmunks – at three spatial scales in the northern Sierra Nevada, California. Locally, we censused these species over two years at 18 trapping grids, and recorded 19 microhabitat metrics at all trap stations. At a macrohabitat scale, we assessed relative abundances at different study sites as a function of forest type. Finally, at a landscape (e.g., geographic range) scale we examined digital vegetation information and calculated extent of range overlap. At this largest spatial scale, both species showed similar habitat affinities, with extensive overlap in distribution within the Sierra Nevada. At the macrohabitat scale, both the species reached their highest mean abundance in red fir forests but showed divergent secondary affinities. At the microhabitat scale, however, habitat affinities differed significantly. Logistic regression models indicate that microhabitat presence of long-eared chipmunks was associated positively with open canopies, cover by rocks, and multiple sapling species, and negatively with east and south facing, steep slopes. Allen’s chipmunks shared the affinity for open canopies but differed in exhibiting a preference for traps on south facing slopes with multiple shrub species, and aversion to traps on hard substrates covered by litter and vegetation mats (e.g., Mahala mat—*Ceanothus prostratus*). Affinities at micro- and macrohabitat scales varied between sampling years, indicating that these species

retain a degree of flexibility in habitat associations while maintaining segregation and minimizing the potential for competition.

2009 Field Season

We continued to capture, record external characteristics, and collect tissue samples from chipmunks while performing live-trapping duties at long-term grids. In future analyses we hope to evaluate our technique of determining chipmunk species using external characteristics.

COLLABORATION

We have continued to maintain and improve collaborative efforts with all PLAS Modules. Most notably, we improved collaboration with the Land bird Module in 2006 and 2007 by establishing temporary trapping grids at songbird census stations. We plan to begin live trapping on the land bird transects once again in 2009 based on the availability of funding. Vegetation and Fuels Modules have collected and continue to collect vegetation, fire and fuels, and microclimate data within some portion of our long-term and land bird trapping grids. In 2008 the Vegetation Module provided the Mammal Module with training, equipment, and data in our effort to collect post-treatment vegetative data in the long term grids. We are currently coordinating an effort in which the Mammal Module will provide valuable feedback to the remote sensing analyses and resultant models developed by the Fire and Fuels Module. In 2008, we continued to collaborate closely with the directors of the University of California Davis McLaughlin Reserve, Cathy Koehler and Paul Aigner, who provided space to train our field crew prior to our housing becoming available at the University of California, Berkeley Forestry Camp. In exchange for housing and training facilities, we provided information on the abundance and distribution of small mammal species within a long-term study grid established on the reserve. We collaborate with the University of Idaho for molecular analyses to determine chipmunk species identification and worked together with them to secure outside funding for these analyses. Lastly, we work closely with the University of California Davis Museum of Wildlife and Fish Biology to preserve specimens for research and educational purposes.

PUBLICATIONS

Theses

1. Coppeto, 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, 39 pp.
2. Innes, R.J. 2006. Habitat selection by dusky-footed woodrats in managed, mixed-conifer forest of the northern Sierra Nevada. M.S. Thesis, University of California, Davis, 31 pp.
3. Smith, J.R. *In Prep*. Home range and habitat selection of the northern flying squirrel (*Glaucomys sabrinus*) in northeastern California. M.S. Thesis, University of California, Davis. Winter 2009.

Peer-reviewed

4. Coppeto, S. A., D. A. Kelt, D. H. Van Vuren, J. A. Wilson, S. Bigelow, and M. L. Johnson. 2006. Habitat associations of small mammals at two spatial scales in the northern Sierra Nevada. *Journal of Mammalogy* 87:402-416.
5. Innes, R. J., D. H. Van Vuren, D. A. Kelt, M. L. Johnson, J. A. Wilson, P. A. Stine. 2007. Habitat selection by dusky-footed woodrats in managed, mixed-conifer forest of the northern Sierra Nevada. *Journal of Mammalogy* 88(6): 1523-1531.
6. Innes, R. J., D. H. Van Vuren, D. A. Kelt. 2008. Characteristics and use of tree houses by dusky-footed woodrats in the northern Sierra Nevada. *Northwestern Naturalist* 89(2).
7. Wilson, J. A., D. A. Kelt, and D. H. Van Vuren. 2008. Home range and activity of northern flying squirrels (*Glaucomys sabrinus*) in the Sierra Nevada. *Southwestern Naturalist*.
8. Wilson, J. A., D. A. Kelt, D. H. Van Vuren, and M. Johnson. 2008. Population dynamics of small mammals in relation to cone production in four forest types in the northern Sierra Nevada, California. *The Southwestern Naturalist* 53(3): 346-356.
9. Innes, R. J., D. H. Van Vuren, D. A. Kelt, M. L. Johnson, and J. A. Wilson. *In Prep.* Spatial organization of the dusky-footed woodrat (*Neotoma fuscipes*) in mixed-conifer forests of the northern Sierra Nevada. *Journal of Mammalogy*. Winter 2008.

Submitted

10. Mabry, K.E., and Wilson, J. A. *Submitted*. Trapping rodents in a cautious world: the effects of disinfectants on trap success. *American Midland Naturalist*.

In Preparation

11. Coppeto, S. A., D. A. Kelt, D. H. Van Vuren, J. Sullivan, J. A. Wilson, and N. Reid. *In Prep.* Different scales tell different tales: niche conservatism vs. niche differentiation in chipmunks in the northern Sierra Nevada. To be determined. Spring 2009.
12. Jesmer, B. J., D. A. Kelt, and D. H. Van Vuren. *In Prep.* Asociality: home range and dispersal of golden-mantled ground squirrels (*Spermophilus lateralis*). To be determined. Spring 2009.

PRESENTATIONS

1. Coppeto, S. A., D. A. Kelt, J. A. Wilson, D. H. Van Vuren, and M. L. Johnson. 2004. Habitat selection by small mammals in the northern Sierra Nevada, California. Poster to the American Society of Mammalogists, Annual Meeting, Arcata, CA.

2. Coppeto, S. A., D. A. Kelt, D. H. Van Vuren, J. A. Wilson, S. Bigelow, and M. L. Johnson. 2005. Spatial scale and habitat use of small mammals in the northern Sierra Nevada, California. Poster to the American Society of Mammalogists, Annual Meeting, Springfield, MO.
3. Innes, R. J., D. H. Van Vuren, J. A. Wilson, D. A. Kelt, and M. B. Johnson. 2004. Factors affecting the distribution and use of dusky-footed woodrat (*Neotoma fuscipes*) houses. Poster to the American Society of Mammalogists, Annual Meeting, Arcata, CA.
4. Innes, R. J., D. H. Van Vuren, J. A. Wilson, D. A. Kelt, and M. B. Johnson. 2005. Space use and social organization of dusky-footed woodrats (*Neotoma fuscipes*) in mixed-conifer forests of the northern Sierra Nevada. Poster to the American Society of Mammalogists, Annual Meeting, Springfield, MO.
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6. Smith, J.R.. 2006. Ecology of *Glaucomys sabrinus*: habitat, demography, and community relations. Presentation to the American Society of Mammalogists, Annual Meeting, Springfield, MO.
7. Wilson, J.A., and K.E. Mabry. 2005. Trap disinfection to reduce Hantavirus risk: does it also reduce small mammal trapability? Presentation to the American Society of Mammalogists, Annual Meeting, Springfield, MO.
8. Wilson, J. A., D. A. Kelt, and D. H. VanVuren. 2005. Effects of maternal body condition on offspring dispersal in golden-mantled ground squirrels (*Spermophilus lateralis*). Presentation to the American Society of Mammalogists, Annual Meeting, Springfield, MO.
9. Wilson, J. A., D. A. Kelt, and D. H. VanVuren. 2005. Effects of maternal body condition on offspring dispersal in golden-mantled ground squirrels (*Spermophilus lateralis*). Presentation to the IX International Mammalogical Conference, Sapporo, Japan.
10. Wilson, J. A., D. A. Kelt, and D. H. Van Vuren. 2006. Home range and activity of the northern flying squirrel (*Glaucomys sabrinus*) in the northern Sierra Nevada. Poster to the American Society of Mammalogists, Annual Meeting, Amherst, MA.

PERSONNEL

This project is currently coordinated and supervised by Brett Jesmer. Field work in 2008 was conducted by Brett Jesmer, Sarah Chinn, Sean Bogle, and Jessica Wright. This study was carried out under the guidance of Dr. Douglas Kelt, Dr. Dirk Van Vuren, and Dr. Michael Johnson, professors at the University of California Davis.

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FIGURE LEGENDS

Fig. 1. — Map of long-term grids in Plumas National Forest with a) locations of 18 long-term grids in 5 forest types and b) trap configuration within a long-term grid. Inset shows the location of the Forest in California. Map extracted from Coppeto et al. (2006).

Fig. 2.— Map of 4 dusky-footed woodrat study areas in Plumas National Forest (PNF), California. Numbers indicate study site location. Inset shows the location of PNF in California. Map extracted from Innes et al. (2007).

Fig. 3-- Map of 4 northern flying squirrel study areas in Plumas National Forest (PNF), California. Squares and circles indicate the location of study sites and major towns, respectively.

Fig. 4.—Mean fall cone production by the major conifers at long-term grids (n=18). Means were derived by counting cone production on 10 individual trees/species on each grid and averaging across forest types. Cones were counted visually during the fall of 2003 and 2004. Statistically significant differences are represented by different letters within each species and in each year.

Fig. 5.— Mean monthly density (A) and survival (B) of deer mouse populations inhabiting four forest types in Plumas National Forest, California: white fir, Douglas-fir, red fir, and ponderosa pine. Population estimates were obtained using long-term grid data and program MARK. Populations were monitored from June 2003 to October 2004.

Fig. 6. — Mean monthly density (A) and survival (B) of golden-mantled ground squirrel populations inhabiting red fir forests in Plumas National Forest, California. Population estimates were obtained using long-term grid data and program MARK. Populations were monitored from June 2003 to October 2004.

Fig. 7.—Mean monthly density of (A) long-eared chipmunk and (B) Allen's chipmunk, inhabiting three forest types (white fir, red fir, Douglas-fir) in Plumas National Forest, California. Density estimates were obtained using long-term grid data and program MARK. Populations were monitored from June 2003 to October 2004.

Fig. 8.—Overall mean abundance of mice, chipmunks, northern flying squirrels, and dusky-footed woodrats regardless of habitat or treatment type in Plumas National Forest, California, during 2003-2008.

Fig. 9.— Mean abundance of mice (*Peromyscus sp.*) across 5 forest types within Plumas National Forest, California, during 2003-2008.

Fig. 10.—Mean abundance of mice (*Peromyscus sp.*) pre and post treatment within the Plumas National Forest, California, during 2005-2008.

Fig. 11.— Mean abundance of chipmunks (*Tamias sp.*) across 5 forest types within the Plumas National Forest, California, during 2003-2008.

Fig. 12.— Mean abundance of chipmunks (*Tamias sp.*) pre and post treatment within the Plumas National Forest, California, during 2005-2008.

Fig. 13.— Mean abundance of northern flying squirrels across 5 forest types within the Plumas National Forest, California, during 2005-2008.

Fig. 14. — Mean abundance of northern flying squirrels (*Glaucomys sabrinus*) pre and post treatment within the Plumas National Forest, California, during 2005-2008.

Fig. 15.— Mean abundance of dusky-footed woodrats across 5 forest types within the Plumas National Forest, California, during 2003-2008.

Fig. 16.-- Mean abundance of dusky-footed woodrats (*Neotoma fuciceps*) pre and post treatment within the Plumas National Forest, California, during 2005-2008.

Fig. 17.—General relationships between mean mouse (*Peromyscus sp.*) mean abundance, mean annual cone production, and mean annual snow fall from 2003-2008. Note: lag in response to mean conifer cone abundance and immediate response to annual snow fall.

Fig. 18-- Mean annual biomass of small mammal species from 2003-2008; summarized across 5 forest types.

Fig. 19-- Mean annual biomass of key spotted owl prey species (mice, northern flying squirrel, and dusky-footed woodrat) from 2003-2008; summarized across 5 forest types.

Table 5. -- Mean annual biomass (g) of all species in experimental plots pre and post treatment.

Fig. 20— Mean annual post treatment biomass in the 3 experimental group select plots.

Fig. 21— 2008 MNKA summarized by experimental plot “clusters”, Dean’s Valley (DV), Snake Lake (SL), and Miller Fork (MF).

Fig. 22. —95% minimum convex polygon (MCP) graphic output for home range analysis for a single animal. Calculating the area within the polygon can be useful to determine what type or area an animal needs to exist. Quality of foraging land can be elucidated as well if MCP area varies between sites.

Fig. 23. —95% fixed kernel (FK) estimator from the same animal from Figure 22. Like contours on a topographic map, each line represents the degree of usage of the home range by the animal. As you move from the exterior to the interior, the animal utilizes the area more frequently.

FIGURES

Fig. 1. — Map of long-term grids in Plumas National Forest with a) locations of 18 long-term grids in 5 forest types and b) trap configuration within a long-term grid. Inset shows the location of the Forest in California. Map extracted from Coppeto et al. (2006).

