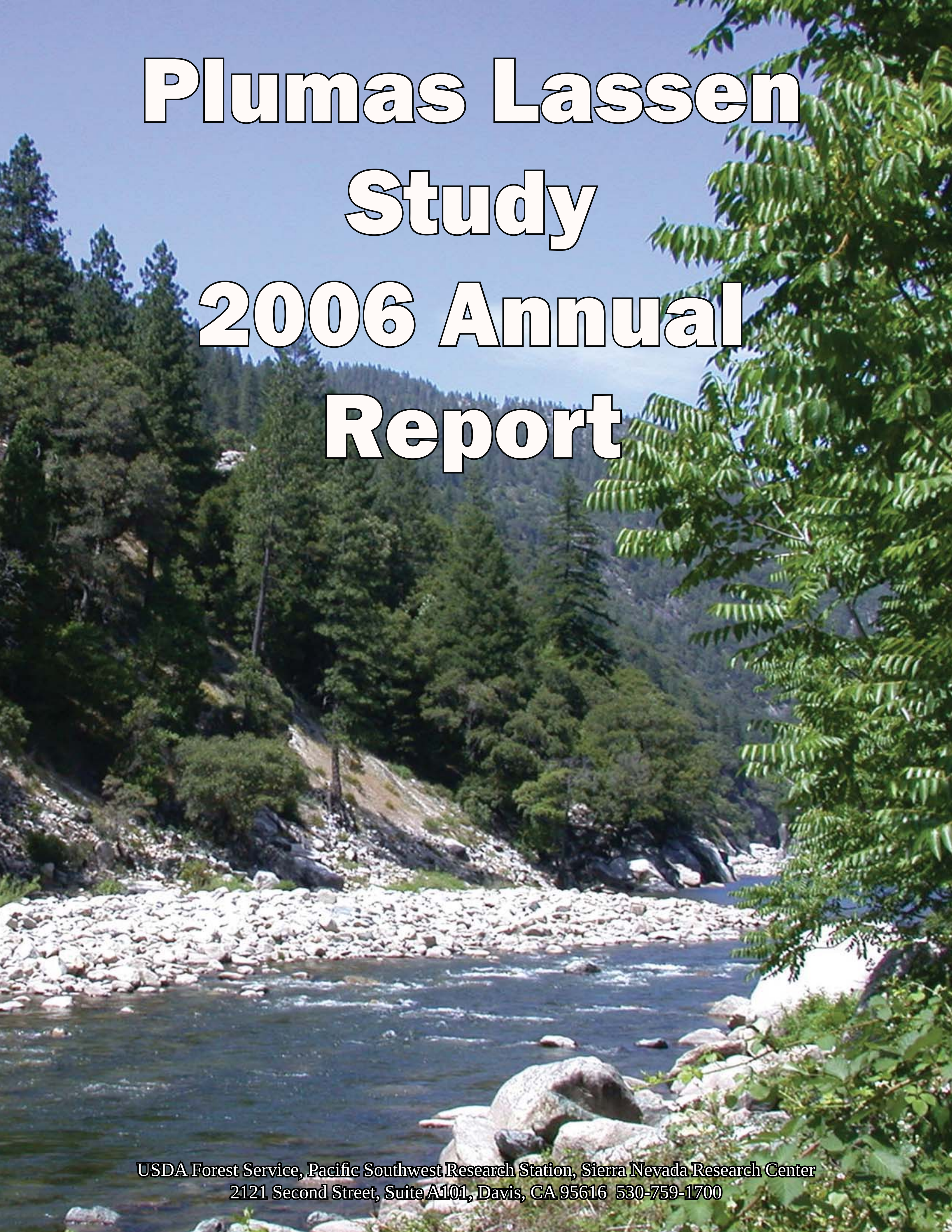

Plumas Lassen Study 2006 Annual Report

USDA Forest Service, Pacific Southwest Research Station, Sierra Nevada Research Center
2121 Second Street, Suite A101, Davis, CA 95616 530-759-1700

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Introduction

The Pacific Southwest Region and the Pacific Southwest Research Station agreed in 2002 to jointly develop and fund an administrative study to fill management information needs concerning the relationship between management-caused changes in vegetation and their effects on spotted owl habitat and population dynamics. The detailed discussions explaining how this program was started is provided in previous Annual Reports. Copies of previous Annual Reports for this program are available on the Sierra Nevada Research Center web site (www.fs.fed.us/psw/programs/snrc) or upon request.

This is the fifth such Annual Report that we have compiled. The primary purpose of this is to provide a periodic synopsis of what we have been learning so all interested parties can remain abreast of the progress. Research products resulting from this effort will be disseminated as they are ready and this will vary from module to module, project to project, and from year to year. We expect that there will be a continuous flow of findings documented primarily with publications in both refereed journals and other publication outlets. The cadre of scientists, support staff, students, and others contributing to this effort will also be making oral presentations and providing other kinds of outreach materials to help inform interested parties and our peers on the results of this work.

We provide some review information here to reinforce the intent of our work. This background information provides general background information on the purpose of this research program and helps set the context for the report. We have had to remind many interested parties and in particular our own program administrators that we embarked on the project virtually from square one. A project of this magnitude and ambition is difficult to initiate under the best of circumstances and we have asked for patience in the development of findings (e.g. scientific publications). When a research program begins work in a new area, addressing large geographic areas with complex questions on a busy landscape that is already subject to many other demands, it is not easy to establish all the field activities and produce results quickly.

However, we now believe we have emerged from the initiation phase and we have collected an impressive amount of information. Many publications are in development and we expect to provide useful information in the immediate future. Of course much of our research purpose depends on forest management treatments to be put in place and then observe short and even long term response to those treatments. Such treatments are now being executed in some locations and thus some of our potentially most significant work is just starting. Observations of response after treatments will logically take place in the ensuing years. If funding can be sustained we intend to continue to follow up with further data collection, field observations and insights addressing the questions we have posed.

We recognize that response of different elements of the forest can occur immediately after treatments however it is also possible that response can occur slowly and not be recognized for some period of time depending on the response variable of interest.

Alternatively it is also possible that some response variables exhibit a notable initial response and then return to a state similar to that of before the treatments. Thus we believe it is prudent to look at a fairly long period of post treatment response if possible.

Purpose of the Study

This study is interdisciplinary by design, examining at least five groups of response variables (spotted owls, small mammals, terrestrial birds, vegetation, and fuels conditions) through collaboration between researchers of the USDA Forest Service Pacific Southwest Research Station (PSW) and cooperators from the Universities of California, Berkeley and Davis, and the PRBO Conservation Science. The study addresses some of the most significant uncertainties that confound management decisions in the Sierra Nevada today, including in the HFQLG Pilot Project Area. How do old-forest-dependent species respond to vegetation management over space and time? Do fuels management approaches effectively address fuels loadings without negatively affecting species viability? How effective are landscape level fuels management strategies in modifying fire behavior and reducing the extent and severity of wildland fire? These and related questions are the focus of the work being done in this study.

Objectives of Study

The original overarching objective of this proposed research was to address an array of related ecological questions in a coordinated, integrated effort, thereby providing empirical data to inform future management decisions. The landscape scale of this design was both the driving force addressing the key questions as well as the largest impediment to successful construction of a scientifically credible experimental design and implementation in the field. Our research team believes that assessing many of the key elements of forest ecosystems should be done over larger spatial and temporal scales than has typically been investigated in past research. The important difference we are investigating is the response to changes in forest structure and composition over space and time rather than simply site specific and immediate response. We believe this difference is especially relevant to forest management practices that are designed for large landscapes, executed over relatively long time frames, such as landscape level fuels treatment strategies.

This research program is designed to address the three principal issues described below. These issues are specifically addressed through research questions and attending hypotheses for five different research components of this research program. These specific questions are detailed in the individual study plans for each module. Here we simply highlight the main objectives of the integrated research program and summarize the primary research questions that we plan to pursue.

- ***Wildland Fire Behavior and Protection.*** How do landscape level fuels and silvicultural treatments affect potential fire behavior and effects? Are specific combinations of defensible fuel profile zones (DFPZs) and subsequent individual tree selection or area treatments to thin the matrix effective in reducing the extent and severity of wildland fires? Are realized fire management benefits consistent with hypothesized results in reducing fire risk and altering fire behavior?

• ***Landscape Dynamics.*** How do combinations of DFPZs, subsequent individual tree selection or area treatments to thin the matrix, group selection, riparian protection standards, and species-specific protection measures affect landscape dynamics such as forest structure, composition, and succession at multiple scales of space and time?

• ***Species Viability.*** Induced by a forest management regime, how will old-forest dependent species, particularly the California spotted owl and its prey base comprised of various species of small mammals, respond to changes in vegetation composition, structure, and distribution over space and time? How is response to treatments manifested at the individual and population levels of biological organization?

Below we provide brief summary statements that capture the essence of the questions we are pursuing under this research agenda. Once again we direct you to the detailed study plans for further information on each module of this research program.

The specific management questions that are being addressed within the five different research components are:

Fuels and Fire Module

1. Current conditions: measurement of vegetation and fuels at the landscape scale
2 Fire modeling: how might current conditions (above) affect fire *behavior* and *effects?*
3. Effects of treatments: how might landscape-scale treatments change fire behavior and effects (as measured by using simulation programs such as FlamMap)?
4. Fire and habitat model integration (how can we address fuels management objectives in ways compatible with sensitive species conservation?).

Vegetation Module

1. What are the effects of canopy reduction due to thinning treatments on understory microclimate and shrub cover? How do we accurately measure changes in canopy cover to meet management prescriptions?
2. What are the appropriate ecological conditions to induce regeneration of shade-intolerant conifer species?
3. How does ecosystem resilience to forest harvesting, particularly group selection silviculture, vary across landscape gradients of precipitation and soil type?

Small Mammal Module

1. What are the habitat associations of the different taxa of small mammals found in coniferous forests in the northern Sierra Nevada (objective of

developing refined yet functional models of habitat associations)? What is the relative abundance and distribution of these taxa with respect to forest structure and composition?
2. Estimate values of the demographic parameters (for example, population size, reproductive output, survivorship, and mortality rates) of these taxa.
3. Estimate values for spatial patterns (for example, home range area and configuration) for these taxa.

Bird Community Module

1. Do current forest management practices promote an ecologically balanced forest ecosystem that supports sustainable populations of the breeding bird community over time?
2. What are the critical local-scale habitat components and landscape-scale composition elements that should be managed for in order to sustain the avian community over time (20 to 50 years)? Can we predict species composition, abundance, and distribution in response to future landscape treatments?
3. How do, or will, a suite of avian species that are associated with a wide range of forest conditions respond to fuels treatments, at the local and landscape scales in the short (one to five years) and long term (five to 20 years)?
4. Do Spotted Owl protected activity centers provide high quality habitat for the broader avian community? What are the differences in the avian community composition within owl territories compared to the surrounding landscape?

California Spotted Owl Module

1. What are the associations among landscape fuels treatments and CSO density, distribution, population trends and habitat suitability at the landscape-scale?
2. What are the associations among landscape fuels treatments and CSO reproduction, survival, and habitat fitness potential at the core area/home range scales?
3. What are the associations among landscape fuels treatments and CSO habitat use and home range configuration at the core area/home range scale?
4. What is the population trend for CSOs in the northern Sierra Nevada and what factors account for variation in population trend?
5. Are barred owls increasing in the northern Sierra Nevada, what factors are associated with their distribution and abundance, and are they associated with reduced CSO territory occupancy?
6. Does West Nile Virus affect the survival, distribution and abundance of California spotted owls in the study area?

Progress to Date

Given that we have completed a fifth year of work we are beyond the initiation phase and some findings are beginning to take shape. Some results, based on primarily pretreatment data, are crystallizing and findings will be reported. Some of the work described here includes activities from other locations but are potentially relevant to the Plumas and Lassen National Forest landscape, thus they are included in this summary. A preliminary list of completed and anticipated publications is summarized below:

Fire and Fuels Module

Menning, K. M. and S. L. Stephens (planned for 2006). "Spectral Entropy Canopy Diversity Analysis (SpECDA) used to Assess Variability in Forest Structure and Composition" To be submitted to Photogrammetric Engineering and Remote Sensing.

Menning, K. M. and S. L. Stephens (planned for 2006). "Fire Behavior and Effects as a Result of Defensible Fuel Profile Zones" To be submitted to International Journal of Wildland Fire.

Menning, K. M., S. L. Stephens, J. Keane (invited) and others. (Planned for 2006). "Integrated modeling of fire and California Spotted Owl habitat conditions given different weather and landscape treatment scenarios" To be submitted to a journal mutually agreed upon.

Menning, K. M. and S. L. Stephens (planned for 2006). "Landscape Forest Variability across the Northern Sierra Nevada" To be submitted to Landscape Ecology.

Vegetation Module

In revision

Bigelow SW, North MP, Horwath WR. Age versus light as influences on growth of Sierra Nevada conifer saplings. Status: in revision.

Papers in preparation

Bigelow SW, Parks SA. Landscape analysis of group selection placement strategy in a patchy East-Side pine forest. For submission Spring 2006.

Bigelow SW, North MP. Group selection harvest impacts in a patchy East-Side pine forest. For submission summer 2007.

Papers planned

Bigelow SW, North MP. Understory light prediction after fuels treatment & group selection in a mixed-conifer forest. Status: pending follow-up measurements immediately after completion of experimental fuels treatments. Estimated completion date Fall 2007.

Salk CF, Bigelow SW, North MP. Interaction of soil texture and light on performance of seedlings of Sierran conifers. Status: data collection complete except for soils analyses. Estimated completion date Fall 2007.

Bigelow SW, Moghaddas J, North MP. Fuels treatments in western forests: relationship between canopy cover reduction and fire hazard reduction. Status: pending completion of experimental fuels treatments. Estimated completion date Spring 2008.

North MP, Bigelow SW. Effects of canopy cover reduction on fire climate and ecosystem trajectory. Status: pending completion of experimental fuels treatments and 1-year post-treatment measurements. Estimated completion date Spring 2009.

Bigelow SW, Moghaddas J, North MP. Surface fuel consumption and conifer mortality in a mixed conifer forest. Status: pending completion of experimental fuels treatments, and subsequent controlled burn, and 1 year of follow-up treatments. Estimated completion date Spring 2010.

Small Mammal Module

Publications (Peer-reviewed)

Copetto, S. A. 2005. Habitat associations of small mammals at two spatial scales in the northern Sierra Nevada, California. M.S. Thesis, University of California, Davis, 39 pp.

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.

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.

Submitted

Innes, R. J., D. H. Van Vuren, D. A. Kelt, M. L. Johnson, J. A. Wilson, P. A. Stine. Submitted. Habitat selection by dusky-footed woodrats in managed, mixed-conifer forest of the northern Sierra Nevada. Journal of Mammalogy

Wilson, J. A., D. A. Kelt, D, H, Van Vuren, and M. Johnson. Submitted. Population dynamics of small mammals in relation to cone production in four forest types in the northern Sierra Nevada. Western North American Naturalist.

Wilson, J. A., D. A. Kelt, and D. H. Van Vuren. Submitted. Effects of maternal body condition on offspring dispersal in golden-mantled ground squirrels (*Spermophilus lateralis*). Oikos.

Wilson, J. A., D. A. Kelt, and D. H. Van Vuren. Submitted. Home range and activity of northern flying squirrels (*Glaucomys sabrinus*) in the Sierra Nevada. Southwestern Naturalist.

In Preparation

Coppeto, S. A., D. A. Kelt, and others. In Prep. A multiple spatial scale perspective of the habitat affinities of sympatric *Neotamias quadrimaculatus* and *N. senex*. Winter 2007.

Innes, R. J., D. H. Van Vuren, M. B. McEachern, J. M. Eadie, D. A. Kelt, M. L. Johnson, and J. A. Wilson. In Prep. Genetic relatedness and social organization of the dusky footed woodrat (*Neotoma fuscipes*) in mixed-conifer forests of the northern Sierra Nevada. Journal of Mammalogy. Winter 2007.

Mabry, K.E., and Wilson, J. A. In Prep. Trapping rodents in a cautious world: the effects of disinfectants on trap success. Journal of Wildlife Management.

Presentations

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.

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.

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.

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.

Innes, R. J., D. H. Van Vuren, D. A. Kelt, M. B. Johnson, J.A. Wilson. 2006. Habitat relations of dusky-footed woodrats (*Neotoma fuscipes*) in mixed-conifer forests of the northern Sierra Nevada. Poster to the American Society of Mammalogists, Annual Meeting, Amherst, MA.

Smith, W. 2006. Ecology of *Glaucomys sabrinus*: habitat, demography, and community relations. Presentation to the American Society of Mammalogists, Annual Meeting, Springfield, MO.

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.

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.

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.

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.

Terrestrial Bird Module

Manuscripts in Preparation

Howell, C.A., R.D. Burnett, et al. Local versus landscape effects on breeding birds in the northern Sierra Nevada with implications for future treatment. Landscape Ecology or Forest Ecology and Management.

Burnett, R.D., C.A.Howell, and N.Nur. Avian community composition in the context of Spotted Owl conservation in the Sierra Nevada, California. Wildlife Society Bulletin.

Humple, D.L, and R.D. Burnett. Nest site characteristics and habitat use of Yellow Warblers in Montane Shrub fields in the Northern Sierra Nevada, California. Western Birds.

Burnett, R.D., M. Herzog, and D. Humple. Reproductive ecology of shrub dependent breeding birds in re-generating clear cut brush fields in the Sierra Nevada, California. Forest Ecology and Management or Condor.

Burnett, R.D. Integrating Avian Monitoring into Forest Management: Pine-Hardwood and Aspen Enhancement on the Lassen National Forest. Partners in Flight publication.

Burnett, R.D., C.Howell, and N.Nur. Short-term response of coniferous forest songbirds to DFPZ treatments in the northern Sierra Nevada.

Other Outreach Activities

Burnett, R.D. and Kim Maute. Presentation and Banding Demonstration. U.C. Forestry Institute for Teachers (FIT). July 2005. Meadow Valley, California.

Burnett, R.D. and Kim Maute. Banding Demonstration. PSW Staff. June 2005.