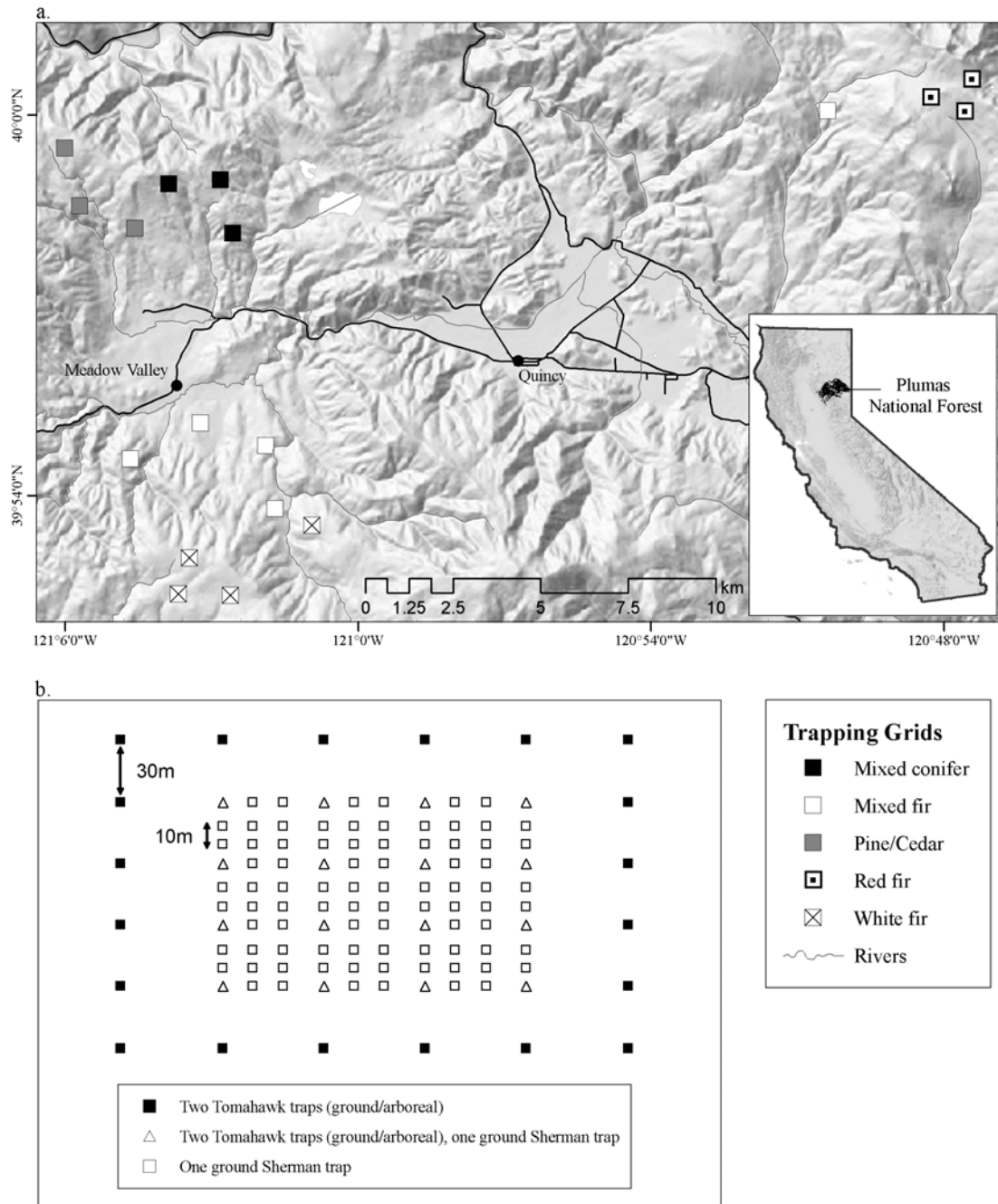


Fig. 2.— Map of 4 dusky-footed woodrat study areas in Plumas National Forest (PNF), California. Numbers indicate study site location. Inset shows the location of PNF in California. Map extracted from Innes et al. (2007).

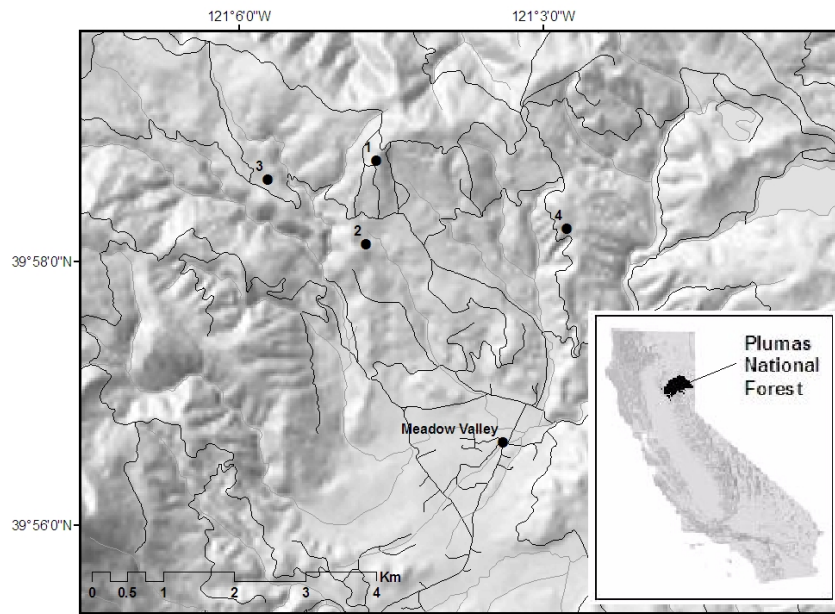


Fig. 3-- Map of 4 northern flying squirrel study areas in Plumas National Forest (PNF), California. Squares and circles indicate the location of study sites and major towns, respectively.

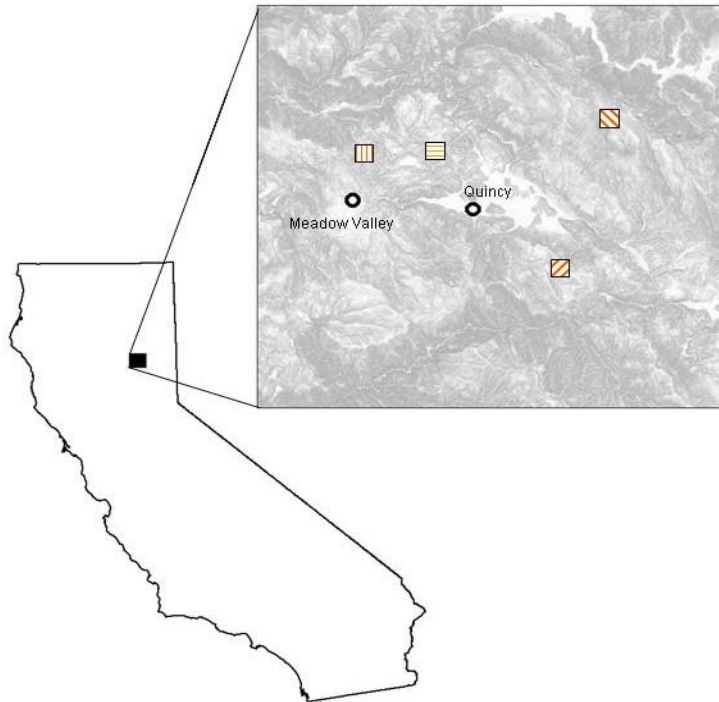


Fig. 4.—Mean fall cone production by the major conifers at long-term grids (n=18). Means were derived by counting cone production on 10 individual trees/species on each grid and averaging across forest types. Cones were counted visually during the fall of 2003 and 2004. Statistically significant differences are represented by different letters within each species and in each year.

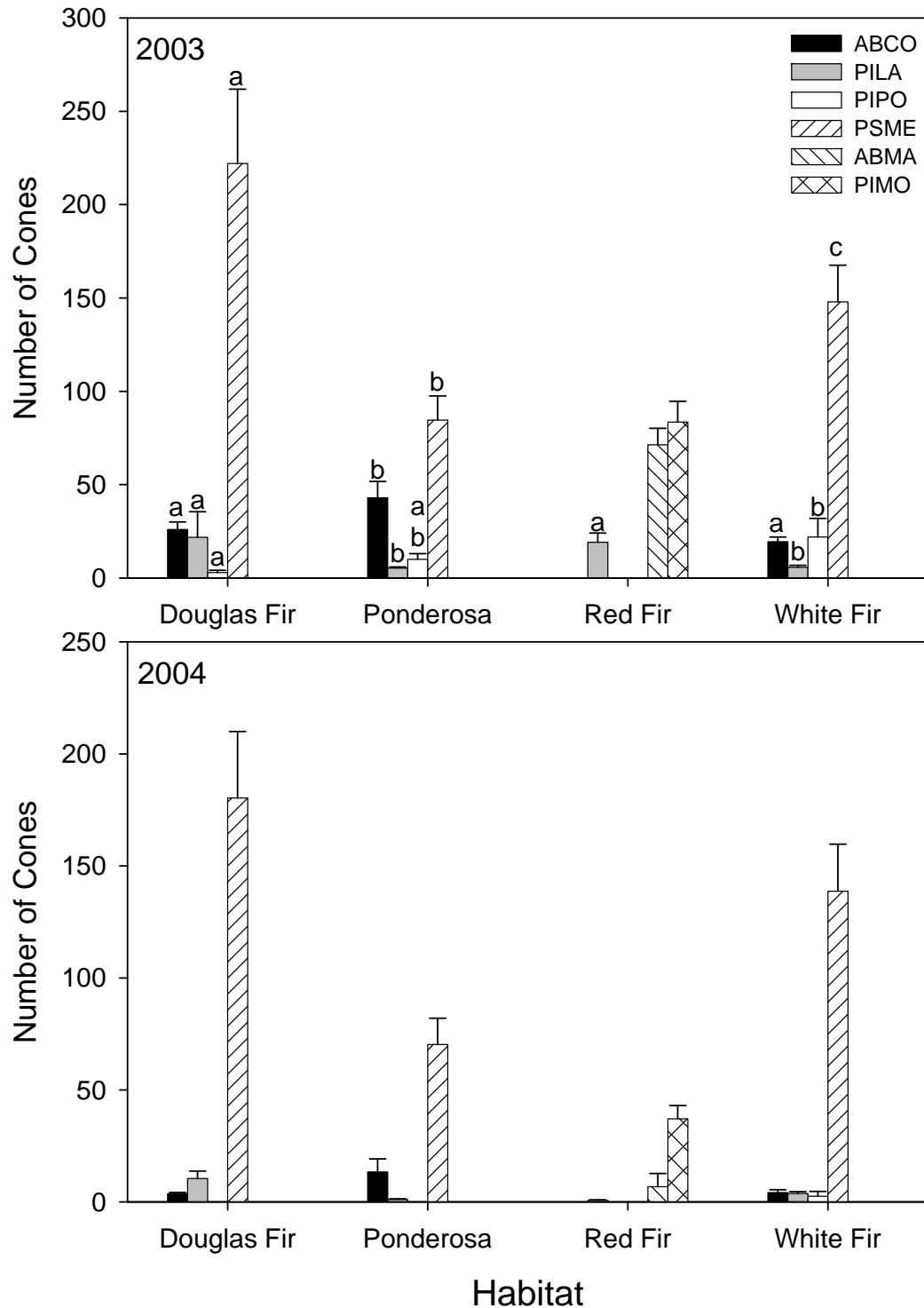


Fig. 5.— Mean monthly density (A) and survival (B) of deer mouse populations inhabiting four forest types in Plumas National Forest, California: white fir, Douglas-fir, red fir, and ponderosa pine. Population estimates were obtained using long-term grid data and program MARK. Populations were monitored from June 2003 to October 2004.

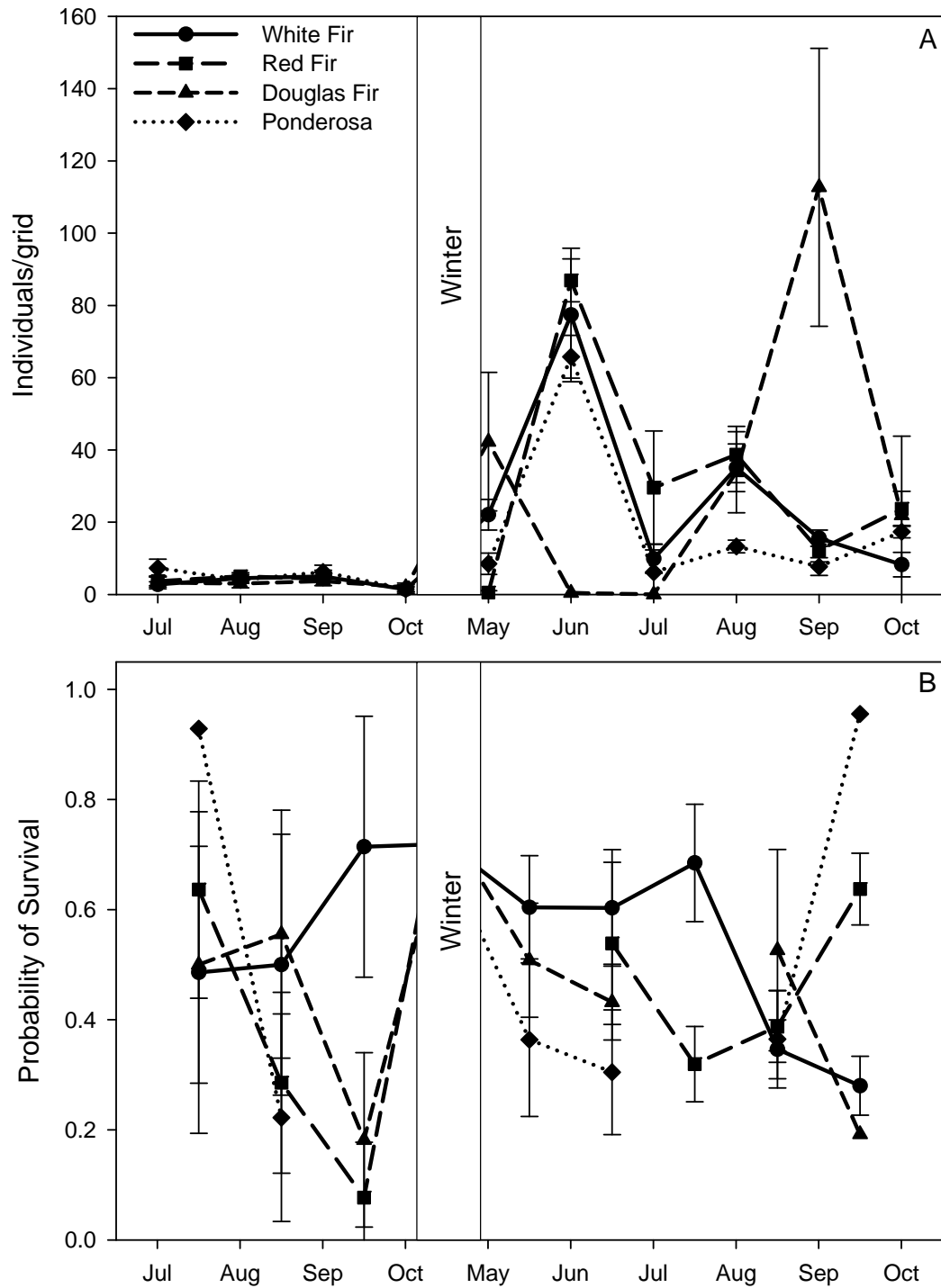


Fig. 6. — Mean monthly density (A) and survival (B) of golden-mantled ground squirrel populations inhabiting red fir forests in Plumas National Forest, California. Population estimates were obtained using long-term grid data and program MARK. Populations were monitored from June 2003 to October 2004.