Burnett, R.D. and Kim Maute. Banding Demonstration Outreach Day to Plumas Audubon

Owl Module

Keane, J.J., J.A. Blakesley, C.V. Gallagher, D.L. Hanson, P.A. Shaklee, and D.W.H. Shaw. Status and Distribution of the Barred Owl in the Sierra Nevada. To be submitted to the Condor.

Keane, J.J., J.A. Blakesley, C.V. Gallagher, D.L. Hanson, P.A. Shaklee, and D.W.H. Shaw. Nest-site habitat characteristics of California spotted owls in the northern Sierra Nevada. To be submitted to Journal of Wildlife Management.

Keane, J.J., J.A. Blakesley, C.V. Gallagher, D.L. Hanson, P.A. Shaklee, and D.W.H. Shaw. Landscape nesting habitat characteristics of California spotted owls in the northern Sierra Nevada. To be submitted to the Journal of Wildlife Management.

Keane, J.J., J.A. Blakesley, J.R. Dunk, and S.A. Parks. Predictive habitat suitability models of California spotted owls for assessing effects of forest management and fuels treatments. To be submitted to Ecological Applications or Forest Ecology and Management.

Keane, J.J., J.A. Blakesley, C.V. Gallagher, D.L. Hanson, P.A. Shaklee, and D.W.H. Shaw. Diets of California spotted owls in the northern Sierra Nevada. To be submitted to Forest Ecology and Management.

Dunk, J.R., J.J. Keane, and S.A. Parks. Predictive habitat suitability models of northern goshawks for assessing effects of forest management and fuels treatments in the northern Sierra Nevada. To be submitted to Ecological Applications or Forest Ecology.

J.J. Keane , J.R. Dunk, and S.A. Parks. Landscape habitat patterns and predictive habitat suitability models for northern goshawks in the Lake Tahoe Basin, Sierra Nevada. To be submitted to Journal of Wildlife Management or Forest Ecology and Management.

J.J Keane, J.R. Dunk, and T. Gaman. Nest-site characteristics of northern goshawks in the southern Sierra Nevada. To be submitted to Condor.

J.J. Keane, B.Woodbridge, and S.A. Parks. Conservations status and distribution of the northern goshawk in California. To be submitted to the Journal of Biogeography or Biological Conservation.

J.J Keane and J.R. Dunk. Predictive habitat modeling of California spotted owl and northern goshawk habitat in the Sierra Nevada. To be submitted to Ecological Applications.

B. Woodbridge, J.J. Keane, J.R. Dunk, and J. Hawley. Habitat conservation assessment for northern goshawks in California. To be published as a GTR.

J.J. Keane. Effectiveness of artificial great horned owls for capturing northern goshawks. To be submitted to the Journal of Raptor Research or Journal of Field Ornithology.

J.J. Keane and B. Woodbridge. Effectiveness of broadcast surveys for detecting northern goshawks. To be submitted to the Wildlife Society Bulletin.

J.J. Keane, E.B. Jepsen, L.A. Tierney and C.V. Gallagher. Effectiveness of survey techniques for detecting great gray owls. To be submitted to the Journal of Wildlife Management.

Summary

This work represents some significant scientific study that has occurred over the last five years and is expected to continue for up to another four years within the HFQLG Pilot Project area. At the conclusion of the pilot project the HFQLG Act requires the Forest Service to commission a team of scientists to evaluate the pilot project and provide the Forest Service with guidance on the efficacy of the work and what were the environmental consequences on the natural resources of the geographic region. The results of these studies will contribute valuable, objective scientific insights that managers can use to develop subsequent management direction for the Plumas and Lassen National Forests, as well as other National Forest lands in the northern Sierra Nevada such as the portions of the Tahoe National Forest that contain similar ecological conditions.

We cannot ignore or deny the fact that designing a credible and useful research program in this area has been challenging. We want to be clear to all interested parties that the Pacific Southwest Research Station was asked to become involved in this project and for the purposes stated in the introduction above and we responded with the intent to provide as much new scientific learning as would be possible. PSW knew that we would be entering into efforts that would have many more challenges than research projects typically encounter. Our goal was to contribute as much as we could to the better understanding of forest ecosystem response to fuels and other forest management practices as they are manifested at a landscape scale.

We understand there is some uncertainty and sometimes controversy over how various forest elements will respond to planned forest management practices. This is likely to be the case under any chosen management regime. The objective of PSW was to tackle the difficult scientific challenges derived from the salient management questions. PSW, as a research organization, remains wholly objective in executing this charge. We have assembled an excellent team of scientists with the appropriate areas of expertise and we have done the best we can to design our work to address the important questions. Many of these questions present significant challenges to experimental design of field ecology experiments and management constraints further constrain our ability to test questions with traditional hypothesis testing approaches. We expect to make the most of these opportunities in advancing our scientific understanding of forest ecosystem response to management practices.

Chapter 1:
Fuels and Fire at the Landscape Scale

Research Team

Principal Investigator:

Dr. Scott Stephens, Assistant Professor of Fire Sciences
Ecosystem Sciences Division
Department of Environmental Science, Policy, and Management
151 Hilgard Hall # 3110
University of California, Berkeley, CA. 94720-3114
510-642-7304 FAX 510-643-5438 e-mail stephens@nature.berkeley.edu

Project collaborator

Kurt Menning, Postgraduate researcher
Ecosystem Sciences Division
Department of Environmental Science, Policy, and Management
151 Hilgard Hall # 3110
University of California, Berkeley, CA. 94720-3114
e-mail kmenning@nature.berkeley.edu

Project staff in 2006

- Bridget Tracy, 2006 field season coordinator
- Nicholas Delaney, field assistant and full time project staff beginning autumn 2006

Project Goals:

In this study, we are investigating how landscape-level fuels and silvicultural treatments affect potential fire behavior and fire effects across the forested landscape of the project area in the Plumas National Forest. This analysis is critical for assessing the potential of severe or extensive fire occurring on the landscape.

In addition, both fuels treatments and fire alter forest structure, pattern and composition and thereby modify wildlife habitat that depends on the vegetation. Our assessments of potential change to landscape-scale vegetation will be instrumental when coupled with assessments of wildlife habitat conducted by the owl research module. This linking of module research relies on an integrative analytical model developed by our team. That model is described here, as the last part of this study.

Objectives and Overview

Past management activities including fire suppression, timber harvesting, and livestock grazing have changed the structure and composition of many coniferous forests in the western United States, particularly those that once experienced frequent, low-moderate intensity fires (Biswell 1961; Hartesveldt and Harvey 1967; Parsons and Debenedetti 1979; Beesley 1995; Erman 1996; Menning 2003). These changes in vegetation have altered habitat for a variety of species. Correspondingly, changes in vegetation and fuel loading have changed the probability of fire spreading across the landscape.

The USDA Forest Service aims to actively manage vegetation with the goal of reducing the probability of large, intense, or severe fires while minimizing negative effects on wildlife habitat and ecosystem stability. Proposed treatments include group selections and defensible fuel profile zones (DFPZs). Group selection treatments involve the harvest of all trees smaller than 30” diameter at breast height (DBH) over a one to two acre area (Stine et al. 2002). DFPZs are areas with extensive forest thinning intended to reduce surface and canopy fuel loads. They are also known as shaded fuel breaks and are designed to allow access for active fire suppression. DFPZs are spatially-extensive, covering hundreds to thousands of hectares (Stine et al. 2002).

Currently, there is limited information on the effects of landscape fuels treatments on reducing severe fire behavior and effects, especially at the landscape scale (Erman 1996; Agee et al. 2000; Fites-Kaufman et al. 2001). Elsewhere in the Sierra Nevada, group selections have been shown to have little effect on the landscape-level behavior of fire (Stephens and Finney 2002); the proposed group selections in the Plumas, however, retain more large trees per acre than typical group selections. To date, the modeled effects of group selections with large tree retention have not been published for this forest type.

Assessing the effects of these vegetation management strategies—group selections and DFPZs—across the forested ecosystems of the Plumas and Lassen National Forests is the goal of the Plumas-Lassen Administrative Study (Stine et al. 2002). The study is composed of five research teams with distinct focuses: California spotted owls, small mammals, songbirds, fuels and fire, and vegetation. Due to practical considerations of a study as spatially extensive as this, we have to mix research with monitoring. The overall study does not comprise a formal scientific experiment in that the scientists involved have little control over actual treatments. The study amounts to far more than monitoring, however, in that we are independently assessing a large landscape and modeling changes to that landscape given a set of prescriptive treatments.

For the Fuels and Fire Module, which is the focus of this study plan, we aim to address the landscape-scale effects of the proposed forest treatments by answering a suite of questions: First, what are current conditions, in terms of fuel loads and vegetation, measured directly in the field? Second, what is the current potential fire behavior and effects given these measured fuel and vegetation conditions? Third, how would landscape fuels treatments affect vegetation condition and fire behavior and effects?

Fourth, in addition to these efforts to characterize fuels and fire relationships, it is essential to link results of our research with findings from the other research modules (figure 1).

It is clear that any landscape-level fuels or forest management strategy will affect many interrelated components of forest ecosystems (Erman 1996; Bahro 2004). Therefore, it is important to understand the synergistic effects between potential treatments and various areas of concern—forest conditions, risks of severe or extensive fire, and habitat alteration. Our goal in answering this fourth question is to produce an analytical model in which we integrate maps of current conditions with models that project responses of fire behavior and effects given prescriptions of treatment and weather scenarios. The vegetation component of the current conditions maps would act simultaneously as input to the Spotted Owl Module's habit suitability models. By coupling these data layers and models between research modules we will model the likely effect of a landscape fuels strategy on both fire and owl habitat given various prescriptions and weather scenarios.

Taken together, these four research goals form the top level of a hierarchical set of research goals that may be best expressed in a table. Hence, we have shown these research objectives and their supporting details and questions in table 1. Details supporting the modeling efforts follow the table.

Fig 1: Ecosystem Relationships Examined in PLAS
(Topics addressed in this module emphasized in bold)

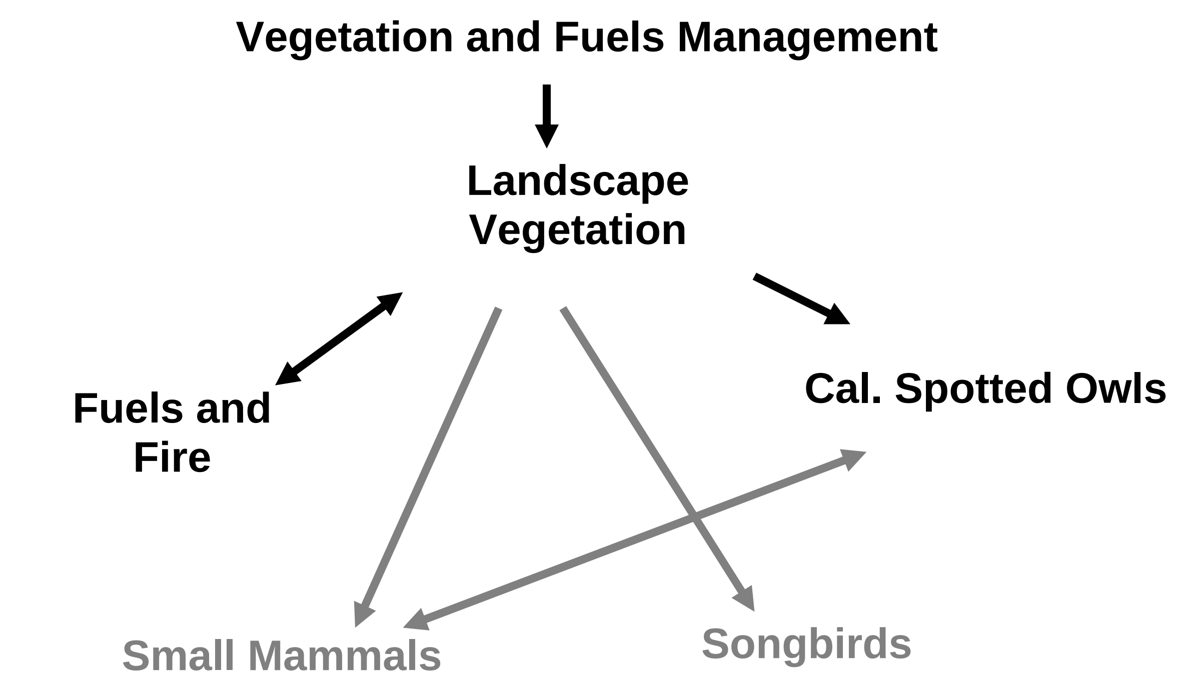


Table 1: Fuels and Fire Module: Summary of hierarchical arrangement of study topics

1.0 Current conditions: measurement of vegetation and fuels at the landscape scale
- 1.1 Current vegetation: What are current vegetation conditions prior to treatment?
  - 1.1.1 Forest sampling in the field (forest plots)
  - 1.1.2 Remote sensing of forest conditions
    - 1.1.2.1 Forest and vegetation classification (IKONOS imagery)
    - 1.1.2.2 Forest structural diversity analysis (IKONOS imagery)
- 1.2 Current fuels: What are current fuel loads prior to treatment?
  - 1.2.1 Fuels sampling in the field (forest plots)
  - 1.2.2 Ladder fuels: probability of fire ascending forest canopy (LaFHA)
  - 1.2.3 Integration of data sources into a fuel model/map for the study area

2.0 Fire modeling: how might current conditions (above) affect fire *behavior* and *effects*?
- 2.1 Fire *behavior*: What is the range of potential fire behavior given current conditions & a range of weather scenarios? (FARSITE & FlamMap models)
- 2.2 What are likely *effects* of fire behavior on these landscapes as determined by simulation models? (Stephens approach using FARSITE & FlamMap outputs)
- 2.3 Temporal dynamics of forest stands, including tree growth (FVS)

3.0 Effects of treatments: how might landscape-scale treatments change fire behavior and effects (using FlamMap)?
- 3.1 Group Selections (GS) and Defensible Fuel Profile Zones (DFPZs)
  - 3.1.1 Measure: how does the installation of GSs & DFPZs affect fuel loads?
  - 3.1.2 Model: how does the placement of GSs & DFPZs affect potential fire behavior? Do they reduce the probability of catastrophic fire under extreme weather conditions?
  - 3.1.3 Modeling: how does the installation of GSs & DFPZs affect fire effects such as mortality to different species and size classes of trees? Would the reduction in fire extent and intensity reduce the severity of canopy fires?
- 3.2 Spatial allocation and efficiency: DFPZs and Strategically Placed Landscape Area Treatments (SPLATs)
  - 3.2.1 How does the installation of alternative treatments affect fuel loading?
  - 3.2.2 How does the placement of alternative treatments affect potential fire behavior?
  - 3.2.3 How do different levels of management intensity (extent of treatment) affect the treatment's ability to reduce the size or intensity of fires?
  - 3.2.4 What effect would alternative treatments have on resulting fire *effects*?

4.0 Fire and habitat model integration
- 4.1 Correlate spectral entropy canopy diversity with habitat variables
- 4.2 Model interaction between vegetation management and both fuels and fire, and owl habitat given current conditions, prescriptions and weather scenarios

Study Area

Our study area is a subset of the Plumas National Forest in Northern California, USA. The Plumas and Lassen National Forests cover hundreds of thousands of acres, and sampling an area this size with a limited field crew and small remote sensing budget is beyond our capacity. As a result, we have chosen to focus on the study area's treatment units (TU) 2, 3 and 4 (Stine et al. 2002), which present widely varying topographical conditions and contain a variety of owl habitat quality. The total area of these three TUs is about 60,000 ha (150,000 ac) (Keane 2004). Vegetation varies widely through this region, presenting a good opportunity to examine fire behavior and end effects across a spectrum of conditions. The town of Quincy lies directly eastward of TU 4 and would be immediately affected by fire in this area and the resulting smoke. In addition, TU 2 has been evaluated to have high quality spotted owl habitat while areas 3 and 4 have lower qualities (Keane 2004). As a result, these three treatment units present a good range of conditions in which to conduct this research and test our model integration.

Vegetative cover in this area is primarily mixed conifer forest. The mixed conifer forest community comprises a mix of three to six conifers and several hardwoods (Barbour and Major 1995; Holland and Keil 1995; Sawyer and Keeler-Wolf 1995). Common conifers include ponderosa pine (*Pinus ponderosa*), Jeffrey pine (*P. jeffreyi*), sugar pine (*P. lambertiana*), incense-cedar (*Calocedrus decurrens*), Douglas fir (*Pseudotsuga menziesii)* and white fir (*Abies concolor*). Red fir (*Abies magnifica*) is common at higher elevations where it mixes with white fir (Holland and Keil 1995; Sawyer and Keeler-Wolf 1995). At mid to lower elevations, common hardwoods include California black oak (*Quercus kelloggii*) and canyon live oak (*Q. chrysolepis*) (Rundel et al. 1995).

In addition, a number of species are found occasionally in or on the edge of the mixed conifer forest: western white pine (*P. monticola*) at higher elevations, lodgepole pine (*P. contorta*) in cold air pockets and riparian zones, western juniper (*Juniperus occidentalis*) on dry sites, California hazelnut (*Corylus cornuta*), dogwood (*Cornus spp.*) and willow (*Salix spp.*) in moister sites, California bay (*Umbellularia californica*) and California nutmeg (*Torreya californica*) in lower, drier areas (Griffen and Critchfield 1976; Holland and Keil 1995; Rundel et al. 1995).

A variety of vegetation types currently comprise the matrix of covers in which the mixed conifer forest is arrayed. Vegetation in the matrix ranges from chaparral on exposed, poorly watered south and west facing slopes to oak woodlands and riparian meadows. At higher elevations, particularly toward the Bucks Lake Wilderness, some red fir may be found in pure stands (personal experience).

Methods

This study is conducted under a passive adaptive management framework administered by the USDA Forest Service; we have no control over the implementation of the landscape fuels treatments. The HFQLG Act outlines the landscape fuels treatment strategies, and defines the types of timber harvest to be implemented. Decisions on the timing and placement of fuels treatments will be determined at a local level by the Plumas National Forest.

We do have control over the data collection and modeling aspects of the project. Our research topics (table 1) can be divided into several methodological groupings. Here, we present summaries of methodologies for field data collection, remote sensing, and model integration. Data are collected from a series of field plots (discontinuous data) as well as from satellites (continuous forest canopy data). Additional data products are derived through modeling.