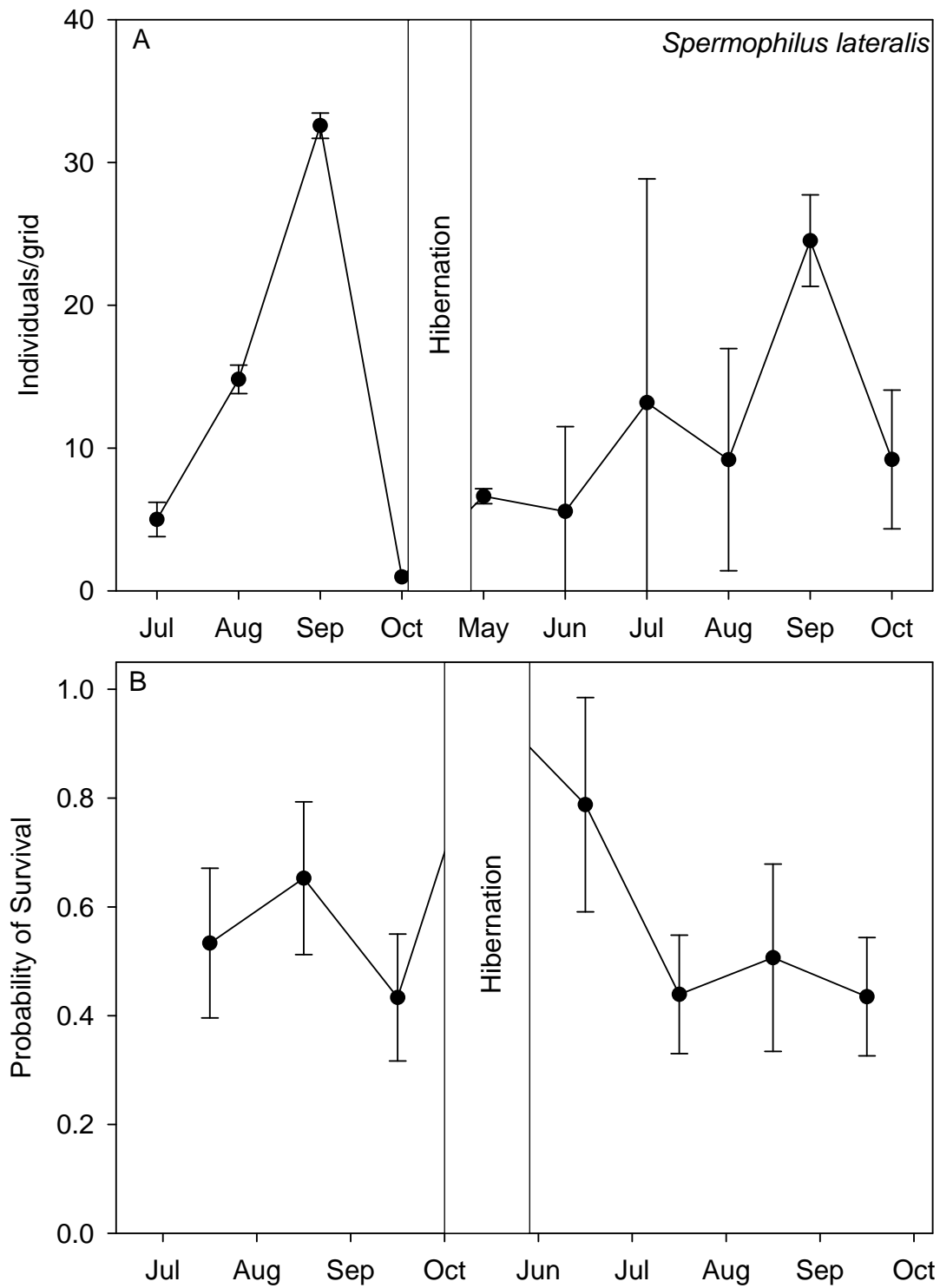


Fig. 7.—Mean monthly density of (A) long-eared chipmunk and (B) Allen’s chipmunk, inhabiting three forest types (white fir, red fir, Douglas-fir) in Plumas National Forest, California. Density estimates were obtained using long-term grid data and program MARK. Populations were monitored from June 2003 to October 2004.

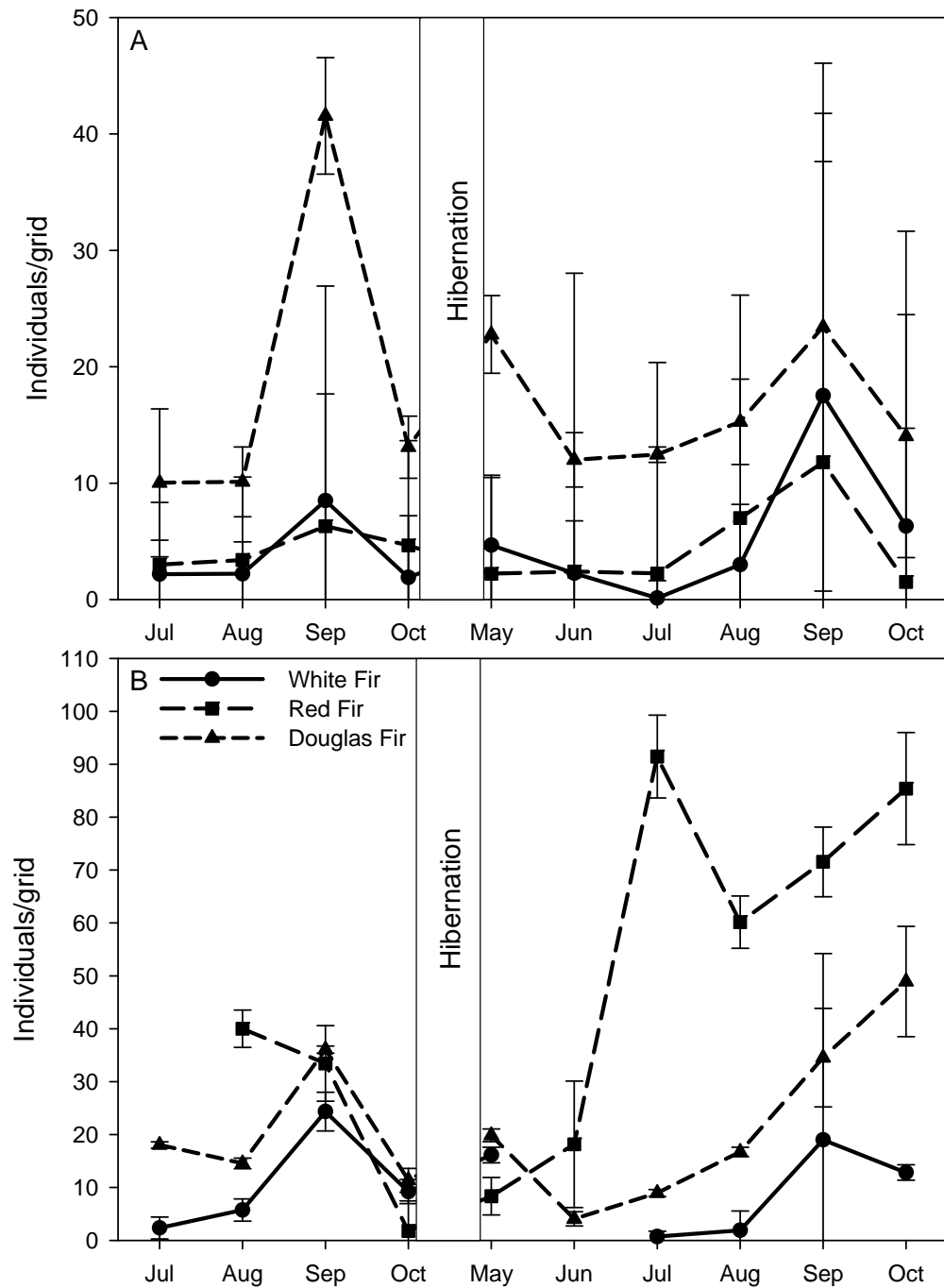


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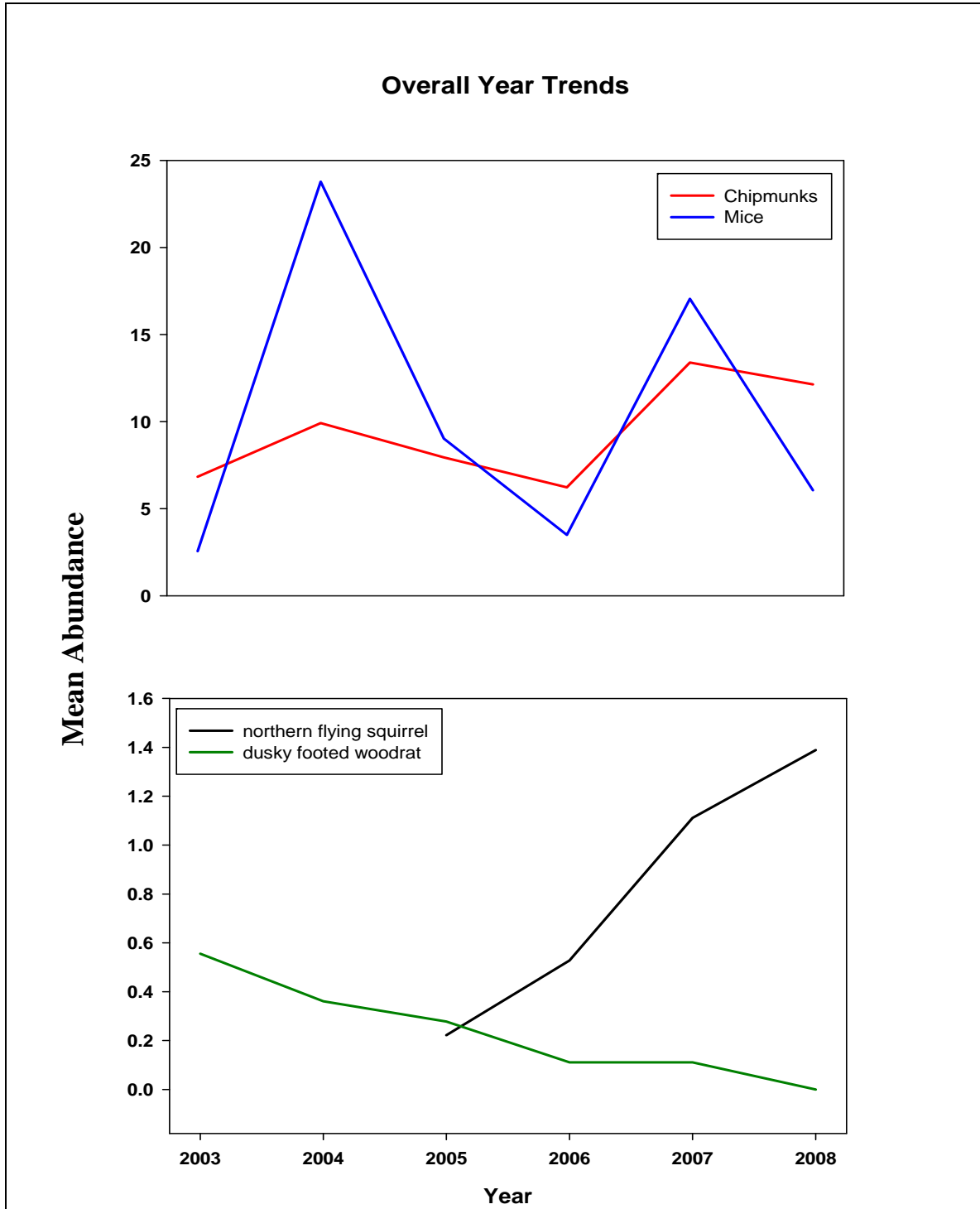


Fig. 9.— Mean abundance of mice (*Peromyscus sp.*) across 5 forest types within Plumas National Forest, California, during 2003-2008.