Methods: Field data collection

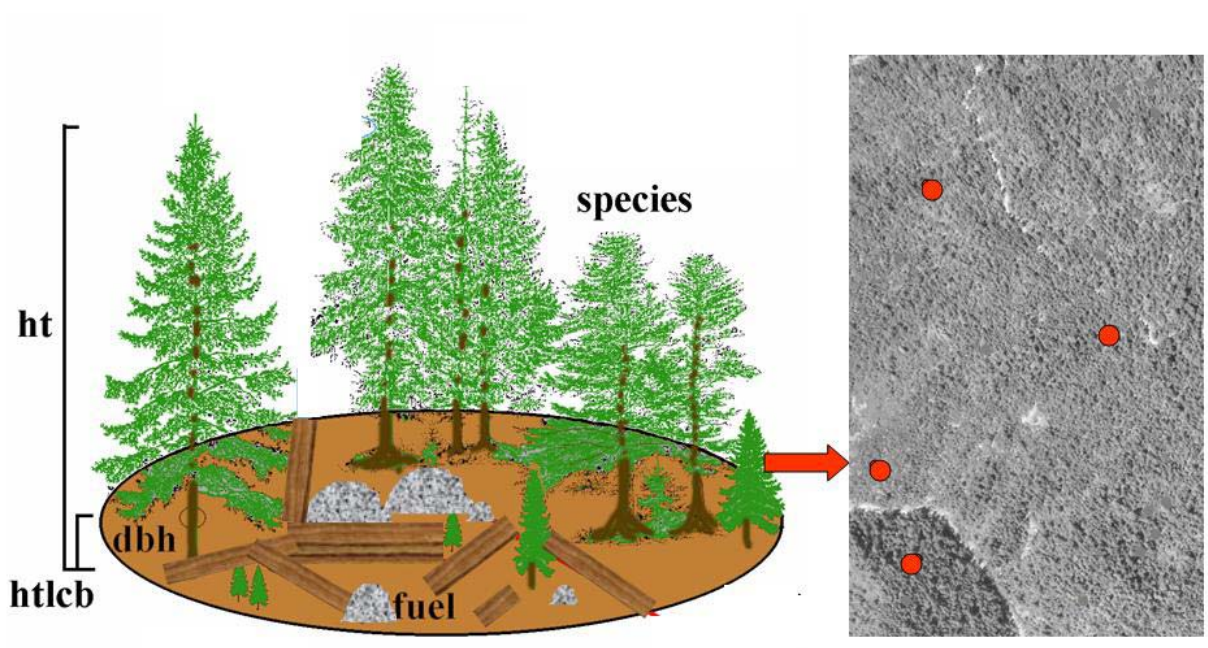
Plot Layout and Design

Data on forest cover and fuels is being collected in 0.05ha (0.125 ac) plots 12.6m (41.3 ft) in radius (figure 2). Plot locations are established using a stratified-random approach. Strata of elevation, aspect and vegetation type were defined using the layers previously supplied by the contractor VESTRA (Stine et al. 2002). This process identified over 700 plot locations in treatment units 2, 3 and 4. In addition to the randomly-stratified plot locations described above, similar data will be collected at locations identified by the other modules: plots are located at each owl nesting site and mammal study grid in the three treatment units.

Forest Structure and Composition; Site Data

We collect data on tree species, diameter at breast height (DBH), categorical estimate of height, and height to lower crown (see Appendix A for sample data sheet). Site data collected include location (using high-precision GPS), slope, and aspect. Canopy cover is assessed at 24 points (every 1 meter) along two linear fuels transects (described below).

Figure 2: Data sources: field plots and satellite imagery
(plots shown scattered on landscape on satellite image to right)



Ground based sampling of ladder, surface, and ground fuels

Surface and ground fuels are sampled in each plot using the line intercept method (Brown 1974; Brown et al. 1982). Ground and surface fuels are sampled along two transects radiating from plot center. The first transect is located along a random azimuth and the second falls 90 degrees clockwise from it. We sample 1 and 10 hour fuels from 10-12 meters along each transect, 100 hour fuels from 9-12 meters, and 1000 hour fuels data from 1-12 meters. Duff and litter depth (cm) are measured at 5 and 8 meters along each transect. Maximum litter height is additionally sampled at three locations from 7 to 8m (Brown 1974; Brown et al. 1982). Total fuel loads for the sites are occularly estimated using fuel photo series developed for the Northern Sierra Nevada and Southern Cascades (Blonski and Schramel 1993).

Ladder Fuel Hazard Assessment (LaFHA)

We have devised and implemented a mixed quantitative-expert system for assessing ladder fuels (submitted paper). The Ladder Fuel Hazard Assessment (LaFHA) requires a trained field crew member to rapidly assess the presence and continuity of fuel ladders in each of four quadrants in a plot using a flowchart. The first step is to determine the presence of low aerial fuels: the fuels that would create sufficient flame lengths to reach several meters from the forest floor. Sparse vegetation, or vegetation widely distributed, probably has too little fuel per volume of air to create and sustain large flames. Therefore, we define a clump of low aerial fuels to be brush or small trees covering an area of at least 4 square meters (2m x 2m) with gaps of less than 50cm. If it is particularly dense, or tall and brushy, a clump may cover a small area. A particularly dense clump may cover as little as $2m^2$ on the forest floor, for example. Branchy dead fuel or stems may be included in the assessment. The size and density of these clumps of fuel and vegetation are based upon personal experience (S. Stephens, K. Menning). If there is no clumping of low aerial fuels, the site would fall in the two lowest ladder fuel hazard categories (C, D); conversely, if there is a clumping of low aerial fuels, the site would fall in one of the two higher-risk categories (A, B). It is important to note that isolated clumps of low aerial fuels, well removed from any ladders, are discounted. Letters (A, B, C, and D) are assigned to hazard ratings instead of numbers to prevent confusion: categories are not of interval or ratio quality (e.g., “Is category 4 twice as risky as category 2?” No, we would not know the quantitative relationship without a direct test).

The second step is to make a determination about the vertical continuity of the fuel ladder from the ground to the canopy. Gaps of more than 2m might be enough to prevent the spread of flames vertically (S. Stephens). Vegetation with gaps of less than 2m from the ground to the upper canopy may present a good ladder to conduct flames. Sparse vegetation lowers the probability and reduces the quality of the ladder. The technician is expected to look at the vegetation and determine whether there are gaps of 2m or more. If the maximum gap is less than 2m, then the site would be categorized as the higher hazard of the two options.

After placing the site in one of the four categories (A, B, C, or D), the technician records the minimum height to live crown (HTLCB) and the size of the maximum gap in the best ladder. These two values may later be used to help verify the classification is correct. The process is repeated for each of the four quadrants of the plot.

The effect of slope is not considered during the hazard evaluation in the field, slope data are used later, to modify the hazard rating. Because the effect of slope on flame length is non-linear (Rothermel 1972), the slope must have a non-linear multiplicative effect on the hazard rating. Final analysis of the plot is performed in the laboratory by combining the ratings of the four quadrants and applying a non-linear slope factor. A plot with one quadrant of high ladder fuel hazard and three low hazard ratings is certainly not as great a risk as a plot with continuous, high-risk ladders in each quadrant. While this semi-quantitative, semi-qualitative process is experimental, and the exact numerical relationships between slope and hazard are yet to be determined, we feel the method has merit; importantly, the field crews report consistent ratings after training and repetition (K. Menning).

Methods: Remote sensing

Initial results of IKONOS imagery indicate that we will be able to use this imagery for classification of landscape vegetation. As a result, we have dropped the LANDSAT imagery analysis. Instead, all our effort in remote sensing goes into analyzing the IKONOS imagery. This high spatial resolution imagery is being used to provide information on continuous forest pattern, structure, cover and variability using methods developed by Menning (2003) including spectral entropy canopy diversity analysis (SpECDA—see appendix E of Fuel and Fire Study Plan). These data and analyses have the benefit of being linked to analyses of vegetation and wildlife habitat conducted by other researchers in the project (see model integration, below). In 2003, high-resolution (1-4m) IKONOS imagery of several treatments was collected covering treatment units 3 and 4. In 2004, IKONOS imagery covering TU 2 and 3—overlapping the data collected in 2003—was collected to provide additional coverage of the area with high owl population.

Methods: Data Processing, Analysis and Model Integration

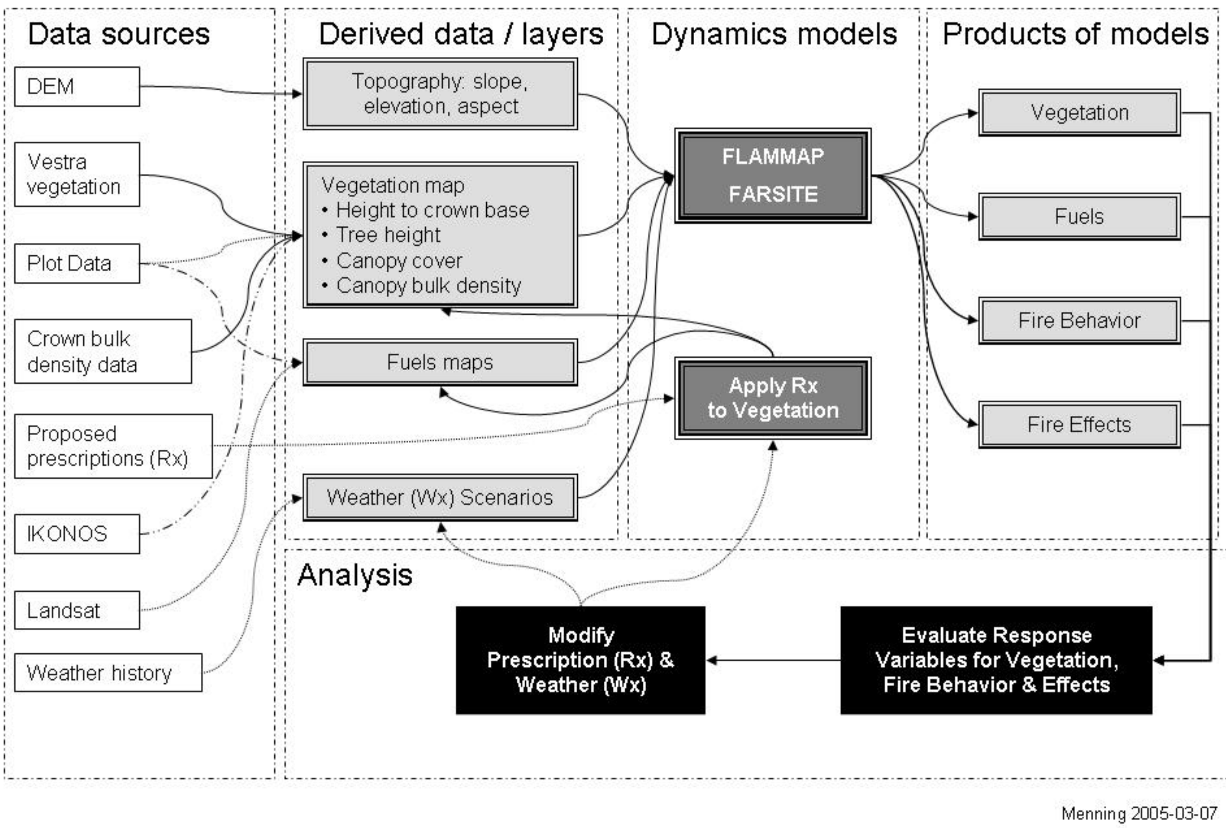
Fire behavior models require maps of vegetation, topography, and fuels, as well as weather scenarios, in order to model the spatial behavior of fire (figure 3). These data are integrated from a variety of different sources. Development of the vegetation map has been described above, in the remote sensing methodology. Topographic variables—slope, elevation and aspect—are mapped across the study area using pre-existing Digital Elevation Models (DEM) on a 30x30m grid. Assembling fuels maps requires that fuels be measured at select sites (a discontinuous set) and then extrapolated across the landscape where fire may burn (continuous coverage). Fire modeling will be conducted in two major phases: first, we will evaluate fire behavior and potential at one time, either the current condition or post-treatment, using Farsite and Flammap; second, we will use Forest Vegetation Simulator (FVS) to create a dynamic simulation of change through time at the stand level.

Calculation of Fuel Loads and Development of Fuel Models

Many fuel inventories done in the Sierra Nevada have assumed that the fuel particles being inventoried had similar properties to those found in the northern Rocky Mountains (Brown 1974) but Van Wagtendonk's work in quantifying Sierra Nevada surface and ground fuel properties allows custom fuel load equations to be developed for a site-specific project such as this. This methodology previously has been used to produce accurate estimates of fuel loads

(Stephens 2001). Additional validation of these fuel load coefficients are provided by Menning's research in Sequoia National Park (Menning 2003). As tree species in the northern Sierra Nevada are the same as those sampled by Menning and van Wagtendonk, the data should be relevant to this study site.

Figure 3: PLAS Landscape Vegetation, Fuels and Fire



Field measurements provide data on species mixes and fuel particle size distribution. Using these data, ground and surface fuel loads are calculated by using equations developed for Sierra Nevada forests (van Wagtendonk et al. 1996; van Wagtendonk and Sydoriak 1998; Menning 2003) as well as the production of fine fuels as determined by field measurements. Coefficients required to calculate all surface and ground fuel loads are arithmetically weighted by the basal area fraction (percent of total basal area by species) that are collected in the plots.

Plot based fuel measurements are being used to create a set of customized and spatially-extensive fuel models for the study area (Burgan and Rothermel 1984) for this area. Fuel model development includes a stochastic element to more closely model actual field conditions that have a large amount of spatial heterogeneity. Stochastic fuel models are being produced for each stratum identified using van Wagtendonk and Root's methods (forest type, aspect, seral stage, etc.). Plot data provide crown cover, height to live crown base, and average tree height at each site. Canopy bulk density estimates are based on previous work by Stephens (Stephens 1998). All of these spatially-discontinuous data derived from plot-specific measurements are extrapolated across the landscape using the remote sensing imagery maps of vegetation.

Simulations: Potential fire behavior

Potential fire behavior is being estimated using a similar technique developed by Stephens (1998) but at much broader spatial scales. The effectiveness of the different restoration treatments will be assessed with computer models such as FARSITE (Finney 1996; Finney 1998; Finney 2000) and FlamMap (Finney 2003). FARSITE is a deterministic, spatial, and temporal fire behavior model that requires as inputs fuel measurements and models; topographic data, including slope, aspect, and elevation; forest structural data including canopy cover, tree height, height-to-live crown base, and canopy bulk density; and weather. A historic fire occurrence map is being produced to estimate the probability of ignitions in the study area. Data come from the Plumas National Forest archives and current GIS layers. This derived map will be used to generate an actual ignition point in each FARSITE simulation. FlamMap is similar to FARSITE but does not use a user-determined ignition but burns the entire landscape using one set of weather data. These models will be used to quantify the potential fire behavior of the different treatment approaches.

The duration of each simulation would be seven days, a period that approximates the duration of many landscape-scale wildfires in the Sierra Nevada before they are contained (Stephens, personal experience). Weather scenarios using data from the 70th (moderate), 90th (severe) and 97th (extreme) percentile conditions is being used and this data is being collected from local weather stations. Fire simulations would be constrained by suppression activities. Constrained simulations will use realistic suppression elements (15 person hand crews, aircraft, bulldozers, etc.; Stephens, personal experience).

Outputs from the fire simulation include GIS files of fire line intensity (kW/m), heat per unit area (kW/square meter), rate of spread (m/s)**,** area burned (ha), emissions (tons) and if spotting and crowning occurred. Scorch height (m) would be calculated from fireline intensity, air temperature, and wind speed. This information will be used to compare the effects of the different landscape level restoration treatments on altering fire behavior.

Simulation: Fire effects

After the fire has passed, the effects of the fire linger: trees die, exposed soils erode, and insects invade. Some fire effects such as tree mortality are being modeled using the GIS outputs from the FARSITE and FlamMap simulations coupled to previously-tested quantitative models that estimate tree mortality (Stephens and Finney 2001). In addition to the tree-mortality measure of fire severity, the amount of bare mineral soil exposed by the simulated fires is being estimated for each 30m by 30m pixel.

Simulation: landscape dynamics over time

The second major phase of fire modeling takes advantage of the temporal dynamics of the Forest Vegetation Simulator (FVS) model. We will place the DFPZs on our virtual landscape at the probable time of their occurrence and use the model to grow trees in all other areas at the same time. The resulting landscape can then be evaluated for fuel loading and fire potential.

Analytical response variables for simulations

Landscape Fire Behavior

The differences in landscape-scale suppression efficiencies among fuels treatments is an essential aspect of this study (Agee et al. 2000; Bettinger et al. 2002). Defensible Fuel Profile Zones (DFPZs) should aid the ability of a wildfire suppression crew to successfully extinguish a fire during initial attack. FARSITE is being used with realistic suppression elements to determine if these landscape level fuel treatments will increase suppression efficiency when compared to the current untreated conditions. To test this efficiency in suppression, one landscape-scale fire response variable is the percentage of wildfires contained below 5 ha (12.5 ac) in size in one burning period before and after landscape fuel treatments.

Second, it is common for wildfires to be propagated by spotting and this can exponentially increase the size of the fire, particularly during the early periods such as the first 24 hours (Pyne et al. 1996). Treatments may reduce the spread of fire into a canopy where flaming brands may be carried into adjacent unburned areas(Pyne et al. 1996). Hence, the ability of a treatment to reduce the number of spot fires is an important measure of the treatment's ability to reduce fire severity or frequency. The number of spot fires is being estimated before and after treatments to determine if treatments reduce fire spread from spotting. Here, the second fire response variable is the percentage change in spot fire initiation before and after landscape level fuel treatments.

A third critical response variable focuses on escapements of fire across the landscape during a longer time period. We will report the probability of simulated fires escaping from or crossing DFPZs and spreading at least another 200 ha (500 ac). This probability will be defined as the percentage of fires given 90th percentile fire conditions. This will be an important measure of the effectiveness of the DFPZs at reducing the chance of fire spreading across the landscape.

The total spatial extent of fire, given treated or untreated areas, is the fourth response variable. Simulated fires will be allowed to burn either until they burn out or are contained. The extent of forested area burned will be compared between treated and untreated areas.