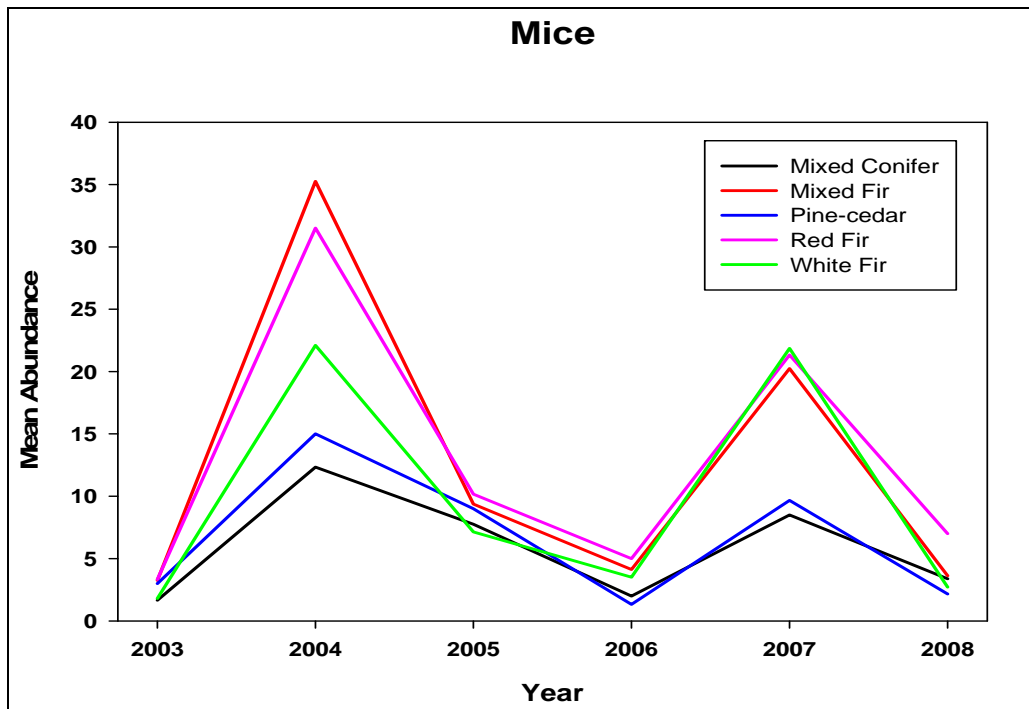


Fig. 10.—Mean abundance of mice (*Peromyscus sp.*) pre and post treatment within the Plumas National Forest, California, during 2005-2008.

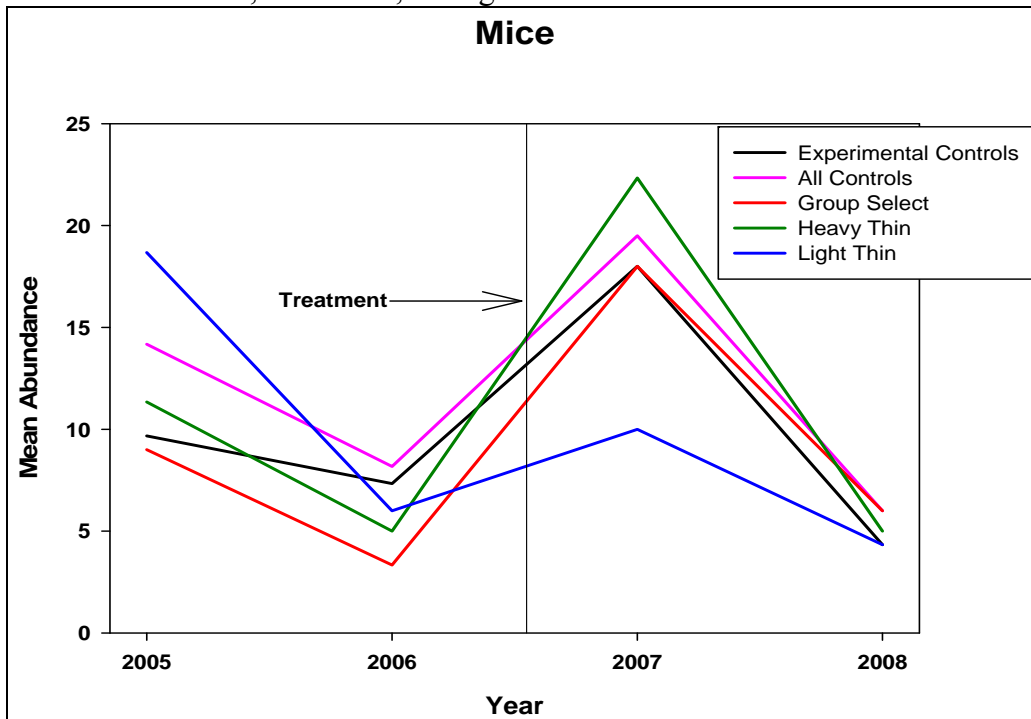


Fig. 11.— Mean abundance of chipmunks (*Tamias sp.*) across 5 forest types within the Plumas National Forest, California, during 2003-2008.

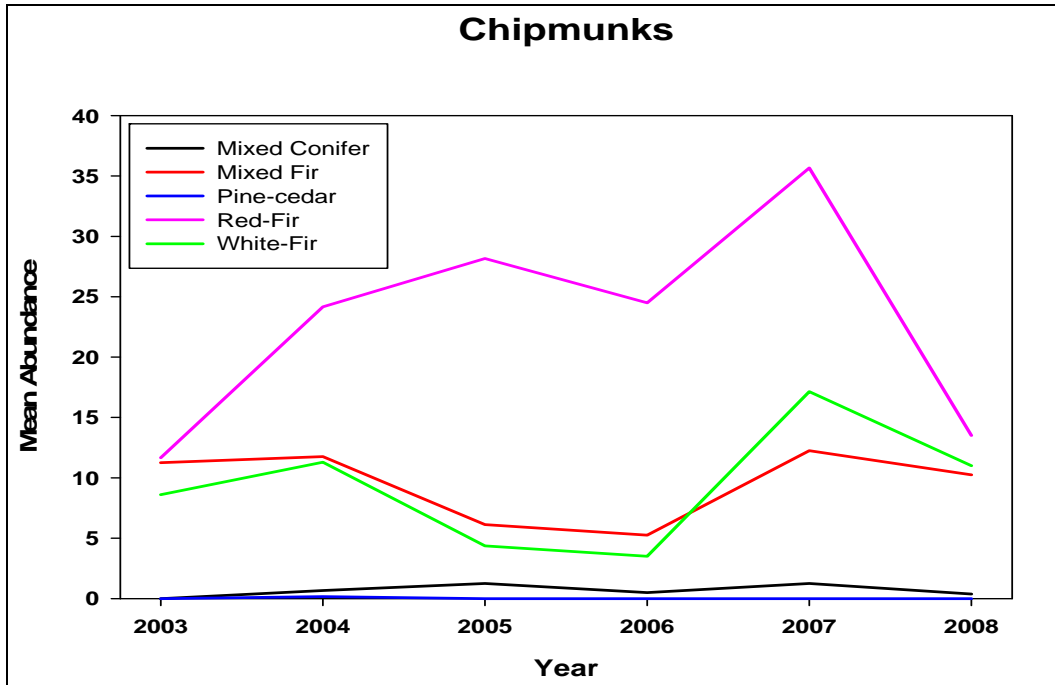


Fig. 12.— Mean abundance of chipmunks (*Tamias sp.*) pre and post treatment within the Plumas National Forest, California, during 2005-2008.

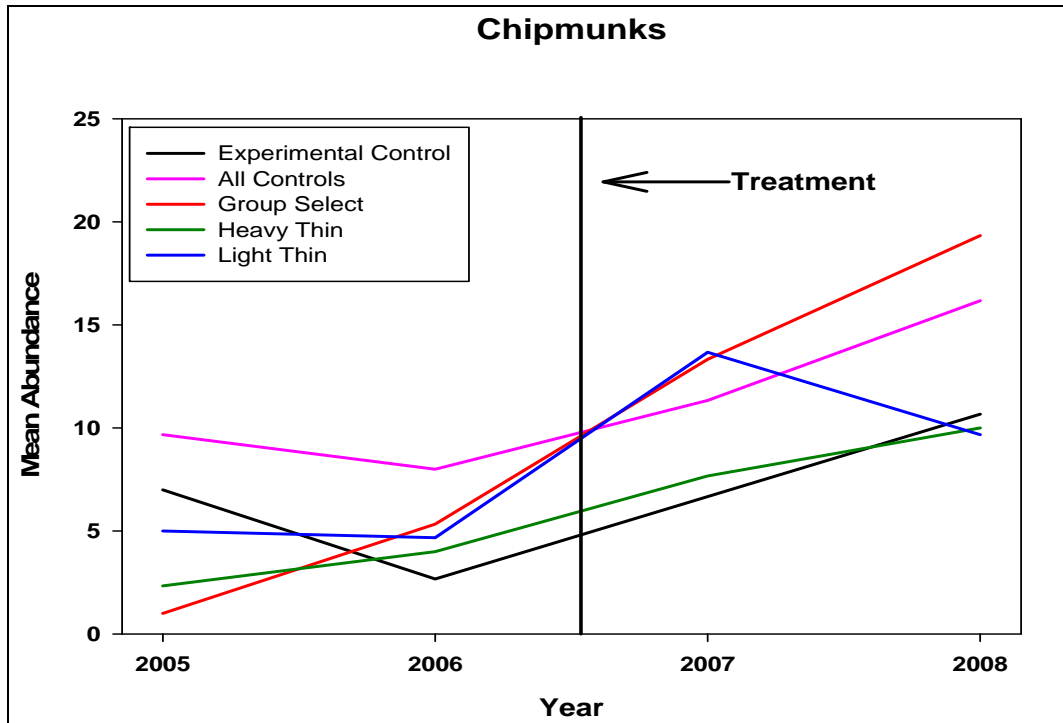


Fig. 13.— Mean abundance of northern flying squirrels across 5 forest types within the Plumas National Forest, California, during 2005-2008.

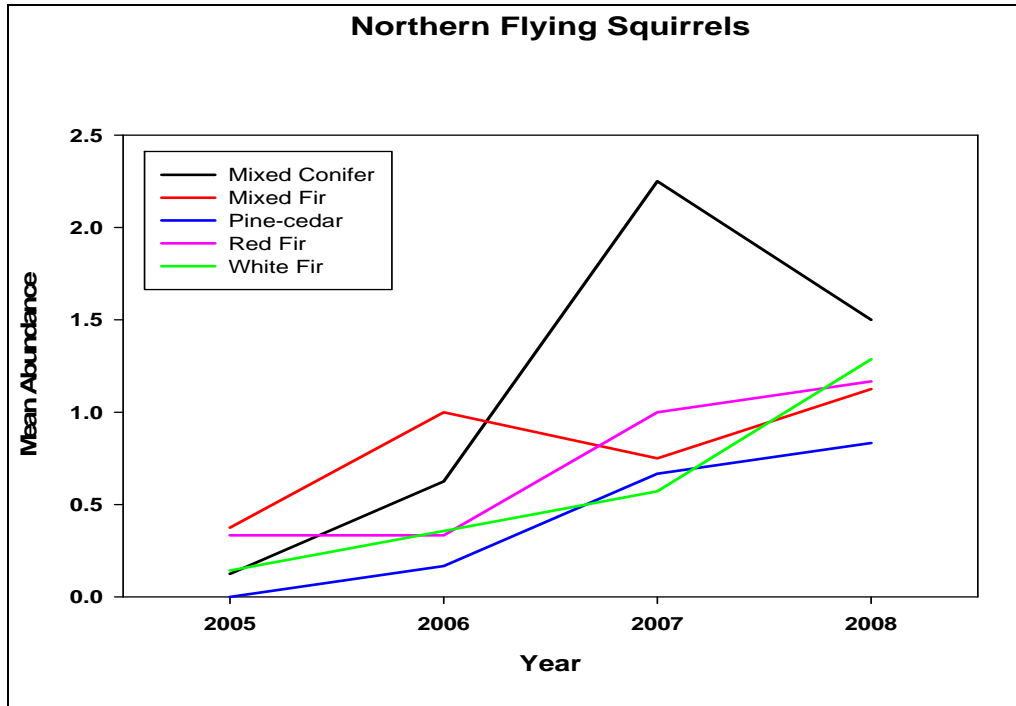


Fig.14. — Mean abundance of northern flying squirrels (*Glaucomys sabrinus*) pre and post treatment within the Plumas National Forest, California, during 2005-2008.

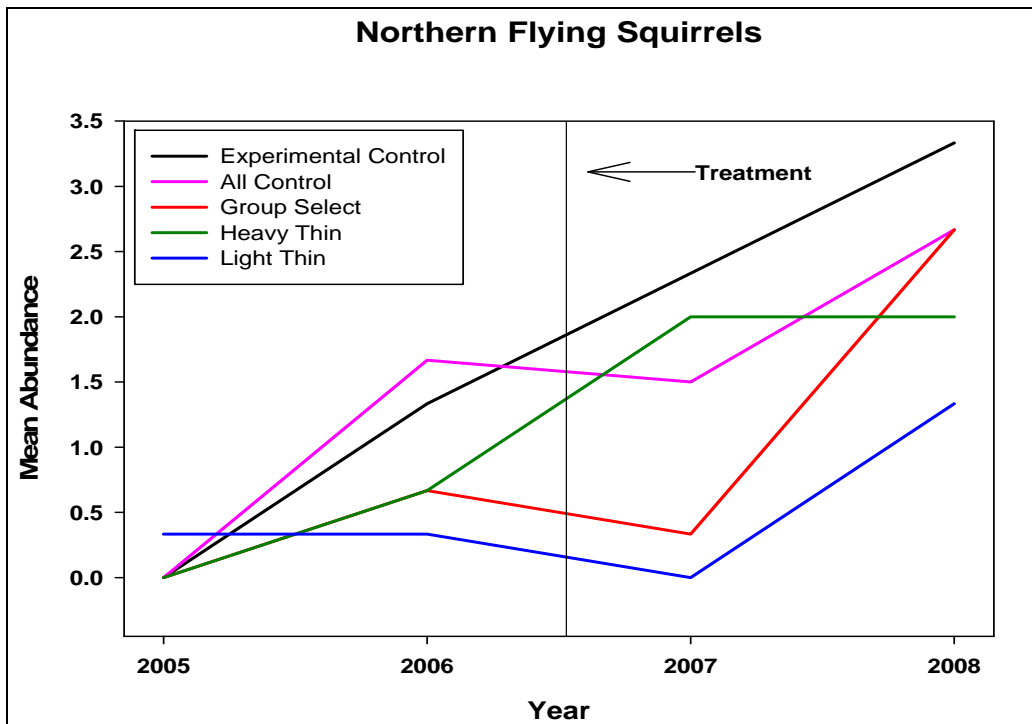


Fig. 15.— Mean abundance of dusky-footed woodrats across 5 forest types within the Plumas National Forest, California, during 2003-2008.