Fifth, ground and canopy fires are dramatically different in behavior, severity, intensity and likelihood to spread across a forested landscape (Pyne et al. 1996). Ground fires are often beneficial, reducing fuel from the ground and surface, and reducing competition for small trees (Stephenson et al. 1991; Stephenson 2000). The fifth response variable, therefore, is a simple ratio of the area of canopy fire to total fire extent.

Analyzing Spatial Efficiency of the Placement of Landscape-Level Fuels Treatments

Location of fuel breaks can play a significant role in the efficiency of fire suppression (Finney 1999; Finney 2001). This is discussed more thoroughly in our Study Plan. SPLATs are passive in nature—no active suppression is performed—and thereby differ markedly from DFPZs which are meant to be the base of active suppression. The efficacy of SPLATs, however, will be tested the same way as the DFPZs, as previously described with the same response variables and over the same time periods. SPLATs, like DFPZs, would be placed on the landscape over a period of years rather than being applied all in the same time period. Performing this analysis with the same base data layers of vegetation and topography will allow us to analyze the efficiency of these different landscape-scale forest fuels management strategies.

We plan to test SPLATs at several spatial extents. The first set of SPLATs tested will have the same spatial extent as the proposed DFPZs. We will test increasing increments of landscape treated by SPLATs by 5% until we find the level of treatment that corresponds with similar degrees of suppression efficiency with the DFPZ network.

Further, we will try re-allocating the DFPZ treatment areas spatially to see if we can improve their efficiency for suppressing large or severe fires. A response variable here would be the percentage of the landscape burned given different configurations given the same weather scenarios and suppression efforts.

Landscape Vegetation and Habitat Response to Fire

A primary concern of this study is the effect of fires on forest structure, pattern and condition. Of particular concern are the older, late-successional forest remnants (Erman 1996). These provide essential habitat to the spotted owl. Wildfires in the Sierra Nevada are commonly low to moderate severity events with patches of high severity fire (Stephenson et al. 1991). Low severity fires may kill only the smallest pole or seedling size-class trees while moderate severity fire may kill both small and moderately sized trees. Fire in the high severity patches—or landscapes in the case of an extensive high severity fire—kills the majority of the small and medium sized and many of the large trees within the perimeter. High severity fire and the corresponding large tree mortality will significantly reduce canopy cover.

Many wildlife species such as California spotted owls prefer diverse forest structure for foraging and breeding and the presence of such variation may affect the success of reproduction (Hunsaker et al. 2002; Blakesley et al. In Press; Lee and Irwin. In press). Telemetry studies indicate that owls prefer to nest in areas with high canopy cover. Some areas of lower cover can also be included in the foraging habitat but this should probably only comprise a fraction of the area. Reduction of canopy cover may reduce the nesting habitat quality for the owl.

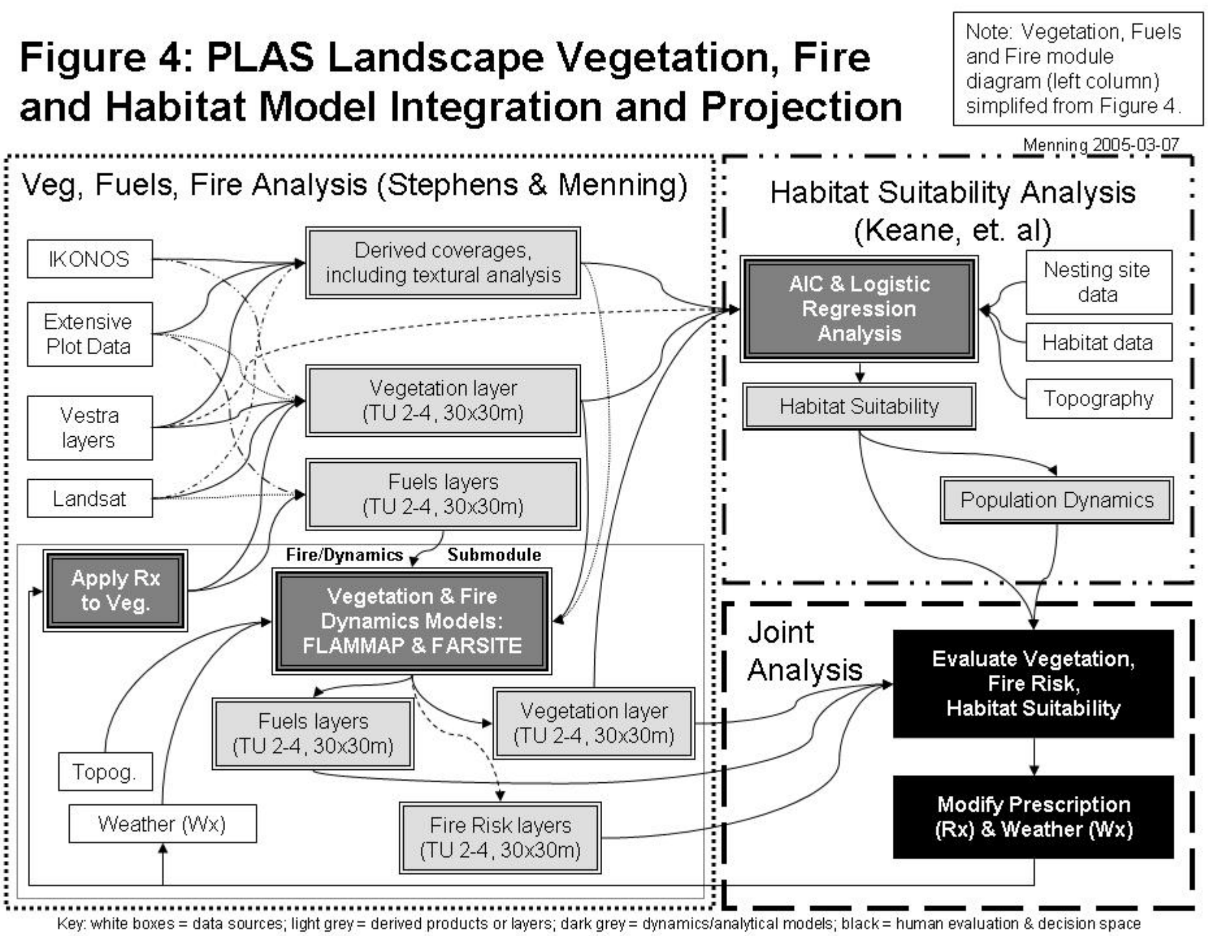
While there is a certain link between vegetation structure, pattern and composition and spotted owl core areas and home ranges (Keane and Blakesley 2005) exact measures of vegetation condition or change are not yet well defined. In addition, the link between different spatial scales of vegetation—extent and variation—and habitat selection is unknown. As a result, the definition of meaningful measures of vegetation condition and change, including appropriate scales of analysis from $30m^2$ to hundreds of hectares, will evolve along with the active analyses conducted in the Spotted Owl module (Keane and Blakesley 2005).

Fire and Habitat Model Integration

The final goal of the Fuels and Fire Module research is to coordinate with the Spotted Owl Module to produce a system in which an input of landscape-scale vegetation layers, weather scenarios, and fire events can be used to derive simultaneous assessments of fire and owl habitat. This effort requires separate but linked analyses by both our module and the Spotted Owl

Module analysts (Keane and Blakesley 2005). The fuels and fire module will use inputs of IKONOS imagery (described above, and in appendix E of Study Plan), extensive plot data, and pre-existing VESTRA vegetation classification data to produce derived coverages, including base vegetation layers. These vegetation layers will be passed to both the Owl Module and the fire behavior and effects part of this module's study. Analysts in the Owl Module use the layers in their Akaike Information Criteria (AIC) and regression analyses to determine owl habitat suitability (Keane and Blakesley 2005).

These paired analytical efforts—fire and wildlife habitat—will yield results covering the same landscape at the same time given the same weather and treatments. Fire behavior and effects and habitat will be evaluated jointly. Revised prescriptions for landscape fuels treatments (such as DFPZs) will be drafted along with a defined set of potential weather scenarios. These prescriptions and scenarios will be used to update the base vegetation layer to a post-treatment condition. Then, the whole process is repeated, with emphasis on analysis of the results (figure 4, Appendix B).



The net result of this collaborative effort will be an integrated analysis of the landscape-level effects of any potential fuels treatments and weather scenarios on both fire and owl habitat. We anticipate that other modules—Small Mammals and Songbird—may be able to develop habitat suitability analysis from vegetation layers that will enable them to integrate with this model, as well. As an interim step, we can probably crudely assess habitat of songbirds and small mammals using the California Wildlife Habitat Relationships system which links vegetation characteristics to the known habitat needs of different wildlife species. Eventually, empirical models derived from the research of the Songbird and Small Mammal Modules could supplant these coarser models.

Coordination with Interested Parties

We plan to work closely with Mark Finney, a fire-modeling expert in Missoula, Montana on FARSITE and FlamMap fire assessments. In addition, we anticipate close coordination with fire management offices at the Forest Service districts. In 2003, for example, we supplied forest structural data to the Plumas National Forest to use in its forest management planning.

Accomplishments in 2006: Results

Field

A field crew of two seasonal workers—Bridget Tracy and Nicholas Delaney—were trained in field work by Kurt Menning. Tracy and Delaney worked in the field for three months, from late May to late August. The field crew collected data from 178 plots this summer. Seventy of the sites had previously been inventoried: 51 plots were revisits of previously established plots (2003) and 19 were replacement plots for those that were eradicated by logging operations. An additional 108 new plots were established throughout the study area (TUs 2-4). In contrast to the previous plots, which were stratified random, these new plots were located at true random locations across the forest without bias for vegetation type, elevation or aspect. The total number of plots inventoried through 2006 is 602 (Table 2). Of these, 494 plots are stratified by slope, elevation, aspect and vegetation type. The other 108 comprise a true random sampling of the same area.

Table 2: Differences between random and stratified plot data. The differences are not significant due to high variability.

Plot type	#	Trees per hectare	Standard dev. (sd)	Trees per acre	sd	Basal area (m^2/ha)	sd	Basal area (f^2/acre)	sd
random	108	651.7	363.2	263.7	147	42.7	24	186.1	105
stratified	494	569.6	362.0	230.5	146	41.6	24	181.3	107

Table 3: Composition of 17,583 trees in 602 plots sampled, including snags. Trees under 10 cm (4 inches) diameter at breast height (DBH) are not included in this table.

Species	Count	Percent	% Without snags
White fir	4963	28.2	30.9
Douglas-fir	4319	24.6	26.9
Incense-cedar	2433	13.8	15.1

Snag	1503	8.5	na
Ponderosa pine	1475	8.4	9.2
Black Oak	1272	7.2	7.9
Sugar pine	930	5.3	5.8
Canyon Live Oak	240	1.4	1.5
Other hardwoods	160	0.9	1.0
Jeffrey pine	156	0.9	1.0
Red fir	132	0.8	0.8
	17583	100.0	100.0

Table 4: Fuel averages over 602 plots.

	Litter Depth	Duff Depth	0-3" fuels	3-9" fuels	9-20" fuels	20"+ fuels	Total
	(cm, in)		(metric tons/ha, tons/acre)				
Metric	3.8	3.3	3.6	2.5	2.7	3.0	11.8
Standard	1.5	1.3	3.2	2.3	2.4	2.7	10.5

Remote Sensing

Remote sensing imagery was acquired for TU 3&4 (2003) and TU 2&3 (2004) (see Figures 5 & 6). These images have been orthorectified and radiometrically enhanced. Orthorectification entails mathematically correcting the geometry of the imagery to remove geographic error and distortion due to the topography. A suite of points located in the field using a high-resolution GPS allowed us to make this set of corrections. We performed radiometric corrections to eliminate haze scattering of blue light and adjust the differences in total illumination due to the angle of the sun given the time and date. With these changes, the imagery is completely pre-processed.

Our next phase of image analysis was creating interpretive coverages of the imagery for use in landscape habitat analysis by the rest of the study team. These coverages include spectral entropy canopy diversity analysis (Figures 7 & 8), supervised classifications (Figure 9), and object-oriented classifications of vegetation (Figure 10 & 11). Spectral Entropy Canopy Diversity Analysis (SpECDA, Menning 2003) measures variability in NDVI (normalized difference vegetation index) values in a local area. The result is an assessment of the heterogeneity in canopy cover both by type (vegetation versus non-vegetated) as well as variability within vegetation type (conifer, chaparral, oak).

Figure 5: Five scenes of IKONOS imagery from 2003 and 2004 arrayed over a digital elevation model (DEM) of the landscape.

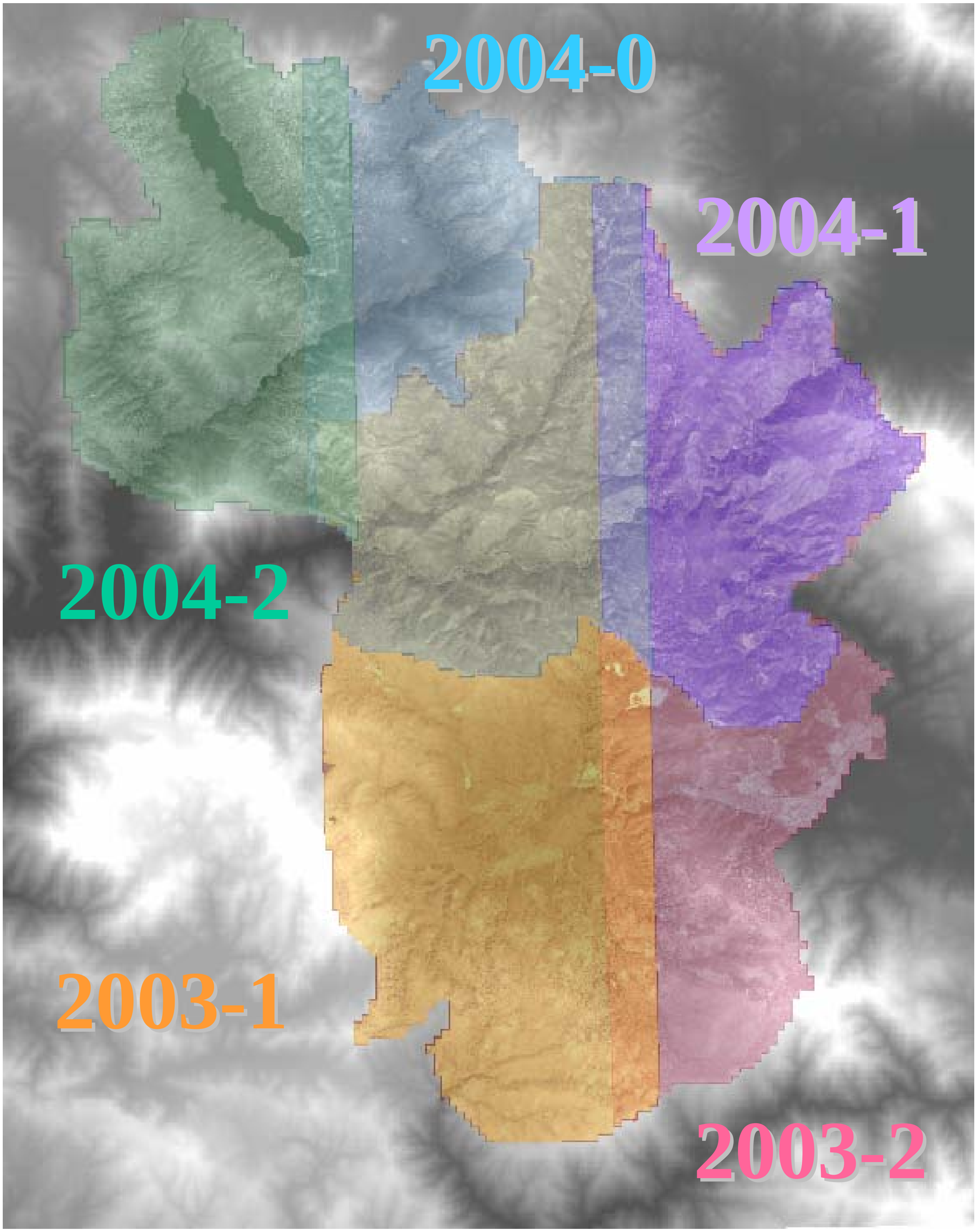


Figure 6: Three scenes of IKONOS imagery from 2004 displayed in true color.

Figure 7: One area, around Butt Valley Reservoir, shown with NDVI (Normalized Difference Vegetation Index), spectral entropy canopy diversity analysis (at plot scale), and SpECDA at the landscape scale.

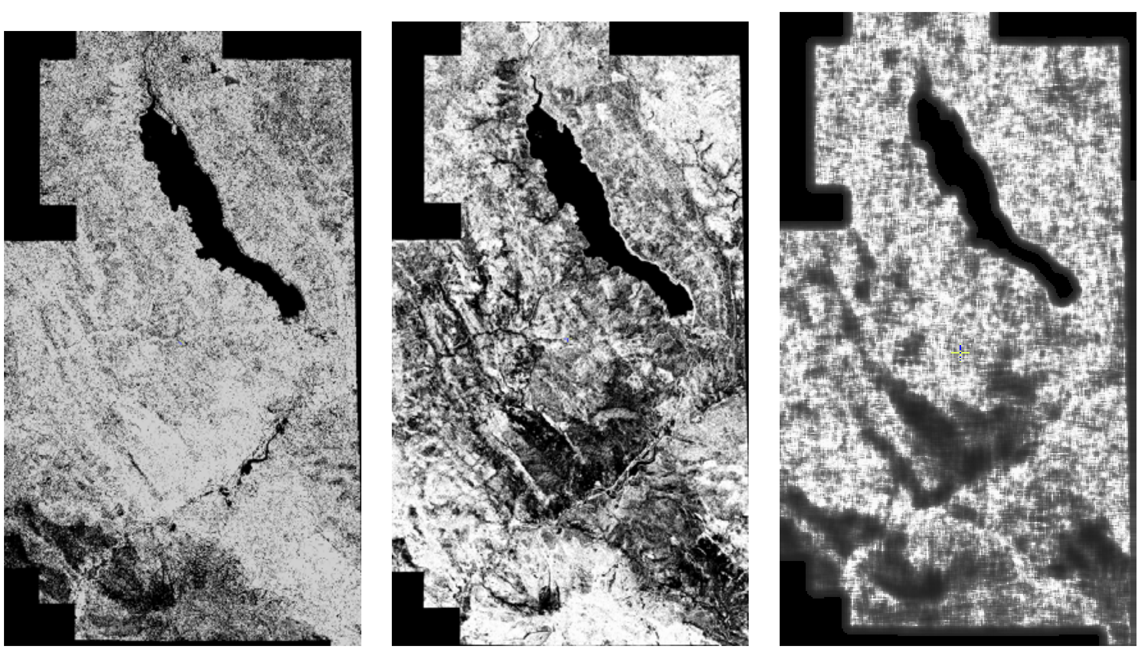


Figure 8: Close up of an area off Highway 70 showing NDVI (left) and SpECDA (right).

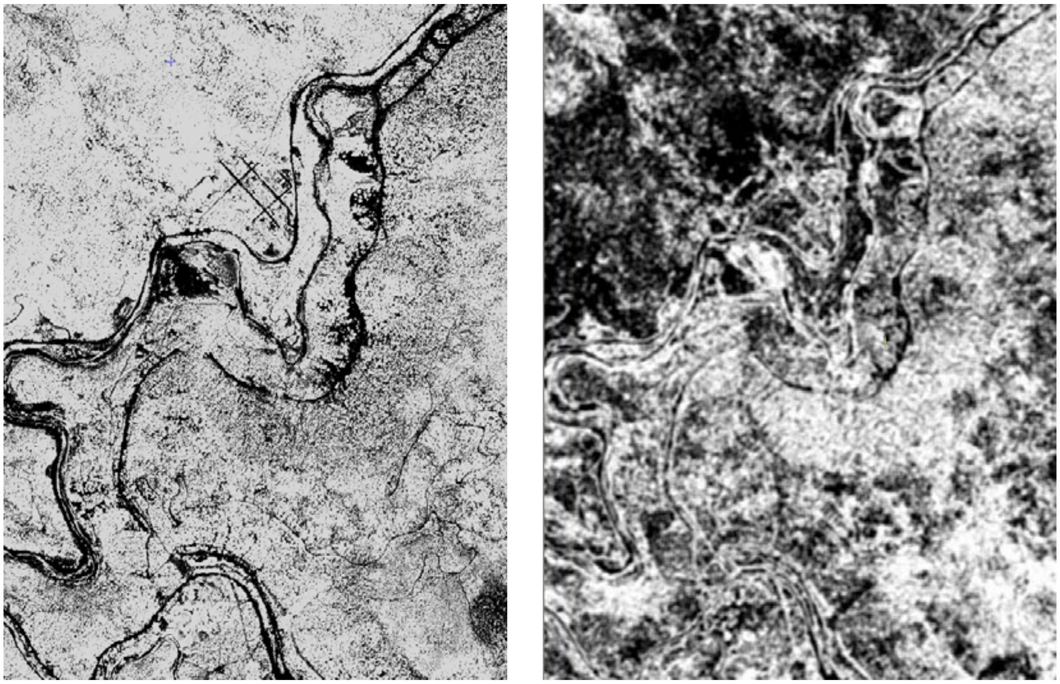


Figure 9: Pixel-based supervised classification of area around Butt Valley Reservoir. Dominant classification separates denser northern aspect forest from sparser southern aspect forest.

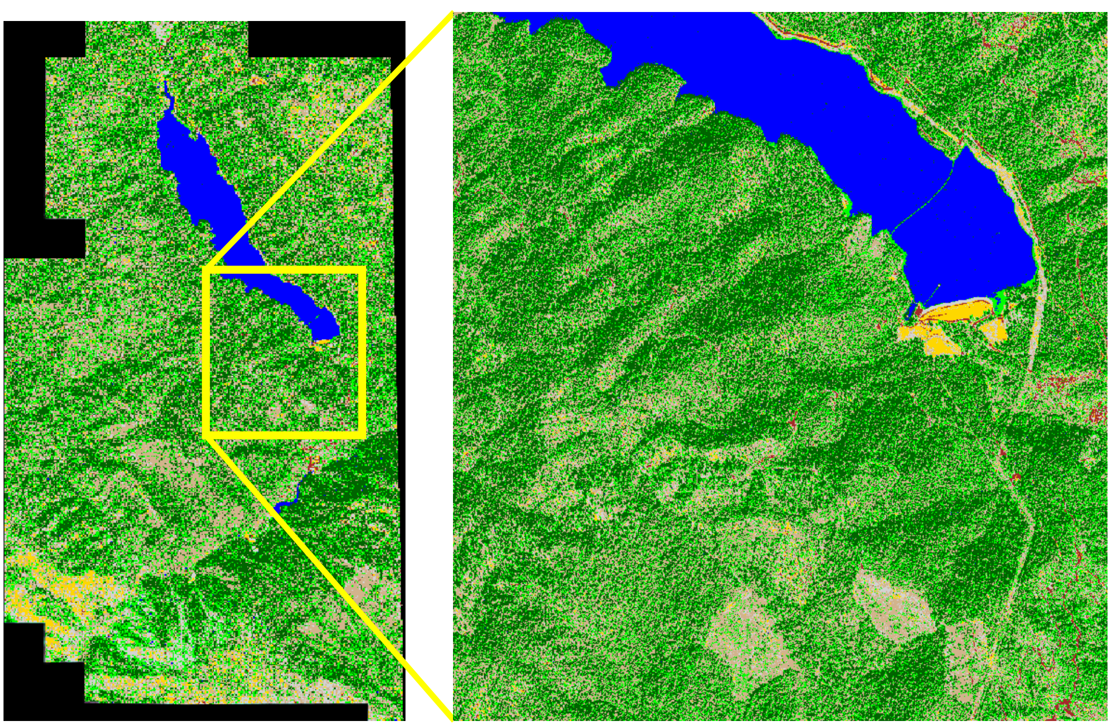


Figure 10: Object-oriented classification in eCognition of vegetation in the Butt Valley Reservoir area.

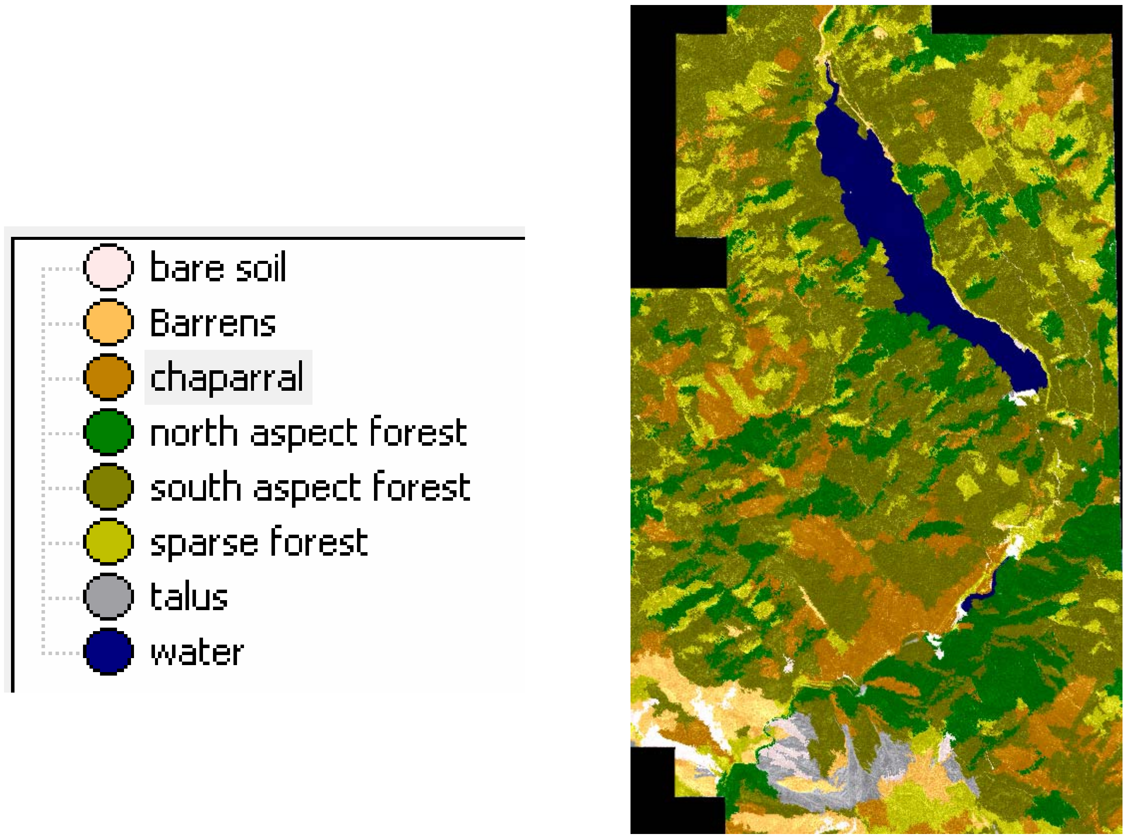
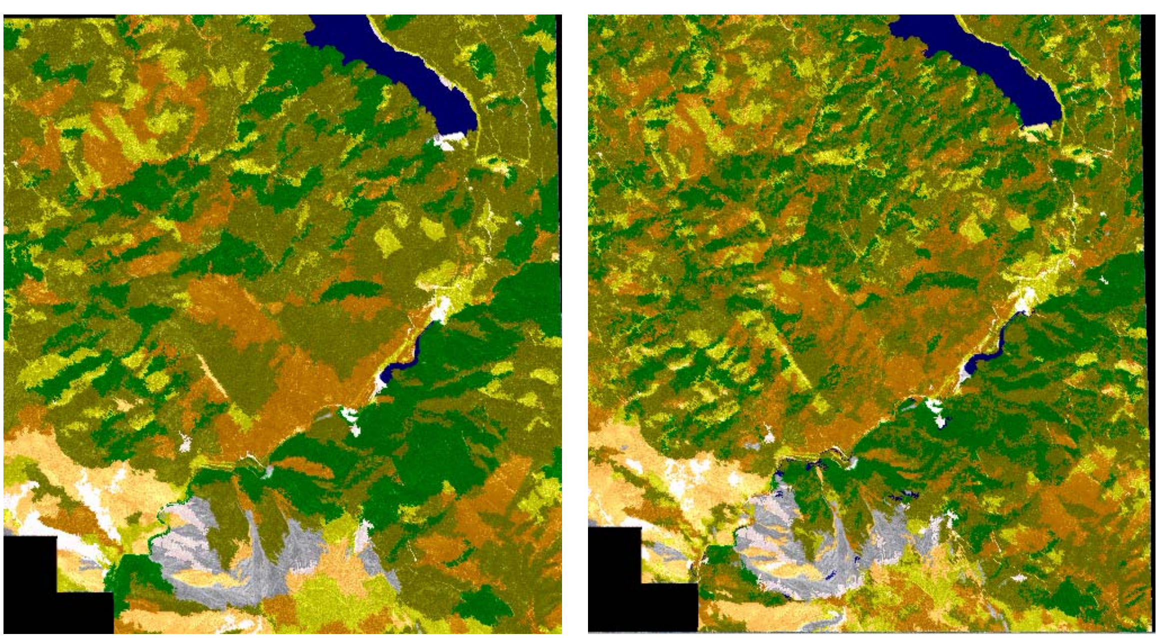


Figure 11: Close up of two different spatial scales of object-based classification.



Our next steps in the remote sensing analysis include performing accuracy assessment of classes using our extensive network of plots, verifying classes (north forest, south forest, rock, dirt, water, chaparral, etc.), identifying and extracting oaks from scenes and performing spatial analysis of classified images.

Modeling Fire and Integrating with Wildlife Habitat Analysis

We have begun the fire modeling with Farsite and Flammap. Initial results are being presented at the March meeting in Quincy. In January 2007, we attended USFS training in FVS software to perform the later phase of fire modeling. Test runs on real data are shown below. We are not presenting fire behavior data yet as thresholds and values are still being calibrated.

Figure 12: Actual data from plot 0014 inventoried in 2006 shown in Stand Visualization System (SVS). This is a very sparse plot with fair clearance from ground to lower live crown on most trees.

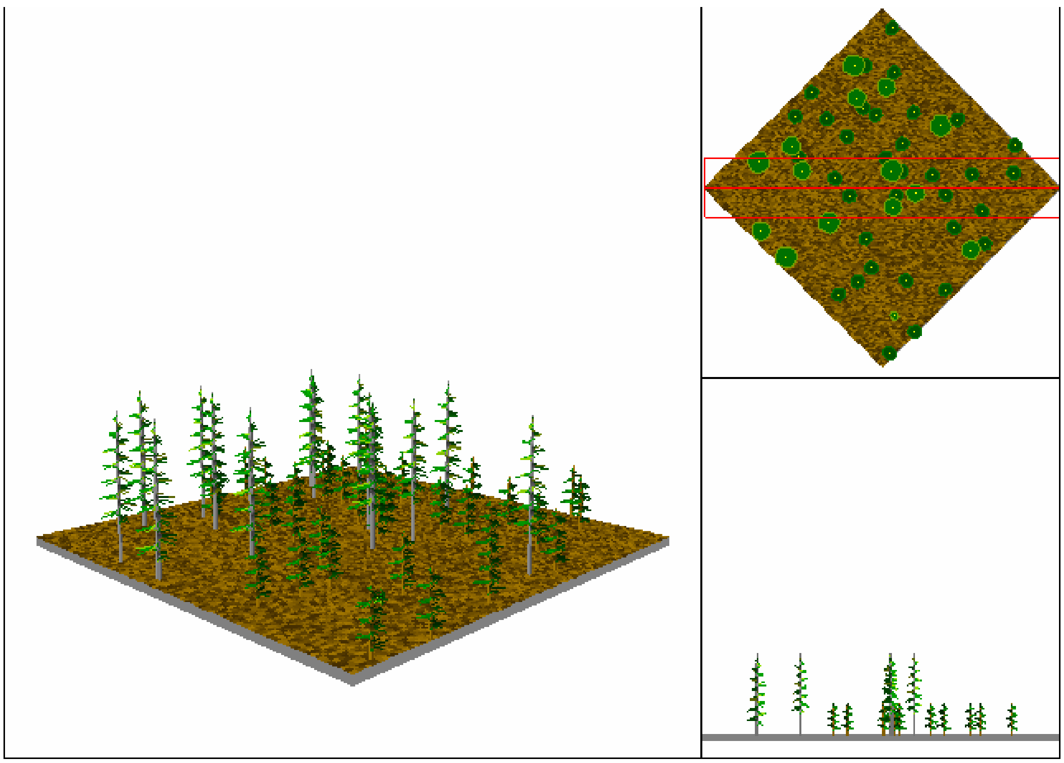


Figure 13: Actual data from plot 0014 shown burning under severe autumn conditions. Most trees survive but a number of small trees with canopy reaching to the ground torch.

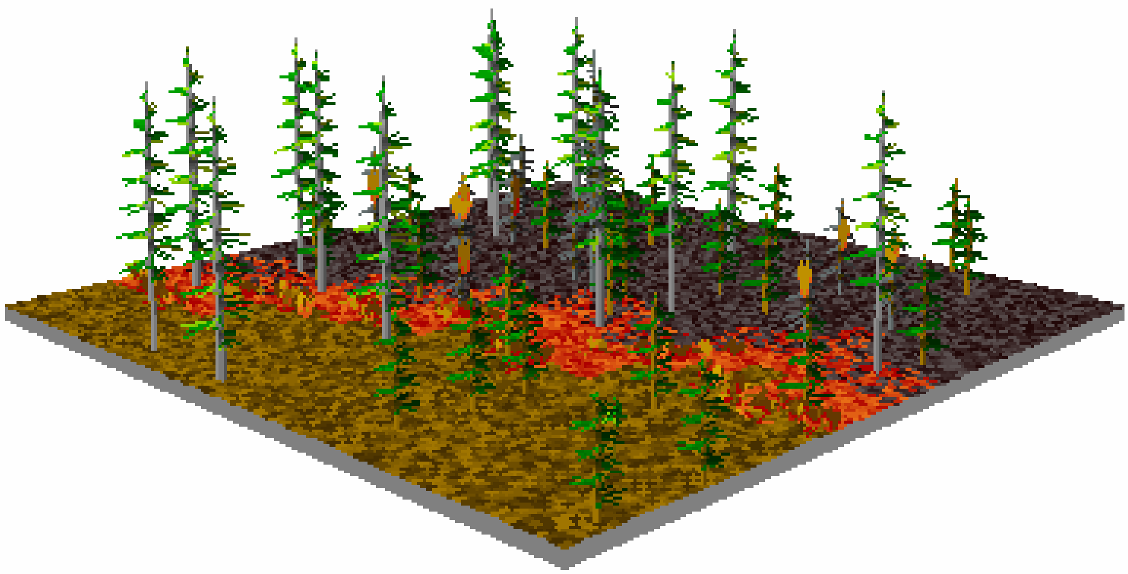


Figure 14: Actual data from plot 1172 inventoried in 2006. This is a dense stand of young trees overtopped by a single larger tree.

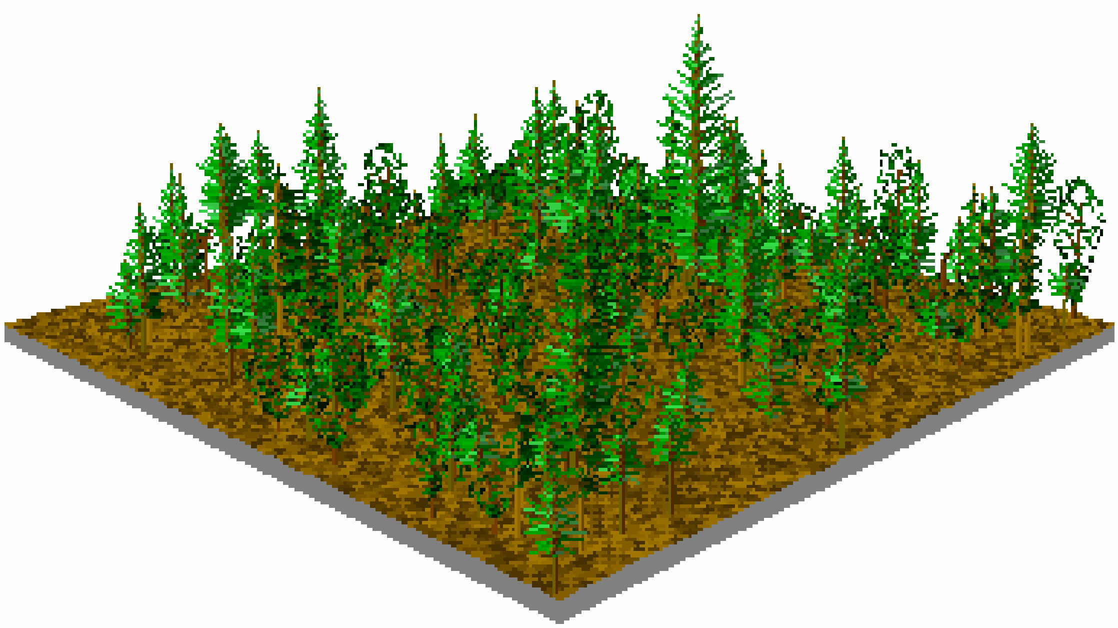


Figure 15: Plot 1172 experiencing moderately severe fire.