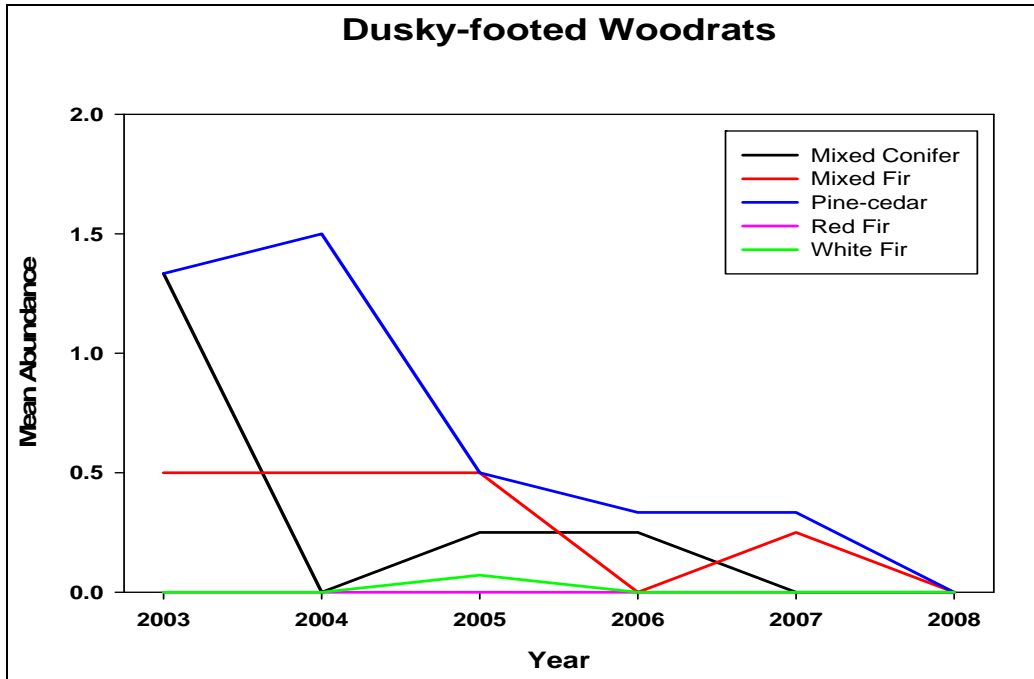


Fig. 16.-- Mean abundance of dusky-footed woodrats (*Neotoma fuciceps*) pre and post treatment within the Plumas National Forest, California, during 2005-2008.

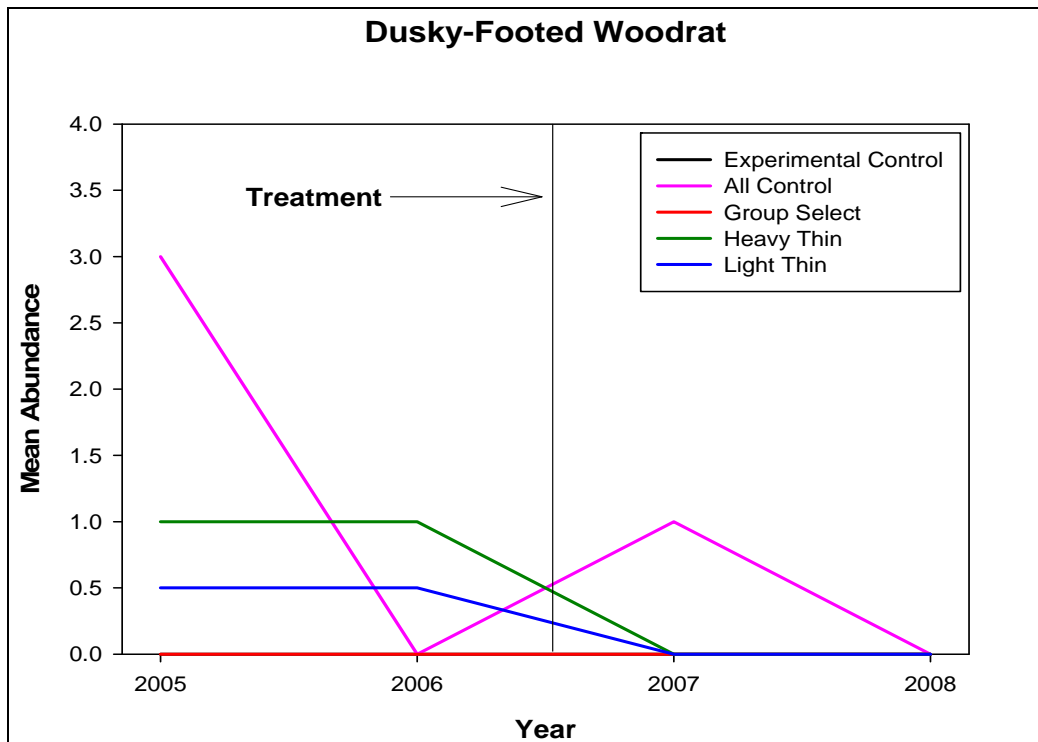


Fig. 17.—General relationships between mean mouse (*Peromyscus sp.*) mean abundance, mean annual cone production, and mean annual snow fall from 2003-2008. Note: lag in response to mean conifer cone abundance and immediate response to annual snow fall.

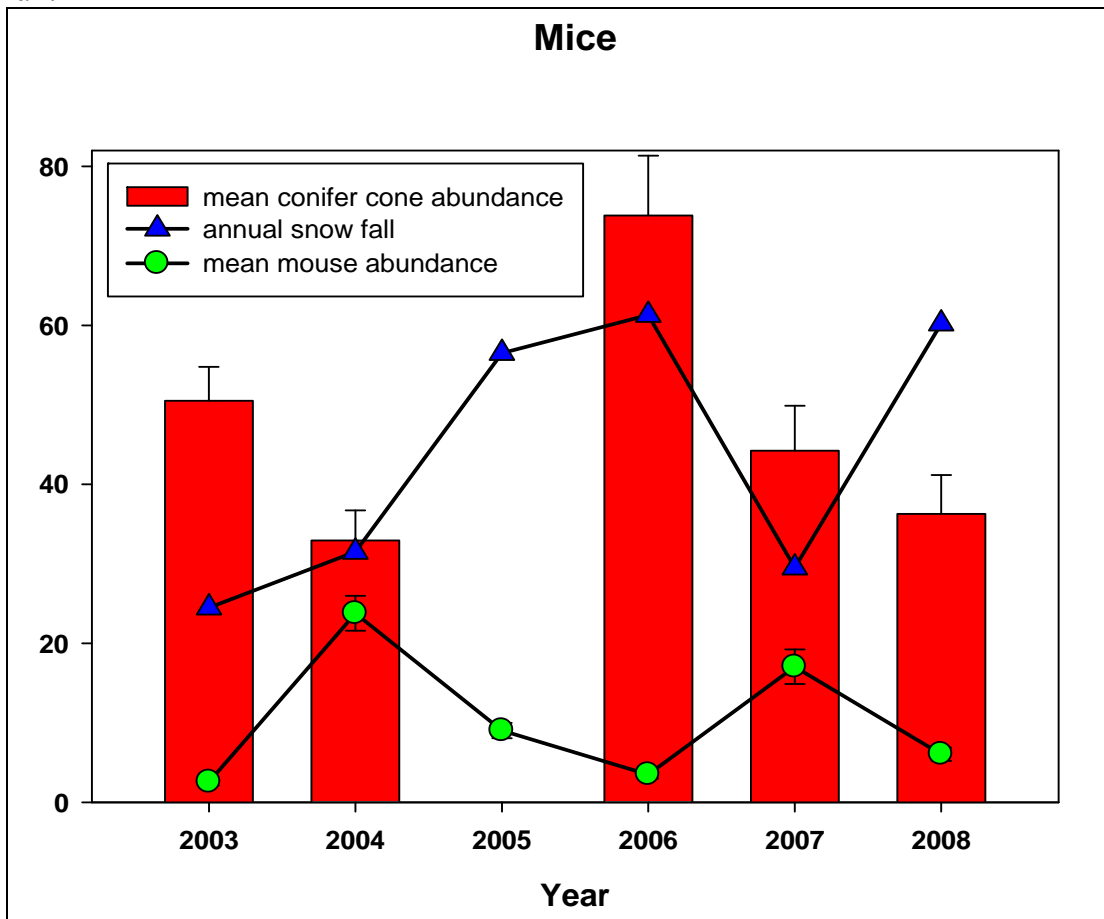


Fig. 18-- Mean annual biomass of small mammal species from 2003-2008; summarized across 5 forest types.

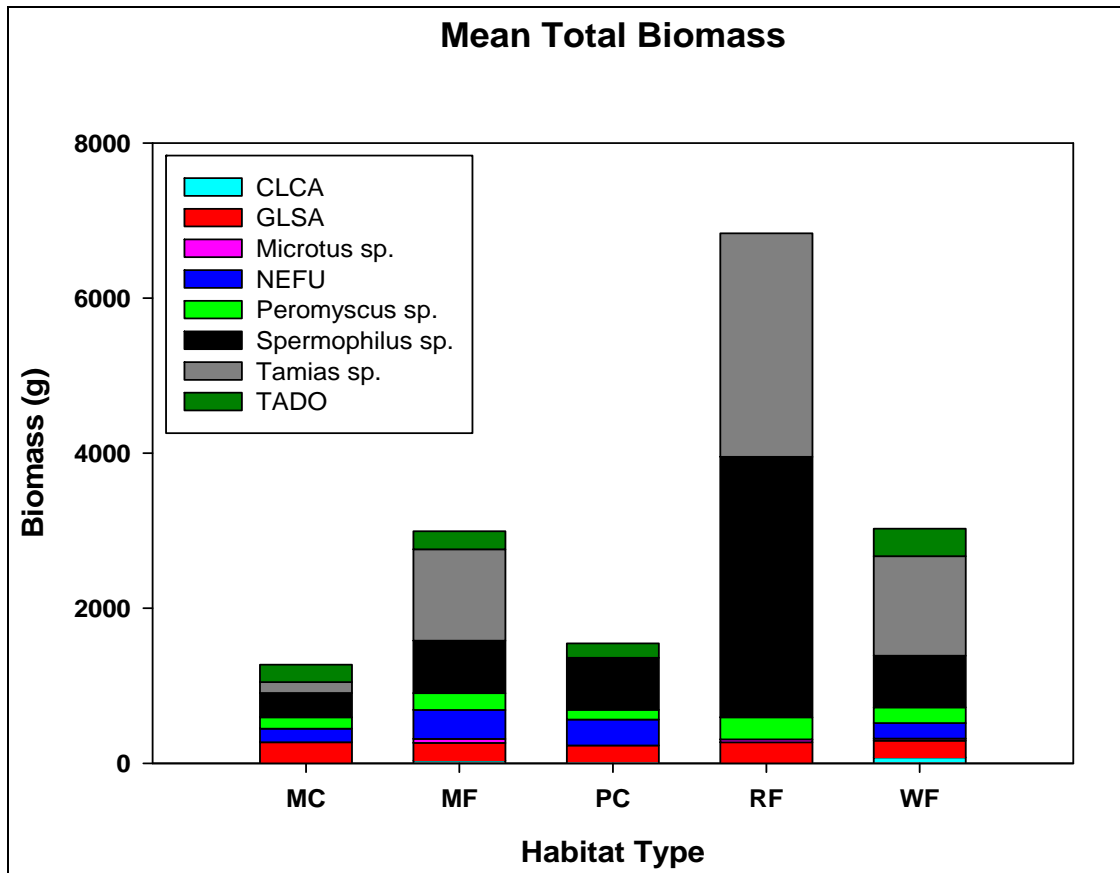


Fig. 19-- Mean annual biomass of key spotted owl prey species (mice, northern flying squirrel, and dusky-footed woodrat) from 2003-2008; summarized across 5 forest types.