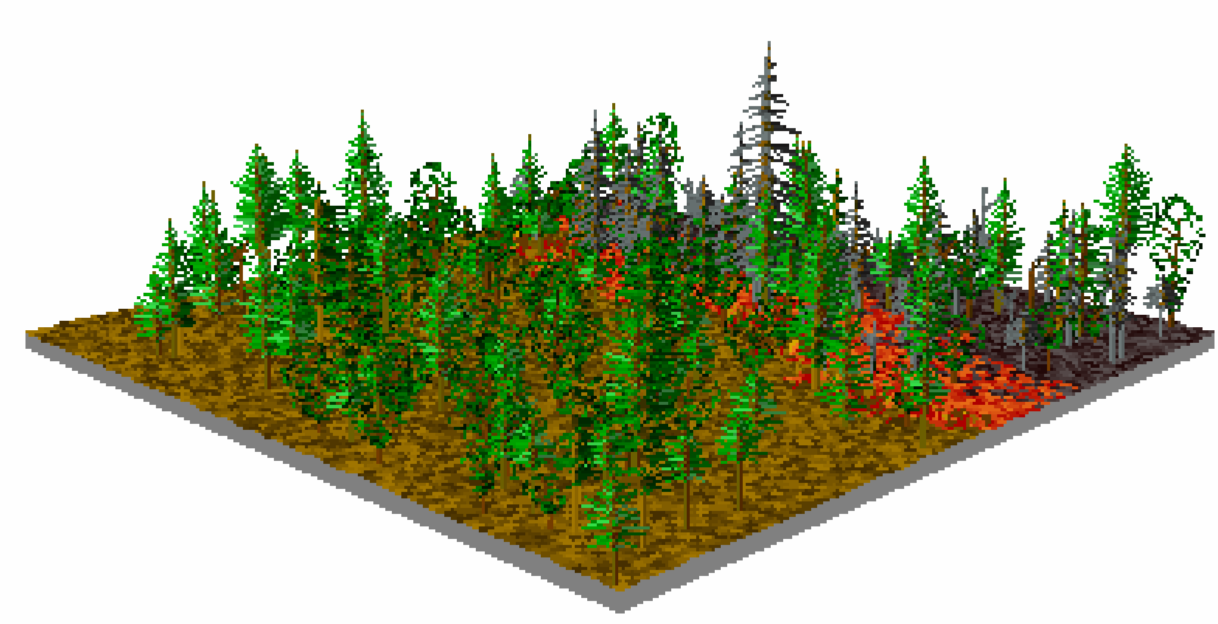
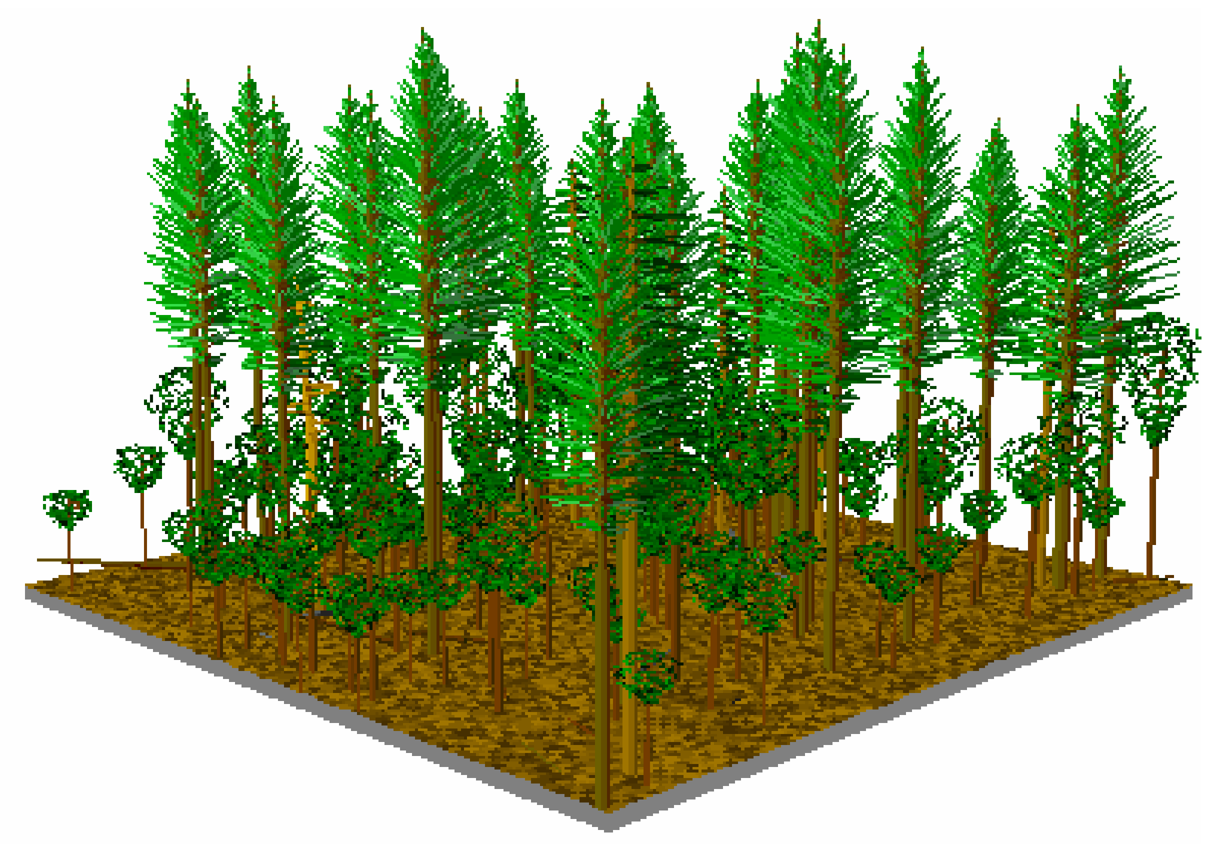


Figure 16: Projected data from plot 1172 shown 50 years in the future assuming standard rates of growth for this region of the Plumas.



Publications and Presentations 2005-7

- Menning, K.M., and S.L. Stephens (in press: 2006-7) Fire Climbing in the Forest: a semi-qualitative, semi-quantitative approach to assessing ladder fuel hazards, Western Journal of Applied Forestry.

- Menning, K. M. and S. L. Stephens (2007) Modeling potential fire based on current conditions across 60,000 ha in the northern Sierra Nevada (California, USA). US Branch International Association of Landscape Ecology Annual Meeting.

- Menning, K. M. and S. L. Stephens (2007) Comparing two populations of a Sierra Nevadan (California, USA) forest community as arrayed across elevational, aspect and slope gradients. US Branch International Association of Landscape Ecology Annual Meeting.

- Menning, K. M. and S. L. Stephens (2006). Modeling Landscape Fire Behavior and Effects in the Northern Sierra Nevada. 3rd International Fire Ecology and Management Congress, San Diego, CA.

- Menning, K. M. and S. L. Stephens (2006). Landscape-scale Fire Risk Wildlife Habitat Considered Jointly. 21st Annual Symposium of the United States Regional Chapter of the International Association for Ecology (US IALE), San Diego, CA.

- Menning, K. M. and S. L. Stephens (2006). Assessing Ladder Fuels in Forests. 3rd International Fire Ecology and Management Congress, San Diego, CA.

- Menning, K.M., and S. L. Stephens (2005) "Fire rising in the forest: Ladder fuel hazard assessment using a mixed qualitative and quantitative approach," Ecological Society of America, August 7-12, 2005, Montreal Canada. (Abstract attached to end of report).

- Menning, K. M. and S. L. Stephens (2005). (Invited speaker:) *Linking fire and wildlife habitat in California: Spectral entropy canopy diversity analysis*. UK Centre for Ecology and Hydrology, Monks Wood, Cambridgeshire, England, UK. November 21, 2005.

- Menning, K. M. and S. L. Stephens (2005). (Invited speaker:) *Spatial Ecological Links Between Fire, Forests and Habitat in the Plumas-Lassen Administrative Project*. Geographic Information Centre Seminar: City University, London, London, England UK. November 22, 2005.

- Menning, K. M. and S. L. Stephens (2005). (Invited speaker:) *Forest Structural Diversity: Spectral Entropy Canopy Diversity Analysis*. Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf, Switzerland. December 5, 2005.

Goals for 2007

Spring

Furthering the remote sensing processing and analysis and fire behavior and effects modeling are our primary goals in spring. Integrative modeling of fire and habitat scenarios with John Keane and the owl module has been planned at a January 2007 meeting.

Field Season

We are not planning on putting a field crew out in the Plumas in 2007. We will be performing fire modeling and remote sensing analyses given current data instead.

Autumn

Autumn goals include publishing remote sensing and modeling analyses (please see the publications list).

Expected Products (Deliverables)

Results will be published regularly in the Plumas-Lassen Administrative Study Annual Reports. We will present results directly, as they are derived, to interested parties. More formal scientific publications are targeted covering a variety of areas including the LaFHA approach being piloted in this study, SpECDA analyses of forest structure and its variability, fire behavior and effects, integrated model results with the Owl Module, and assessments of the efficiency of DFPZs and other treatments in moderating the landscape-level effects of fire.

Additional Publications Planned for 2007

- Menning, K. M. and S. L. Stephens. "Spectral Entropy Canopy Diversity Analysis (SpECDA) used to Assess Variability in Forest Structure and Composition" submitted to Photogrammetric Engineering and Remote Sensing.
- Menning, K. M., S. L. Stephens, J. Keane, D. Kelt, and others. "Integrated modeling of fire and California Spotted Owl habitat conditions given different weather and landscape treatment scenarios" To be submitted to a journal mutually agreed upon.
- Menning, K. M. and S. L. Stephens. "Fire Behavior and Effects as a Result of Defensible Fuel Profile Zones" To be submitted to International Journal of Wildland Fire.
- Menning, K. M. and S. L. Stephens. "Landscape Forest Variability across the Northern Sierra Nevada" To be submitted to Landscape Ecology.

Additional publications based on analysis of the field data, remote sensing products, and results of integrative modeling with Keane.

Data Management and Archiving

All data will be archived with the USDA Forest Service's Sierra Nevada Research Center (SNRC) in Davis, California, as well as the Fire Science Lab (Stephens Lab) at the University of California, Berkeley. Some derived products will be put on-line by the SNRC or Stephens Lab.

Appendix A: Datasheet for field data collection, page 1 of 2

Plumas Veg Module — Data sheet

3/4/2004

Data for the whole plot

Plot	Date	UTM-E		UTM-N			Habitat typ		Snags <10	
		Aspect		Slope			Water Y/N		Snags 10-30	
		Recorders		Photo #			% Road		Snags >30	

50m radial plot — Logs

Variable Radius (50m) Plot Species Tallies (panama angle gauge)

Species (live)											
Number stems											

50m Plot Layers + --> Species and their percent cover

	Herb (+seed) (<50cm)	Real Shrub (0.5-5m)	Small tree (Tree shrub)	All veg 0.5-5 (Tot. shrub)	Big tree (Tree)
%cover					
Low Bnd					
Low Bnd Sp					
Up Bnd					
Up Bnd Sp					
DBH min					
DBH min sp					
DBH max					
DBH max sp					

Real shrub (0.5-5m)		Small Trees (tree shrub, 0-5m)		
Species	% Cover	Size class	Species	% Cover
		Small Tree (Tree Shr) (<5m)		
			total	100%
		Big Tree (Tree, >5m)		
total	100%		total	100%

12.6 m Radial Plot Fuels & Fire Risk Assessments

Fuel Photo Series		LaFHA			
Fuel size	Count	Quadrants	Haz. Rating	Min Cr Ht	Max Lad Gap
0-3"		N (1)			
3-9"		E (2)			
9-20"		S (3)			
>20"		W (4)			

Brown's Transects 12.6m

Tallies		1 hr (0-0.6cm)	10 hr (0.6-2.5)	100 (2.5-7.6)	Litter @ 5	Duff @ 5	Litter @ 12	Duff @ 12	max depth 1	max depth 2	max depth 3	Sight tube
A												
B=A+90												
A: 1000hr	Diam											
	Sound/Rot											
Shrubs	Species											
	Length											
	Ht class											
B: 1000hr	Diam											
	Sound/Rot											
Shrubs	Species											
	Length											
	Ht class											

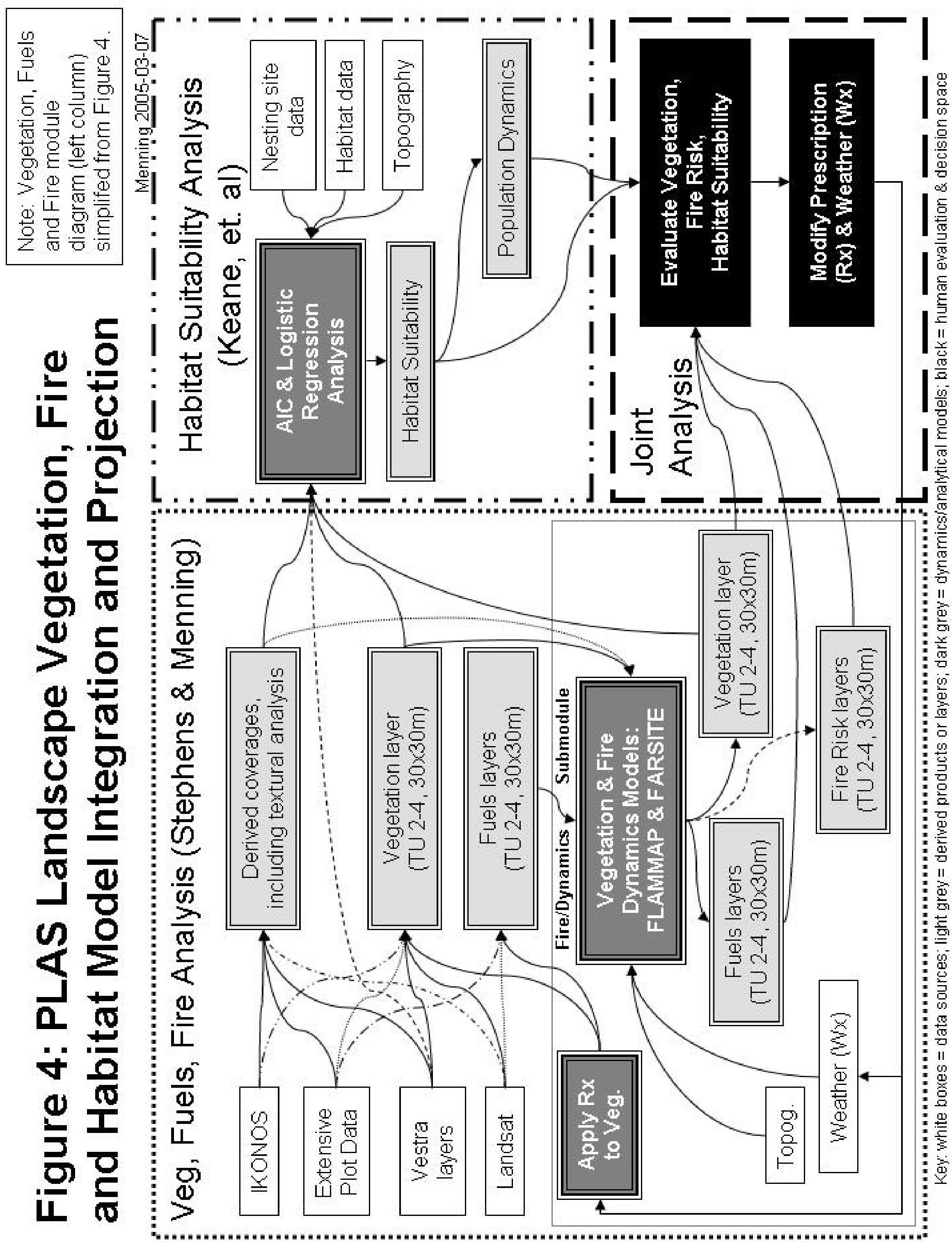
Appendix A (continued): Datasheet for field data collection, page 2 of 2

Plot

Sheet 2

Trees in 12.6m radius plot								Snags in 12.6m radius plot			
Species	DBH	Height	Ht. Low Cr.	Cr. Width	Shape	Mistletoe 0-6		DBH	Ht. Class	Decay class	Cav>10cm

Appendix B: Model integration with California Spotted Owl team (Keane)



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Chapter 2:
Vegetation Module

Forest Restoration in the Northern Sierra Nevada: Impacts on Structure, Fire Climate, and Ecosystem Resilience.

Project Staff
Dr. Malcolm North, Research Plant Ecologist. Phone: 530-754-7398. email: mpnorth@ucdavis.edu.
Dr. Seth Bigelow, Biologist. Phone: 530-759-1718. email: sbigelow@fs.fed.us
Mr. Keith Perchemlides, Biological Sciences Technician Phone: 530-927-9927. Email: kperchemlides@fs.fed.us

Sierra Nevada Research Center, Pacific Southwest Research Station U.S. Forest Service,
2121 2nd Street, Suite A-101. Davis, CA 95616

Collaborators
Sean Parks, Geographer/Ecologist, Sierra Nevada Research Center
Carl Salk, Research Associate, Department of Biology, Duke University
Will Horwath, Professor, Department of Land, Air, and Water Resources

Objectives

The vegetation module of the Plumas-Lassen Administrative Study studies how changes in the forest canopy affect ecosystem functioning, including microclimate, tree growth, understory diversity and competition of shrubs and juvenile trees. The module objectives are:

1) determine the effects of reduction in tree canopy cover on microclimate, fuels dryness, and other factors contributing to flammability of the forest understory, and

2) determine effects of reduction in tree canopy cover on light, soil moisture, and other factors influencing composition and growth of the understory plant community.

Research approaches include stand-level experimental manipulations, measurement of plant growth and survival along existing environmental gradients, and assessment of impacts of routine (i.e., non-experimental) forest management activities.

Research Activities 2006

Study on Effects of Experimental Thinning and Group Selection on Forest Structure, Fire Climate, and Plant Communities in West-Side Mixed-Conifer Forest.

The forest management treatments for this study are scheduled for summer 2007. In 2006, we continued to collect pre-treatment data in the nine 22-acre and three 2-acre plots. Data relevant to fire climate included 1) continuous monitoring of windspeed, air temperature, and humidity and 2) monthly monitoring of moisture in duff and 1000-, 100-, and 10-hr activity fuels (**Fig. 1**). Data relevant to plant community dynamics include soil temperature (2 cm below mineral soil surface) and soil wetness in the 0 - 15 cm, 15 - 40 cm, and 40 - 70 cm horizons.

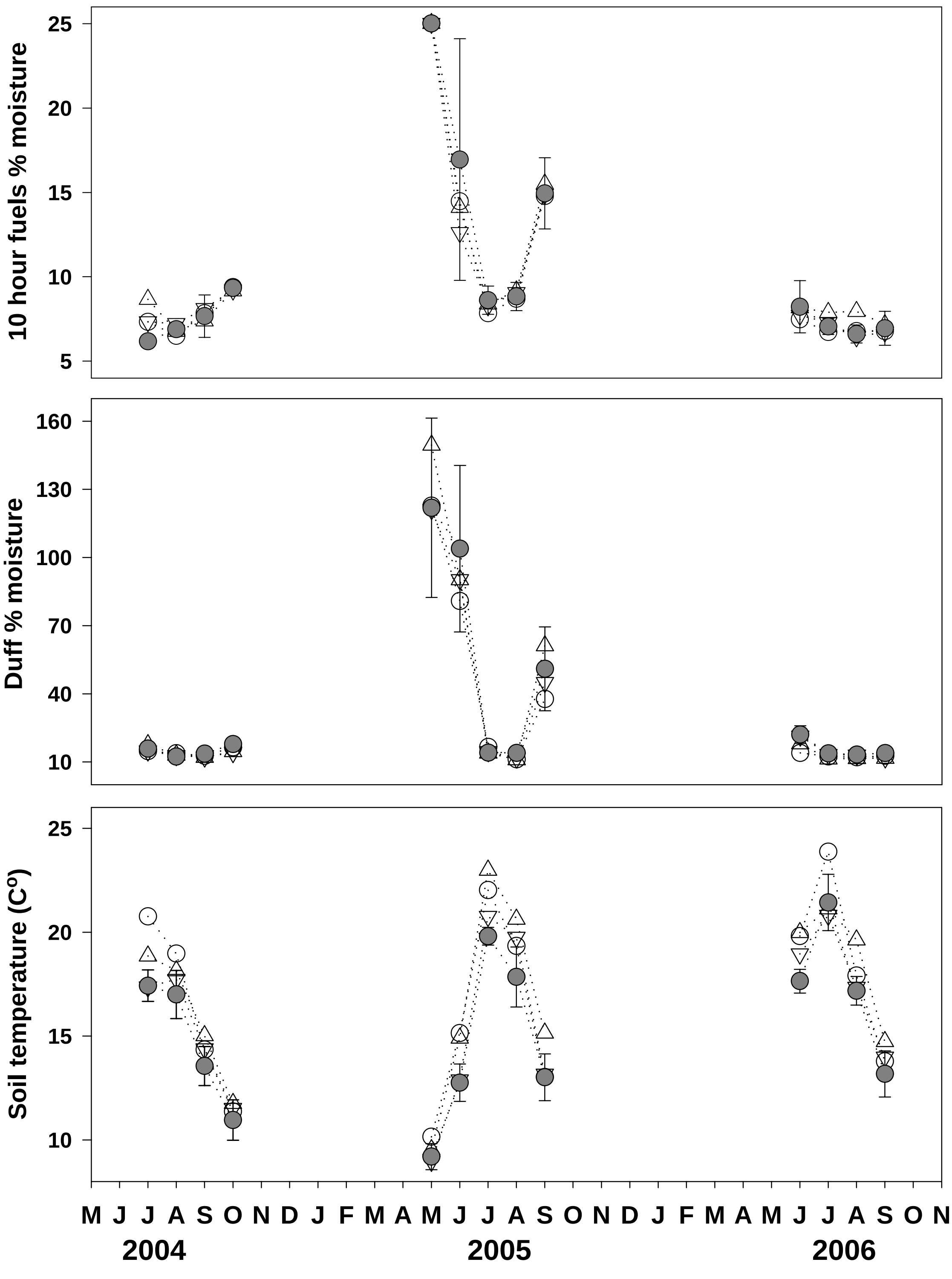

Figure 1. Seasonal trends in 10-hr fuel moisture, duff moisture, and soil temperature in experimental thinning plots prior to treatment. Open circle is group selection, downward triangle 30% canopy, upward triangle 50% canopy, and dark circle is control.

Study on light transmittance in treated stands
Availability of light in the understory is a major determinant of plant community dynamics, and understory light is expected to increase immediately after treatments are done. Before-and-after comparisons will be done on understory light measured with canopy photography. In 2006 we calibrated the canopy photography light estimates by measuring light with quantum sensors throughout the season in the same places where some of the canopy photographs were taken. We also measured light transmission through the canopy of mature trees (**Fig. 2**) and shrubs (**Fig. 3**). These parameters will go into an existing computer model that will allow precise prediction of understory light in spatially mapped tree stands. Data collected in our treatment stands will allow determination of the predictive accuracy of the light model.

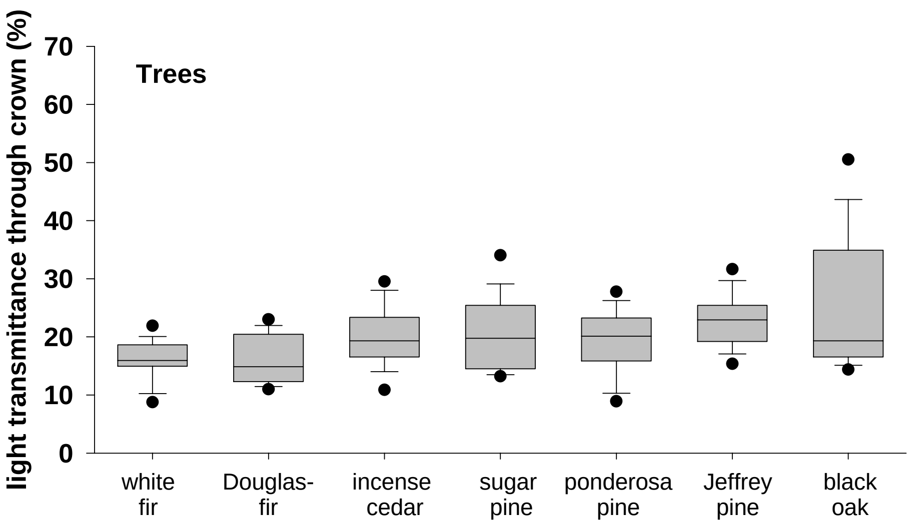

Figure 2. Light transmittance through crowns of canopy trees of the mixed-conifer community: transmittance increases as shade-intolerance increases.

Studies on performance of mixed-conifer saplings with respect to light and other factors (*Seth Bigelow, Carl Salk, and Malcolm North*). The fourth census of the 500 saplings in this study took place this season. Although the extremely low mortality rates of these saplings over the past 4 years will make it difficult to estimate mortality with respect to light availability, annual height measurements will allow accurate estimate of height growth with respect to light.

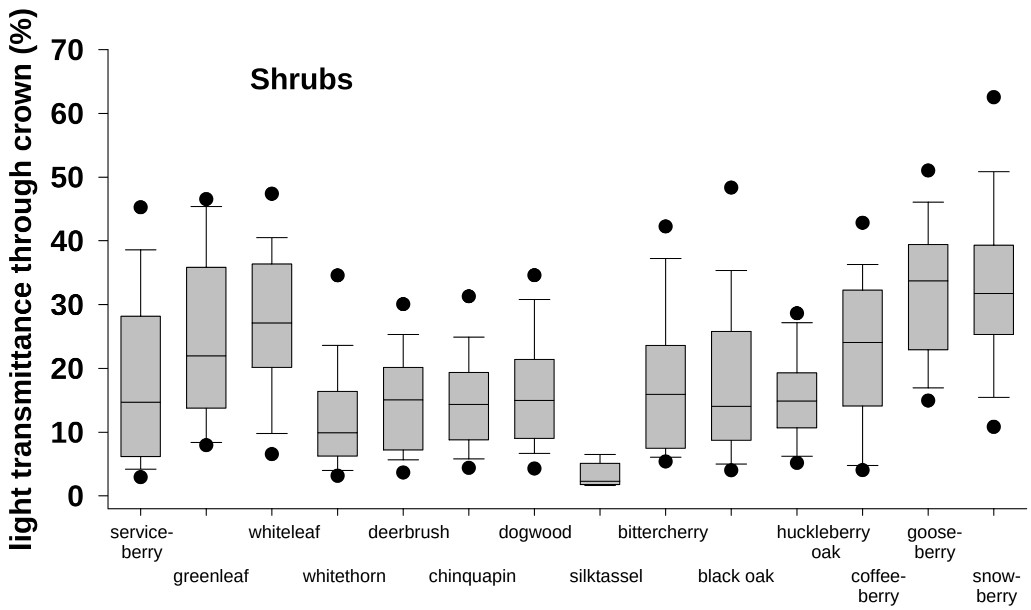

Figure 3. Light transmittance through crowns of common Sierran shrubs. Many shrubs are capable of casting extremely dense shade (= low light transmittance).

<u>Outreach, Training, and Safety</u>

Outreach

Vegetation module personnel gave a public presentation on their work at the 2006 Plumas-Lassen study symposium.

Training and Personnel Development

Seth Bigelow participated in a workshop on use of the R statistics and programming language for ecological studies. Keith Perchemlides completed a course for certification as a Wilderness First Responder.

Safety

The vegetation module's field technician developed an allergy to bee stings, which necessitated several trips to the emergency room.

Chapter 3: Small Mammal Distribution, Abundance, and Habitat Relationships

Project Leader:

Robin J. Innes

University of California Davis
Department of Wildlife, Fish, and Conservation Biology
One Shields Avenue
Davis, CA 95616
rjinnes@ucdavis.edu

Principal Investigators:

Douglas A. Kelt[1], Dirk H. VanVuren[1], and Michael L. Johnson[2]

[1]University of California Davis
Department of Wildlife, Fish, and Conservation Biology
One Shields Avenue
Davis, CA 95616

[2]University of California Davis
John Muir Institute of the Environment
One Shields Avenue
Davis, CA 95616

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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 2006 marked the fourth year of implementation of the study. As of the end of the 2006 field season, none of the proposed treatments have been implemented, thus everything we report on reflects pre-treatment conditions.

The information provided in this report is intended to provide background information on the pre-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 2006, Robin Innes, who has been with the project since 2002, succeeded James Wilson as Project Leader of the Mammal Module of the PLAS. James Wilson continues to improve manuscripts initiated during his time as a postdoctoral fellow with the PLAS, as a staff member at California State University, Fresno. To date, we have had two 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. In 2006, Jaya Smith joined the Mammal Module and will complete his graduate work in 2008. He is studying the abundance and distribution, home range, and habitat use of the northern flying squirrel.

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., spotted owl, *Strix 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. 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. We plan 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 small mammal abundance and species diversity. We will do this 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 live-trapping grids (long-term grids) and temporary live-trapping grids (landbird grids) located throughout Plumas National Forest.

In addition to the valuable feedback that can be gained by determining how the full compliment of small mammals responds to different forest management regimes, we will more closely examine the responses of several key small mammals to forest management practices. Due to differing seasonal energy requirements, hibernating and non-hibernating small mammals are likely to be effected differently by forest management practices. Hibernation may reduce mortality of small mammals during the winter months through conservation of energy and protection from predators (Broadbooks 1970), with mortality rate more heavily influenced by the quantity and quality of food caches (Post et al. 1993), and body condition prior to hibernation (Murie and Boag 1984), parameters which can be related to forest productivity. Non-hibernating small mammals may exhibit elevated mortality during the winter months due to increased levels of thermal stress, limited food resources, and exposure to predators. Thus, our objective was to evaluate the effects of forest management treatments on the ecology of both hibernating and non-hibernating species.

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 (*Strix o. occidentalis*; 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 appear to 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, Smith et al. 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 as compared to the rest of 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 wetter regions in the Sierra Nevada where truffles, their primary food source, are more abundant. This disjunctive distribution of food resources may drive differences in 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 populations in other parts of their range. We used live-trapping and radiotelemetry techniques to determine the abundance and distribution, habitat use, and home range of northern flying squirrels in the Sierra Nevada, compared this with data with data from other parts of their distribution, and evaluated 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 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. Dusky-footed woodrats typically construct conspicuous, conical houses on the ground using sticks, bark, and plant cuttings, although some houses are built 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 house-site selection 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 houses. 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 will be to examine the home range and space use of dusky-footed woodrats.

Other key small mammals include two diurnal, hibernating rodents, the golden-mantled ground squirrel (*Spermophilus lateralis*) and chipmunks (*Tamias sp*.). As mentioned previously, the body condition of individual small mammals appears critical to hibernation and over-winter survival (Lenihan & Van Vuren 1996; Murie & Boag 1984). Body condition may also influence reproduction; for example, small mammals that are heavier on emergence form hibernation may produce larger litters (Dobson et al. 1999) that are more likely to be successfully weaned (Neuhaus 2000). Additionally, first-year over-winter survival of juvenile small mammals is positively related to pre-hibernation body mass (Bennett 1999; Lenihan & Van Vuren 1996). Body condition can also affect behavior; for example, juvenile dispersal may be influenced by body condition (Barash 1974) since body fat may be an important cue for dispersal, with lighter individuals dispersing later than heavier individuals (Barash 1974; Nunes et al. 1998). Offspring condition at the time of dispersal may be influenced not only by post-weaning food acquisition by the juvenile, but also by maternal condition (Dobson et al. 1999). Although body condition is important to all animals, it is particularly so for hibernating ground-squirrels, which face a short active season (<5 months) and require large energy reserves. Thus, our objective was to evaluate the influence of forest management practices at they relate to forest productivity on the body condition of the golden-mantled ground squirrel, a species found commonly at higher elevations (>2000 m) in the Sierra Nevada, where the length of the snow-free growing season could severely limits the animal's ability to acquire enough energy to sustain activity and support reproduction (Armitage 1989). We measured the amount of fat reserves (*i.e.*, body condition) using the total body electrical conductivity (ToBEC) method (Koteja 1996; Walsberg 1988), used radiotelemetry methods to document dispersal and maternal home range, and developed a model which relates offspring natal dispersal to body condition, and incorporates the influence of maternal condition on these factors.

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 cache seeds beneath the layer of decaying vegetation on the forest floor (scatter-hoarding), where they stand a better chance of germinating than those remaining on the surface litter (Sumner and Dixon 1953), or deposit seeds in underground burrows where seeds can not establish seedlings (larder-hoarding). Chipmunks scatter-hoard seeds more frequently than other small mammals, thus potentially having a greater impact on seedling establishment (Hollander and Vander Wall 2004). 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 hider the return of timber (Smith and Aldous 1947, Tevis 1953). We were particularly interested in two species that occur commonly throughout the Plumas National Forest, the long-eared (*T. quadrimaculatus*) and shadow (*T. senex*) chipmunks. 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 shadow chipmunks at three spatial scales in Plumas National Forest and evaluate the affect of forest management practices on these species.

OBJECTIVES

The primary objective of the small 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. Determine the fitness correlates of a hibernating small-mammal, the golden-mantled ground squirrel, to forest management.
8. Evaluate the taxonomy and habitat affinities of two sympatric chipmunks, the long-eared and shadow chipmunks, at multiple spatial scales.

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. To date, all data have been collected prior to any treatments to determine baseline conditions. In 2003, we established 18 semi-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 haphazardly-selected tree located <10 m from the grid point; arboreal traps may or may 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 run-ways, when possible.

We trapped all long-term grids (n=21) in 2006. 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 more a desirable bait mixture, in accordance with the recommendations of Carey et al. (1991).

The 18 long-term grids established in 2003 were placed in 5 principal forest types as described by Coppeto et al. (2006, Publication #1, 2). 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, *Pinus ponderosa* and *P. jeffreyi*, and incense cedar, *Calocedrus decurrens*, *n* = 3). In 2003, group selects were established 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, the Plumas National Forest 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 whitethorn and deerbrush (*Ceanothus cordulatus* and *C. intigerrimus*), bitter cherry (*Prunus emerginata*), and huckleberry oak (*Quercus vaccinifolium*). Pinemat manzanita (*Arctostaphylos nevadensis*) occurred almost exclusively in red fir forests, and buckbrush (*Ceanothus cuneatus*) predominantly in pine-cedar/ponderosa pine forests.

Twelve of the long-term grids were placed within the experimental management plots established by the Vegetation Module of the PLAS (Appendix B). These 12 study plots were placed in 3 groups 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. In 2006, one individual golden-mantled ground squirrel was documented to move between two grids in red-fir habitat. No small mammals were documented to move between any other long-term grids in any year.

Long-term grids were trapped monthly (May-October) during 2003-2004 and biannually (June, Oct) during 2005-2006. 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. This enabled us to sample both diurnal and nocturnal species while reducing deaths that result from heat exposure 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.