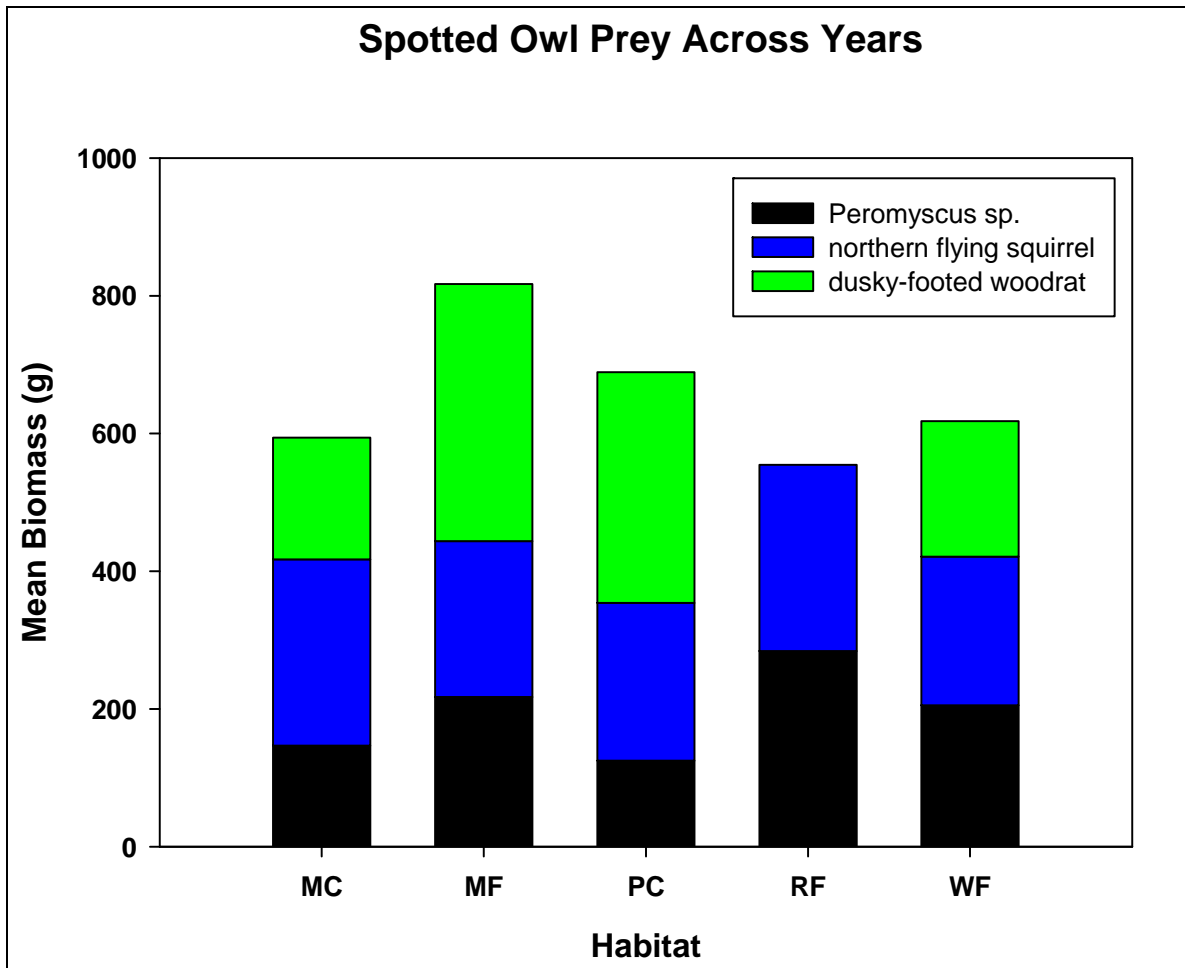


Fig. 20— Mean annual post treatment biomass in the 3 experimental group select plots.

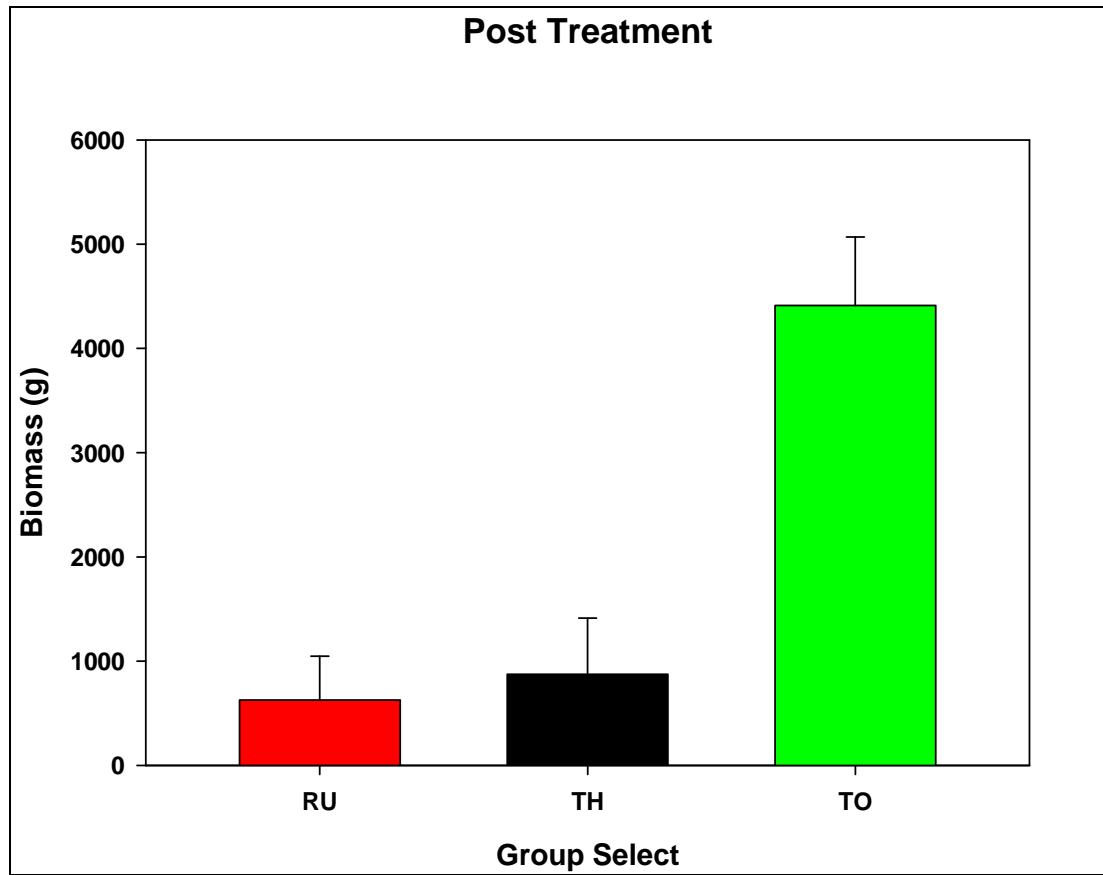


Fig. 21— 2008 MNKA summarized by experimental plot “clusters”, Dean’s Valley (DV), Snake Lake (SL), and Miller Fork (MF).

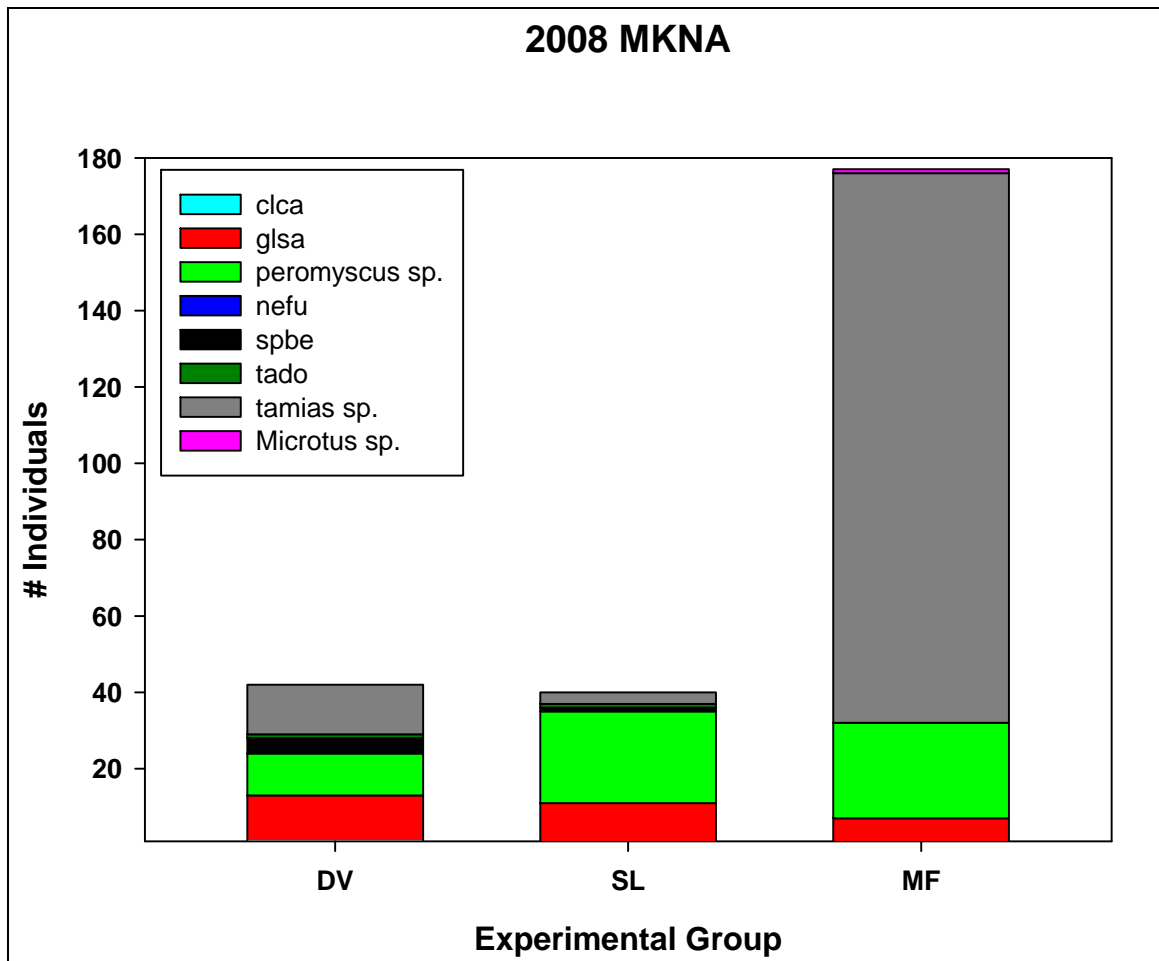


Fig. 22. —95% minimum convex polygon (MCP) graphic output for home range analysis for a single animal. Calculating the area within the polygon can be useful to determine what type or area an animal needs to exist. Quality of foraging land can be elucidated as well if MCP area varies between sites.

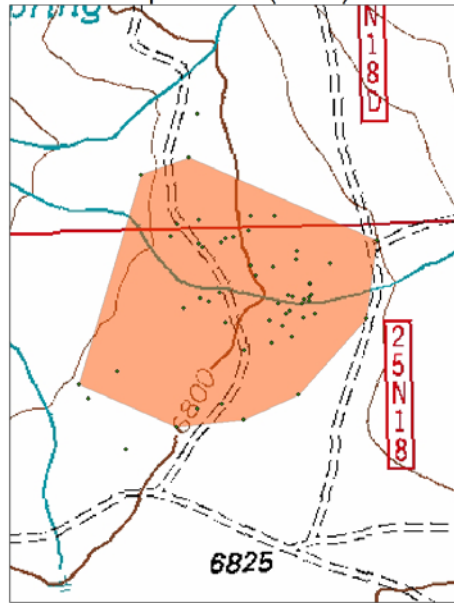


Fig. 23. —95% fixed kernel (FK) estimator from the same animal from Figure 22. Like contours on a topographic map, each line represents the degree of usage of the home range by the animal. As you move from the exterior to the interior, the animal utilizes the area more frequently.

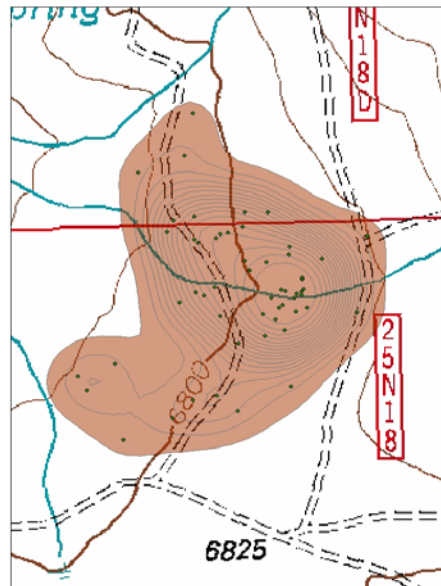


Fig. 24.-- Graphical output for incremental area analysis for northern flying squirrels, generated by adding subsequent points to a home range. The area (percentage) is generated by comparing the home range with “x” locations to the largest home range generated with all locations. In this figure, the home range stabilizes at 21 locations.

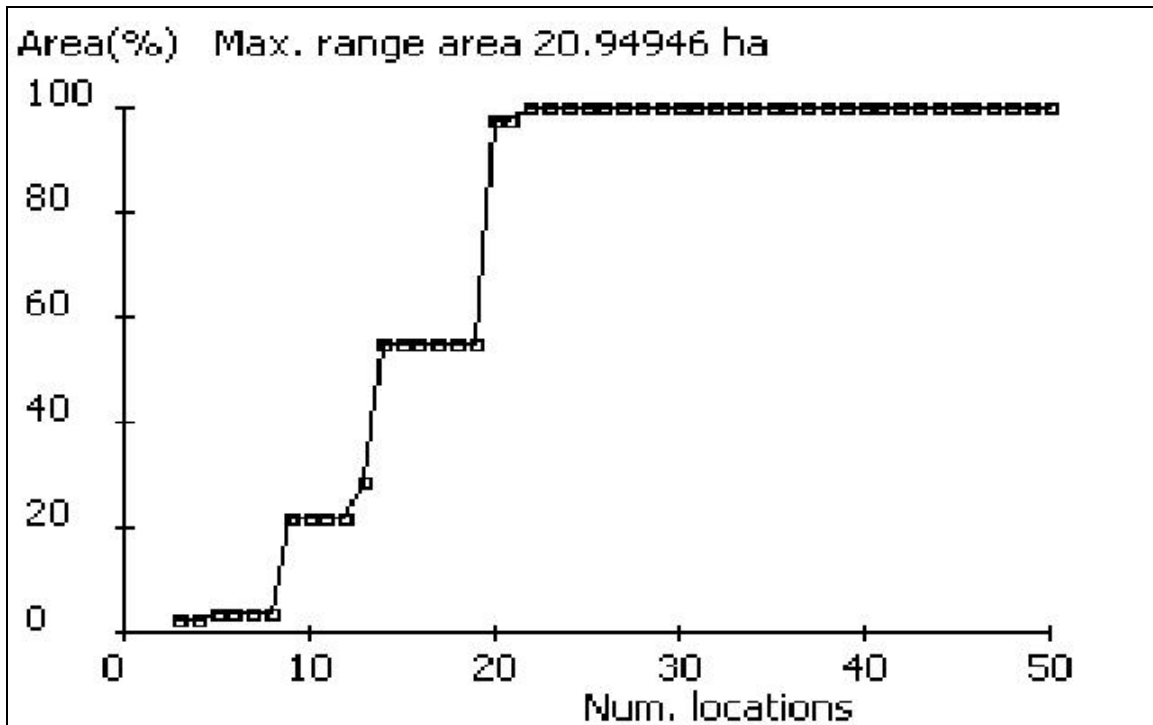


Fig. 25.— Total number and percentage (n, %) of tree species available (A) and used (B) by northern flying squirrels at den sites (n = 53) and paired random sites (n = 53) in the Plumas National Forest, California, 2006 – 2007.

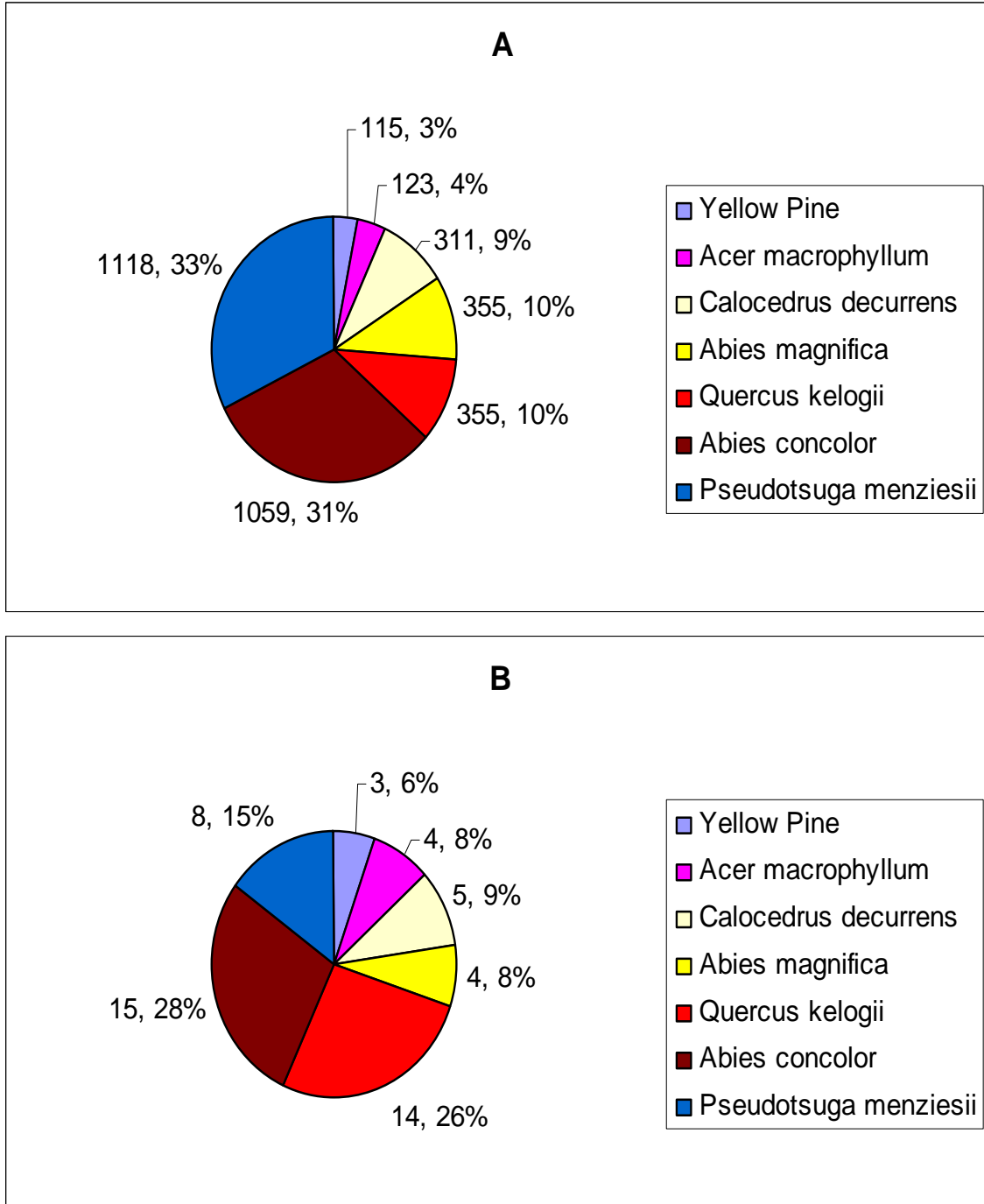


Fig. 26. —Proportional use of tree houses by dusky-footed woodrats, by month, in Plumas National Forest, 2004 to 2006.

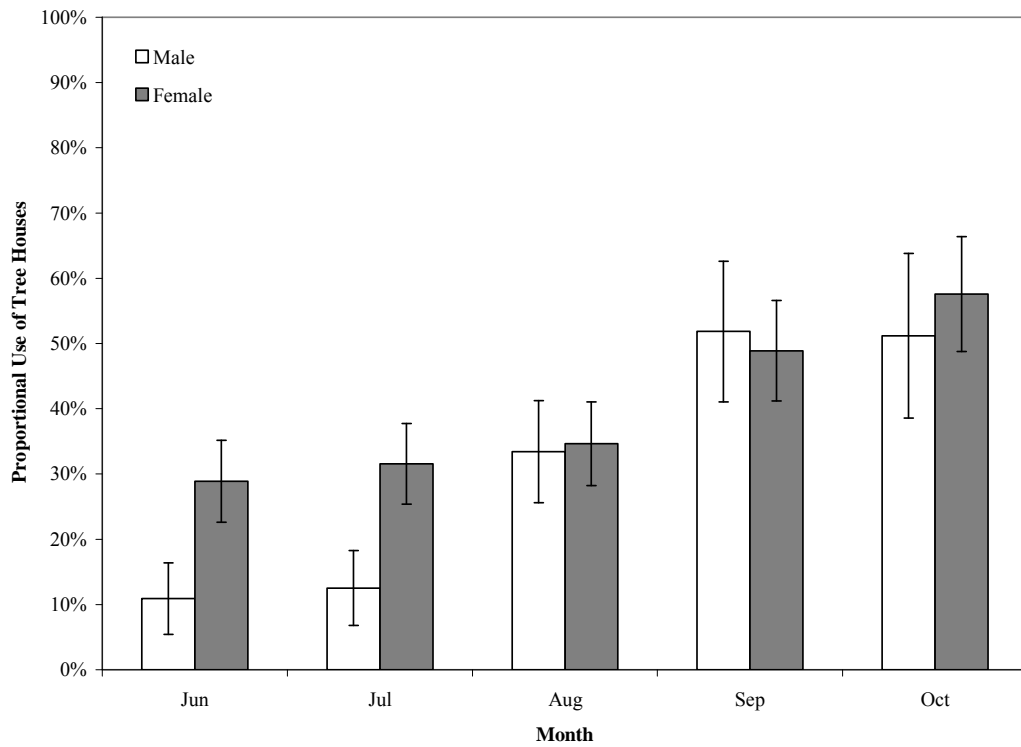


Fig. 27.—Core areas (a) and home ranges (b) of dusky-footed woodrats at study site 1 in Plumas National Forest, California, during May-October 2004. The minimum convex polygons for core area (50% MCP) and home range (95% MCP) are shown for graphical simplicity. Solid lines indicate adult females and dashed lined indicate adult males.

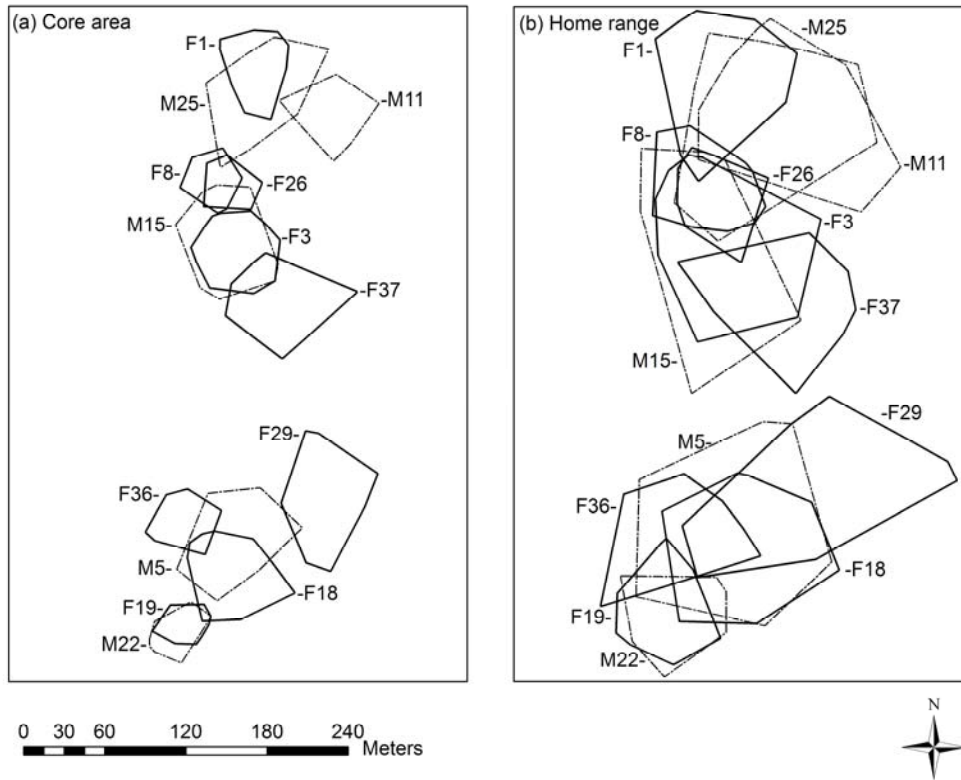


Fig. 28.— Frequency of house sharing (%) by dusky-footed woodrats, by month, in the Plumas National Forest, 2004 to 2006.

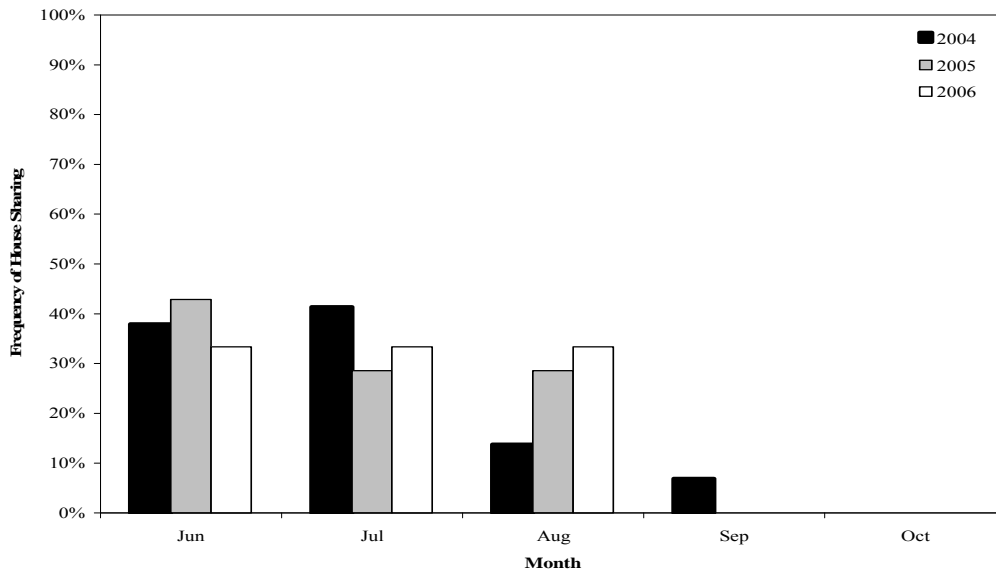


TABLE LEGENDS

Table 1.—Description of microhabitat variables measured in 1-m radius (3.14m²) plots at all long-term and landbird grid trap stations.

Table 2.— Results of the Program MARK analyses for 4 species of rodent in Plumas National Forest, California. All species were analyzed individually using the Cormack-Jolly Seber data type. Best-fit models are shown for each species. Akaike's corrected information coefficient (AICc), adjusted for overdispersion, and the model weight relative to other less fit models is given. Data for other species were too sparse for analysis with Program MARK.

Table 3.-- Mean annual biomass (g) of small mammal species from 2003-2008; summarized across 5 forest types.

Table 4.-- Mean total biomass (g) of key spotted owl prey species (mice, northern flying squirrel, and dusky-footed woodrat) across from 2003-2008; summarized across 5 forest types.

Table 5. -- Mean annual biomass (g) of all species in experimental plots pre and post treatment.

Table 6.-- Home range areas (in hectares) generated by minimum convex polygon (MCP) and kernel home range estimation methods for all northern flying squirrels from 2006 and 2007.

Table 7.—Mean size (cm; dbh) of trees by species available and used by northern flying squirrels at den sites (n = 53) and paired random sites (n = 53) in Plumas National Forest, California, 2006 – 2007. Presence of an asterisk indicates significant differences. Yellow pine includes ponderosa pine (*Pinus ponderosa*) and Jeffrey pine (*P. jeffreyi*).

Table 8.— Availability and use of trees for tree house locations by dusky-footed woodrats, by species (%) and by mean size (cm), in the northern Sierra Nevada, 2004 to 2006. Other trees include mountain dogwood (*Cornus nuttallii*), green and white-leaf manzanita (*Arctostaphylos sp.*), and willow (*Salix sp.*). Availability was calculated as the mean proportion of trees and snags.

Table 9.— Proportional (%) availability and use of ground and tree houses by dusky-footed woodrats in Plumas National Forest, 2004 to 2006. Numbers in parentheses indicate standard error.

Table 10.— Mean home range (95%) and core area (50%) estimates and associated standard errors (\pm SE) of dusky-footed woodrats using minimum convex polygon (MCP) and fixed kernel (FK) methods at 2 study sites in the Plumas National Forest, California.

TABLES

Table 1.—Description of microhabitat variables measured in 1-m radius (3.14m²) plots at all long-term and landbird grid trap stations.

| | |
|--------------------|---|
| Rocks | Exposed large rocks and stones |
| Bare ground | Exposed soil |
| Litter | Dead leaves, pine needles, wood chips, sawdust like debris |
| Branches | Twigs with diameter <10 cm |
| Small logs | Logs and stumps with diameter \geq 10 - 50 cm |
| Large logs | Logs and stumps with diameter > 50 cm |
| Forbs/grasses | Herbaceous and flowering vegetation and grasses |
| Live shrubs | Woody vegetation not considered sapling; height \leq 2 m |
| Dead shrubs | As for live shrub but with no living foliage or no foliage |
| Vegetation mats | Near ground surface shrub cover (<i>Ceanothus prostratus</i>) |
| Woody perennials | Shrub- and forblike vegetation lacking woody stems |
| Moss | Any plant resembling "moss" in appearance and growth form |
| Saplings | Small trees with height \leq 2 m |
| Live tree boles | Live standing tree |
| Snags | Dead standing tree |
| Stumps | Remaining portion of tree still attached to root after falling or being cut |
| Shrub richness | Number of distinct, live shrub species |
| Sapling richness | Number of distinct, sapling species |
| Tree richness | Number of distinct, live tree species |
| Canopy closure (%) | Percentage open sky above breast height (1.4 m) |
| Degree slope | Degree incline or decline of the forest floor |
| Aspect | Probable direction in which water will flow |

Table 2.— Results of the Program MARK analyses for 4 species of rodent in Plumas National Forest, California. All species were analyzed individually using the Cormack-Jolly Seber data type. Best-fit models are shown for each species. Akaike's corrected information coefficient (AICc), adjusted for overdispersion, and the model weight relative to other less fit models is given. Data for other species were too sparse for analysis with Program MARK.

| Species | Model | AICc | Weight | C-hat |
|-------------------------------|--|--------|--------|-------|
| <i>Peromyscus maniculatus</i> | □(habitat*t+overwinter+mean cones)p(habitat*t) | 1740.6 | 0.99 | 1.85 |
| <i>Spermophilus lateralis</i> | □(t)p(t) | 358.2 | 0.96 | 1.14 |
| <i>Tamias quadrimaculatus</i> | □(habitat*t+overwinter+mean cones)p(habitat*t) | 923.5 | 1.00 | 1.22 |
| <i>Tamias senex</i> | □(habitat*t)p(habitat*t) | 683.2 | 0.60 | 1.23 |
| | □(habitat*t+overwinter)p(habitat*t) | 684.1 | 0.39 | |

Table 3.-- Mean annual biomass (g) of small mammal species from 2003-2008; summarized across 5 forest types.

| Species | MC | MF | PC | RF | WF |
|----------------------|----------|----------|----------|----------|----------|
| <i>Clethrionomys</i> | 0 | 34.5 | 0 | 0 | 74.8 |
| <i>Glaucomys</i> | 270.2 | 226.5393 | 229.125 | 270.6 | 215.694 |
| <i>Microtus</i> | 0 | 53.2 | 0 | 37.72222 | 29.5 |
| <i>Neotoma</i> | 176.75 | 373.3 | 335.2333 | 0 | 197 |
| <i>Peromyscus</i> | 146.853 | 217.1592 | 124.6859 | 283.9552 | 205.264 |
| <i>Spermophilus</i> | 312.5 | 676.8437 | 672.55 | 3358.914 | 664.6714 |
| <i>Tamias</i> | 139.0125 | 1177.346 | 0 | 2883.879 | 1284.306 |
| <i>Tamiasciurus</i> | 226 | 234.4167 | 185 | 0 | 353.3333 |
| Total Biomass | 1271.316 | 2993.305 | 1546.594 | 6835.071 | 3024.568 |
| % of Biomass | 0.081126 | 0.191011 | 0.098692 | 0.436165 | 0.193006 |

Table 4.-- Mean total biomass (g) of key spotted owl prey species (mice, northern flying squirrel, and dusky-footed woodrat) across from 2003-2008; summarized across 5 forest types.

| Species | MC | MF | PC | RF | WF |
|----------------------|---------|----------|----------|----------|----------|
| <i>Peromyscus</i> | 146.853 | 217.1592 | 124.6859 | 283.9552 | 205.264 |
| <i>Glaucomys</i> | 270.2 | 226.5393 | 229.125 | 270.6 | 215.694 |
| <i>Neotoma</i> | 176.75 | 373.3 | 335.2333 | 0 | 197 |
| Total Biomass | 593.803 | 816.9985 | 689.0443 | 554.5552 | 617.958 |
| % Biomass | 0.18146 | 0.249667 | 0.210565 | 0.169466 | 0.188842 |

Table 5. -- Mean annual biomass (g) of all species in experimental plots pre and post treatment.

| | Pre | Post | Pre | Post | Pre | Post | Pre | Post |
|----------------------|----------|----------|------------|----------|------------|----------|--------------|----------|
| Species | Control | | Light Thin | | Heavy Thin | | Group Select | |
| <i>Clethrionomys</i> | 168.3 | 0 | 37.6 | 0 | 0 | 34 | 18.5 | 0 |
| <i>Glaucomys</i> | 263.25 | 382.3222 | 109.25 | 232.3333 | 116.8333 | 248.7917 | 118.5 | 178.575 |
| <i>Microtus</i> | 17 | 0 | 0 | 0 | 0 | 42 | 0 | 0 |
| <i>Neotoma</i> | 0 | 0 | 149.5 | 0 | 214.125 | 0 | 0 | 0 |
| <i>Peromyscus</i> | 166.5413 | 207.219 | 234.583 | 124.5587 | 150.1573 | 213.2201 | 140.74 | 180.9655 |
| <i>Spermophilus</i> | 364 | 468.25 | 523 | 0 | 430 | 172 | 982.1 | 659 |
| <i>Tamias</i> | 499.865 | 1031.132 | 572.6054 | 1870.285 | 389.5691 | 705.8455 | 368.1875 | 2117.016 |
| <i>Tamiasciurus</i> | 437 | 347.5 | 364.6667 | 241 | 0 | 216.25 | 0 | 240 |
| Total Biomass | 1915.956 | 2436.423 | 1991.205 | 2468.177 | 1300.685 | 1632.107 | 1628.027 | 3375.556 |

Table 6.-- Home range areas (in hectares) generated by minimum convex polygon (MCP) and kernel home range estimation methods for all northern flying squirrels from 2006 and 2007.

| Squirrel ID | Number of Locations | MCP (ha) | Fixed Kernel (ha) | Year |
|-------------|---------------------|----------|-------------------|------|
| 8 | 50 | 3.02 | 3.87 | 2006 |
| 6 | 50 | 10.55 | 10.16 | 2006 |
| 27 | 35 | 17.67 | 29.68 | 2006 |
| 1 | 51 | 12.35 | 21.58 | 2006 |
| 2 | 33 | 9.24 | 14.34 | 2006 |
| 7 | 60 | 1.90 | 3.77 | 2006 |
| 12 | 68 | 3.76 | 3.35 | 2007 |
| 6 | 67 | 9.74 | 12.36 | 2007 |
| 7 | 54 | 2.04 | 2.33 | 2007 |
| 15 | 63 | 6.05 | 3.88 | 2007 |
| 16 | 55 | 12.60 | 11.34 | 2007 |
| 17 | 59 | 13.15 | 17.51 | 2007 |
| 18 | 61 | 6.94 | 7.61 | 2007 |
| 19 | 53 | 10.56 | 13.78 | 2007 |
| 20 | 55 | 10.45 | 13.21 | 2007 |
| 27 | 66 | 3.72 | 6.80 | 2007 |
| 21 | 55 | 15.58 | 15.15 | 2007 |
| 22 | 57 | 8.42 | 9.18 | 2007 |
| 23 | 61 | 2.65 | 3.72 | 2007 |
| 24 | 51 | 10.66 | 9.83 | 2007 |
| 25 | 65 | 14.68 | 17.46 | 2007 |

Table 7.—Mean size (cm; dbh) of trees by species available and used by northern flying squirrels at den sites (n = 53) and paired random sites (n = 53) in Plumas National Forest, California, 2006 – 2007. Presence of an asterisk indicates significant differences. Yellow pine includes ponderosa pine (*Pinus ponderosa*) and Jeffrey pine (*P. jeffreyi*).

| Tree Type | Available- mean DBH (cm) | # of observations | Used- mean Den size DBH (cm) | # of observations |
|--------------------------|--------------------------------|----------------------|------------------------------------|----------------------|
| <i>Abies concolor</i> | 26.76 | 1059 | 61.07* | 15 |
| <i>Abies magnifica</i> | 32.42 | 355 | 58.25 | 4 |
| <i>Calocedrus</i> | | | | |
| <i>decurrans</i> | 26.38 | 311 | 73.60* | 5 |
| Yellow Pine | 36.17 | 115 | 121.33* | 3 |
| <i>Pseudotsuga</i> | | | | |
| <i>menziesii</i> | 30.45 | 1118 | 89.25* | 8 |
| <i>Quercus keloggii</i> | 17.59 | 355 | 29.61* | 14 |
| <i>Acer macrophyllum</i> | 18.96 | 123 | 19.00 | 4 |

Table 8.— Availability and use of trees for tree house locations by dusky-footed woodrats, by species (%) and by mean size (cm), in the northern Sierra Nevada, 2004 to 2006. Other trees include mountain dogwood (*Cornus nuttallii*), green and white-leaf manzanita (*Arctostaphylos sp.*), and willow (*Salix sp.*). Availability was calculated as the mean proportion of trees and snags.

| Species | Availability (%) | Tree houses | |
|----------------------|-------------------|-------------|-----------|
| | | Cavity (%) | Limb (%) |
| White fir | 30 | 3 | 56 |
| Incense cedar | 20 | 0 | 10 |
| Ponderosa pine | 7 | 0 | 0 |
| Sugar pine | 4 | 1 | 0 |
| Douglas-fir | 16 | 3 | 15 |
| California black oak | 13 | 72 | 15 |
| Snag | 7 | 21 | 0 |
| Other trees | 4 | 0 | 3 |
| Size group | Availability (cm) | Cavity (cm) | Limb (cm) |
| Tree size | 16.7 | 49.6 | 18.4 |
| Snag size | 10.5 | 58.2 | - |

Table 9.— Proportional (%) availability and use of ground and tree houses by dusky-footed woodrats in Plumas National Forest, 2004 to 2006. Numbers in parentheses indicate standard error.

| | Ground houses | Tree houses | |
|------------------|---------------|-------------|---------|
| | | Cavity | Limb |
| Female (%) | 61 (4.7) | 37 (4.6) | 2 (0.7) |
| Male (%) | 71 (5.2) | 24 (5.3) | 5 (1.7) |
| Availability (%) | 58 | 27 | 15 |

Table 10.— Mean home range (95%) and core area (50%) estimates and associated standard errors (\pm SE) of dusky-footed woodrats using minimum convex polygon (MCP) and fixed kernel (FK) methods at 2 study sites in the Plumas National Forest, California.

| Site | Year | Sex | MCP | | | FK | | |
|------|------|--------|-----|---------------|----------------|----|---------------|---------------|
| | | | N | Home range | Core area | N | Home range | Core area |
| 1 | 2004 | Male | 5 | 1.2 \pm 0.2 | 0.3 \pm 0.1 | 3 | 1.1 \pm 0.4 | 0.4 \pm 0.2 |
| | | Female | 9 | 0.8 \pm 0.1 | 0.2 \pm 0.04 | 6 | 1.1 \pm 0.3 | 0.4 \pm 0.1 |
| | 2005 | Male | 5 | 1.9 \pm 0.6 | 0.6 \pm 0.2 | 5 | 1.7 \pm 0.7 | 0.6 \pm 0.2 |
| | | Female | 8 | 1.2 \pm 0.2 | 0.3 \pm 0.1 | 7 | 1.4 \pm 0.3 | 0.6 \pm 0.1 |
| | 2006 | Male | 3 | 1.8 \pm 0.5 | 0.4 \pm 0.1 | 1 | 3.0 | 0.9 |
| | | Female | 7 | 1.2 \pm 0.3 | 0.4 \pm 0.1 | 5 | 1.2 \pm 0.3 | 0.5 \pm 0.1 |
| 2 | 2004 | Male | 7 | 3.7 \pm 0.3 | 0.9 \pm 0.1 | 4 | 3.5 \pm 0.4 | 1.0 \pm 0.2 |
| | | Female | 6 | 2.8 \pm 0.3 | 0.7 \pm 0.1 | 4 | 2.9 \pm 0.7 | 1.0 \pm 0.3 |
| | 2005 | Male | 2 | 7.0 \pm 0.4 | 2.6 \pm 0.3 | 2 | 7.7 \pm 0.2 | 2.8 \pm 0.3 |
| | | Female | 4 | 5.0 \pm 0.5 | 1.5 \pm 0.2 | 4 | 6.3 \pm 0.7 | 2.4 \pm 0.2 |
| | 2006 | Male | 2 | 4.6 \pm 0.4 | 1.2 \pm 0.6 | 2 | 3.6 \pm 1.6 | 1.5 \pm 0.9 |
| | | Female | 5 | 2.9 \pm 0.6 | 0.7 \pm 0.1 | 3 | 4.0 \pm 1.2 | 1.3 \pm 0.2 |