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. We changed the bait because the latter bait is recommended for capturing the difficult-to-capture northern flying squirrel (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, natural cover (e.g., bark, moss) or cover boards and synthetic bedding material (nonabsorbent polyethylene batting) were provided as needed for thermal insulation in all traps. After the trap session was completed, bait was deposited on the ground at the grid point and all traps were removed.

Demographic profiles.—Population demographics will be modeled by species using program MARK. Species that do not have enough individuals 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.

Landbird grids

To complement the data collected at our long-term grids and more fully integrate our live-trapping efforts with that of other modules, we established temporary, small-mammal trapping grids at a subset of Landbird Module census points in 2006. Eight to 10 census points within each landbird census transect were randomly selected for small mammal sampling; selection of census transects was stratified to include transects located throughout (former) treatment units 2-5. At each census point, a 2 x 2 array of live-traps with 50 m spacing was established by pacing 35 m from the census point in the four cardinal directions (north, south, east and west; Fig. 2). The live-trapping grids covers 0.25 ha (1 ha with a ½ inter-trap distance buffer). All live-trapping methods were designed to optimize the capture and recapture of the northern flying squirrel, the most difficult to capture small mammal in our study area, and in this way provide the best means of trapping for the full suite of small mammals, including the dusky-footed woodrat (Carey et al. 1991). The live-trap array we used ensured that the 4 trap-stations resided within the 50 m radius vegetation plot that was established by the Landbird Module to access vegetation characteristics around each census point (Appendix D), and provided the recommended spacing between trap-stations and the suggested minimum number of trap-stations per home range area recommended for the northern flying squirrel (Carey et al. 1991).

One Sherman and 2 Tomahawk (1 ground, 1 arboreal) traps were placed at each point in the array; thus, each array consisted of 12 live-traps. Arboreal Tomahawks were placed

1.5 to 2 m above the ground on the largest tree within a 10-m radius of the grid point. The largest tree was chosen since large trees provide better support for the trap, thus improving functionality of the trap and improving capture success (Carey et al. 1991). Ground traps were placed within 1 m of the grid point and were placed under protective cover, such as a shrub or log, at small mammal burrow entrances, and along small-mammal run-ways, when possible.

Landbird grids were sampled during May – September 2006. Each landbird grid trapping session consisted of 2 sets of 4 consecutive trap-nights each; each set was separated by 3 nights when no trapping was conducted, thus allowing a period of rest for animals from the stress of capture and handling (Carey et al. 1991). This trapping scheme ensured a duration short enough to avoid changes in the sampled population due to births, deaths, immigration, and emigration, and long enough to maximize the number of captures and recaptures of northern flying squirrels and other small mammals (Carey et al. 1991). All traps were set and baited every evening just before dusk; baiting was completed in 3-4 hours. Trap check began just after dawn and completed within 4-6 hours; thus, all traps were closed prior to 12:00 and remained closed until after 15:00 each day.

All traps were baited with a mixture of rolled oats, molasses, raisins, and peanut butter which was formed into a small, sticky ball. 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, natural cover (i.e., bark, moss) or cover boards and synthetic bedding material (nonabsorbent polyethylene batting) were provided as needed for thermal insulation for all traps. To encourage capture and recapture of small mammals and to avoid damage to traps by black bear, traps were emptied of bait between trap sets and bait was deposited at the grid point. At the end of the trapping session, traps were again emptied of bait and bait was deposited on the ground at the grid point, and all traps were permanently removed.

Species Richness. — We analyzed species richness indices for each sampled landbird census point. Species richness is defined as the total number of species detected over the course of the trapping session. We utilized a restricted list of species that excluded species that are not accurately surveyed using our live-trapping method (e.g., shrews, skunks, hares). Additionally, long-eared and shadow chipmunks were lumped together; we cannot consider these species separately in these analyses until we have completed taxonomic analyses. Following the completion of data collection in 2007, we plan to begin more detailed analyses of this data in close collaboration with Landbird Module.

Flying squirrels

We captured and radiocollared northern flying squirrels at long-term grids, landbird grids, and at areas predicted to have moderate and high suitability for northern flying squirrels, hereafter flying squirrel transects. At long-term grids and landbird grids, 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 and 2006 in order 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, hereafter study site FS-2, in mixed-conifer forest located at 1,500 m elevation; in 2006, additional transects bisecting or parallel to original transects were established. Study site FS-2 was selected using a GIS-based northern flying squirrel habitat-relations model developed using available information from the literature, 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 successful captures in an area where triangulation was also feasible; study site FS-2 was predicted to have moderate suitability for northern flying squirrels.

We primarily established flying squirrel transects along riparian areas, due to the importance of this habitat type to northern flying squirrels reported by 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 by pacing. Sherman and Tomahawk traps were set and baited every evening just before dusk, and checked just after dawn; all traps remained closed from 12:00 – 16:00. 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. 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, natural cover (i.e., bark, moss) or cover boards and synthetic bedding material (nonabsorbent polyethylene batting) were provided as needed for thermal insulation for all traps.

Dusky-footed woodrats

Four study sites (1,450–1,750 m elevation; Fig. 3) where established in early-seral forest (30–40 years post-logging), representative of the Sierra Nevada westside mixed-conifer forest type characterized by California black oak, sugar pine (*Pinus lambertiana*), ponderosa pine, Jeffrey pine, white fir, Douglas-fir, and incense cedar. All study sites had a brushy understory consisting primarily of deerbrush, buck brush, and mountain whitethorn, with lesser coverage by green- and whiteleaf manzanita, and mountain dogwood (*Cornus nuttallii*). 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. Study sites WS-1 and WS-2 had moderately sloping topography; sites WS-3 and WS-4 had mixed terrain or undulating topography. 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.

We documented house use by livetrapping in the spring (May-June) and late summer-early fall (August– September) of 2004-2006. Each trap session consisted of 4 consecutive trap-nights. In 2004 and 2005, 4 Sherman live-traps were used at each house; in 2006, 2 Sherman live-traps were used. All houses within each study site were trapped to ensure that all individuals were captured. Traps were baited with raw oats and sunflower seeds coated with peanut butter. Synthetic batting was provided for thermal insulation. Traps were opened before dusk and checked and closed each morning at dawn. Woodrats were readily captured and frequently recaptured. We assumed that all animals within the population were captured at least once, and we calculated woodrat density as the minimum number known alive divided by study area size. A house was considered used if a woodrat was captured at the house at least once during the 4-day trapping session and unused if no woodrats were captured at that house during that time.

Golden-mantled ground squirrels

We studied golden-mantled ground squirrels at long-term grid located in red-fir habitat at an elevation of 2,100 m from 2003 through 2005. Animals were captured with Tomahawk traps baited with rolled oats and sunflower seeds coated with peanut butter, set in the early morning and checked at mid-morning and noon. In 2003 and 2004, we experimentally manipulated maternal diets by supplying supplemental food to a sample of adult females (treatment females, n=6), to assess the effects of maternal condition on offspring growth and fat development as well as exploratory and dispersal distance, and compared treatment and control mothers (n=6) and their offspring. These 12 females were randomly assigned to control (n = 6) or treatment (n = 6) groups, uniquely marked with numbered Monel ear tags, and fitted with radio-collars. We radiotracked treatment squirrels animals to their burrows in late afternoon and dispensed ca. 30 g of black oil sunflower seeds per day of supplementation down the burrow opening. Supplemental feeding began on 1 September 2003 and took place 4 days per week until all individuals entered hibernation in early October. Individuals in the control group were trapped at the same interval as the treatment group, but were not provided supplemental food. We evaluated the effectiveness of food supplementation by comparing the slope of mass gain in female squirrels for control vs. treatment groups during the 2003 field season, with initial mass treated as a covariate. All females survived through the summer and entered hibernation. In spring 2004, we relocated and captured 7 study animals (3 treatment, 4 control), which were fitted with new radiocollars and radiotracked until their offspring (3 females had 2 offspring, while the fourth female had 3) emerged in early July. In 2005, we studied additional unmanipulated females (n=9) and their offspring (9 male, 5 female) to augment our data on control females and their offspring dispersal distances.

We attempted to capture all females and their offspring on a monthly basis to measure mass, body condition, and head+body length. At each capture we returned individuals to our field laboratory; there we chemically immobilized them with ketamine hydrochloride (100 mg/ml KCl), removed their radiocollars, and recorded rectal temperature, total mass to the nearest 0.1 g, and head+body length (measured as tip of nose to anus). We quantified body fat using the ToBEC method (Walsberg 1998, Koteja 1996). Conductivity was measured on anesthetized animals using an EM-SCAN SA-3000 body composition analyzer (EM-SCAN, Springfield, IL, USA). Pulawa & Florant (2000) calibrated the ToBEC machine for golden-mantled ground squirrels, and we used their calibration curve to obtain fat-free mass for our samples. Following analysis, the radio-collar was reattached, and the animal was allowed to recover before release at the site of capture.

Mothers and offspring were radiolocated from July-October 2003-2005. Location of all adult females was determined by triangulation $\geq$ 3 times daily for $\geq$ 5 days/mo from July to September 2003. Burrows were located by homing after animals had settled into their burrows for the night and locations were measured using a handheld GPS unit accurate to ca. 3 m. Burrow locations used for hibernation were noted to facilitate relocation of individuals the following spring. For use in calculating offspring exploratory behavior, we calculated 95% kernel home ranges for each mother.

Dispersal was defined as establishing a new home range distinct from the natal home range, and was identified using adaptive kernel home range estimators which produced two home ranges for offspring; one encompassed the natal burrow and one was the final place of residence before hibernation. Dispersal distance was calculated as the linear distance between the point of initial capture (mother's burrow) and the final location for a particular individual (presumed hibernaculum). We defined exploratory movements as round-trip visits to locations that were > 1 radius of the mother's home range from the offspring's initial point of capture.

All statistical analyses were performed using SAS (SAS Institute, 2000). Comparisons of monthly maternal and offspring mass and percent fat were analyzed using a repeated measures analysis of variance (rmANOVA) with initial mass or percent fat as a covariate. All measures of percent fat and mass were log transformed prior to analyses. Analyses of offspring exploratory and dispersal distance were analyzed using a 2-way ANOVA with sex and treatment as explanatory factors. Because dispersal parameters usually are not normally distributed and because we had small sample sizes, all data were log transformed prior to analyses. Comparisons of the rate of mass or fat gain between treatment and control groups was quantified with linear regression (PROC REG) with tests of slope (β) and intercept differences. All data are presented as means $\pm$ standard error, and all differences were considered significant at $\alpha = 0.05$.

Chipmunks

Chipmunk species in the Plumas National Forest display considerable overlap in habitat requirements, diet, and activity. Two chipmunk species, the long-eared and shadow chipmunk, are frequently captured during our live-trapping efforts. These species overlap greatly in external characteristics and are thus difficult to identify in the field (Clawson et al. 1994; Gannon and Forbes 1995). To date, the only sure means to identify these species is by using skeletal features obtained by sacrificing animals. To evaluate the habitat affinities and distribution of these chipmunks, we first needed a non-lethal means of identifying them in the field. First, we collected representative samples of chipmunks to identify species through the use of pubic bones, and collected tissue samples from these known species to develop molecular markers for non-lethal identification of chipmunk species in the future. We collected a sample of reference chipmunks throughout Plumas National Forest by salvaging animals from trap mortalities at long-term grids and euthanizing a small portion of animals from landbird grids (≤3 chipmunks per census transect). So as 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 Natural History Field Museum. Individuals collected were prepared as standard museum specimens (full skeleton plus skin) and tissues (e.g., liver, heart, muscle, and kidney) were collected for use in molecular analyses. Next, we collected tissue samples (small sections (< 1 mm) of ear pinna stored in cryovials containing 95% ethanol and stored in a freezer) from all chipmunks captured at long-term grids, landbird grids, and flying squirrel transects. Then, tissue samples and specimens were sent to the University of Idaho for molecular analysis to determine species identification; we secured outside funding for these analyses. Finally, we collected data on various aspects of each chipmunk's appearance. In 2005 and 2006, we recorded the presence of six external 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 compare external characteristics with molecular identification and skeletal features to determine what characteristics, if any, are reliable for species identification. Once we have identified individuals to species, it is then possible to examine habitat use and management implications for these species.

Animal handling

Similar animal handling protocols were used regardless of live-trapping sampling design. Captured animals were transferred to a mesh handling bag, identified to species, 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 Nunc cryovial with 95% Ethanol. Tissue samples were placed in a freezer for long-term storage to preserve genetic material for current and future studies. In 2006, we collected tissue samples from all captured animals. Prior to 2006, we collected tissue samples from dusky-footed woodrats and chipmunks.

All specimens, including incidental trap deaths, are thoroughly documented, frozen, and submitted to the University of California, Davis Field Museum of Natural History, in accordance with the permitting requirements of the California Department of Fish and Game and used for the educational and research purposes of the PLAS, and other interests. 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).

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 the day during 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. 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. Woodrats were allowed to fully recover from anesthesia (4-5 hours) prior to being released at the point of capture. Northern flying squirrels were not anesthetized prior to radiocollaring and were immediately released after application of the radiocollar at their point of capture. Radiotelemetry activities of newly collared individuals were initiated after a 24-hour acclimation period succeeding their release.

Triangulation

Nocturnal telemetry sessions using triangulation techniques occurred during 5 nights per month in 2003 and 8-10 nights per month during 2004-2006. 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 (or more) directional bearings within as short a time interval as possible (typically <10 minutes). Radiolocations were obtained for each animal 2-3 times per night, a minimum of 2.5 hours and 1 hour 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. Field technicians were thoroughly trained and rotated among stations and study sites each radiotelemetry session, to reduce the error due to differences among technicians. 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 about once per week. To assess bearing error rates, dummy collar locations were determined and compared to their actual location.

Program Locate II was used to calculate northern flying squirrel and dusky-footed woodrat 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 (≥ 3), and signal quality. Special attention was paid to signal quality of bearing that had an overwhelming affect in determining the location of the animal. Accepted locations were analyzed in Ranges VI or in Arc GIS 9.1 using the Animal Movements Extension. We estimated home range (95%) and core range (50%) using the minimum convex polygons (MCP) and fixed kernel (FK) methods (Kenward 2001). To provide an index of activity for northern flying squirrel throughout the night we measured the distance between each location and the nearest known den tree. These distances were used to generate a time series of distances each individual was found from its nearest den tree. We constrained this analysis to the period between 18:00 and 06:00 as that represented the active time for flying squirrels (Weigl and Osgood 1974). Analysis of home range size and nocturnal activity was performed for northern flying squirrels using a 2 x 2 factorial design, with habitat (FS-1: red fir, FS-2: mixed conifer) and time of night (4 categories) as primary factors, and sex (male, female) as the secondary factor. PROC MIXED was used to calculate F-test values, and Satterthwaith's approximation was used to calculate the degrees of freedom for the error term (SAS Institute 2000. If there were no significant interactions, differences in the main effects were compared using the PDIFF option in the LSMEANS statement. Differences in terms with significant interactions were compared using the SLICE option in the LSMEANS. All data are presented as means ± standard error, and all differences were considered significant at $\alpha = 0.05$.

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. 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.

Vegetation

Long-term grids

Coppeto et el. (2006, Publication #1,2) 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 Plumas National Forest during 2003-2004. The Mammal Module staff did not measure the macro- or microhabitat characteristics on the long-term study grids 2005-2006, although the Vegetation Module has continued to monitor habitat and microclimate characteristics on a portion of these plots (Appendix B).

Cone Counts.—To evaluate the effects of conifer seed production on small mammal abundance, we measured cone production during fall of 2003, 2004, and 2006, 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 ≥1.5x 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.

Landbird grids

Microhabitat characteristics were sampled July-October 2006. All measurements were recorded within a 1-m radius circular plot (3.14 m^2) centered at each grid point. We followed the protocols and definitions established by Coppeto et al. (2006, Publications #1, 2); however, we measured canopy closure using a Moosehorn with an 8.5 × 8.5 cm grid viewed at eye-level (1.7 m) from the center of the plot, and recorded the number of squares obscured by vegetation, as opposed to using hemispherical photographs, due to logistical constraints. We visually estimated percent cover of the same 12 ground cover and recorded 3 species richness variables (Coppeto et al. 2006, Table 1). We used the following ground cover classes: 0, rare, 1, 5, 10, 15, …, 90, 95, 99, and 100%, since these cover classes approximate a normal distribution. In addition, we tallied the number of trees of each species at each point using a Panama gauge. All ocular estimates were performed by trained observers.

Flying squirrels

Den use.—We documented northern flying squirrel den locations during homing activities. We recorded the DBH, species, condition (live tree, snag), den height, and type (cavity or external) of each den tree. 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 and 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.

Dusky-footed woodrats

*Macrohabitat selection.—*To determine if woodrat density was positively related to California black oak abundance, we estimated California black oak density (ha^{-1}) at each study site by counting trees ≥5 cm DBH during September 2005 in 10 x 100 m belt transects placed in a stratified random fashion, such that ≈ 10% of the total area was sampled. We regressed mean adult woodrat density (2004 and 2005 combined) on oak density. Because California black oaks begin to produce acorns in substantial quantities (>9 kg) at about 80 years of age (≈ 33 cm DBH—McDonald 1969), we ran separate analyses on small (<33 cm DBH) and large (≥33 cm DBH) oaks. We assessed the relationship between mean adult woodrat density and California black oak density among the 4 study sites with simple linear regression using JMP IN 5.1.2 (SAS Institute 2004). Because we predicted a positive association, we used a 1-tailed test. We ran residual diagnostics to confirm that the model was appropriate for the data set (Neter et al. 1996).

*Microhabitat selection.—*We measured microhabitat variables within a 4-m radius circle (50.3 m^2) centered on 144 houses and 144 paired random sites during September–November 2003, May–October 2004, and May–September 2005. Plot size was based upon ocular estimates of patch size at woodrat houses (i.e., the microhabitat changed beyond a 4-m radius). We randomly selected 66% and 87% of houses at sites WR-1 and WR-2, respectively, where houses were more abundant, and sampled 100% of houses at sites WR-3 and WR-4.

At each woodrat house, we visually estimated percent cover of 3 ground cover variables and measured density and cover of shrubs, trees, snags, stumps, and logs (Table 2). We determined density of short and tall shrubs by counting individual stems. To determine if woodrats were selecting for greater density and basal area of smaller trees, we measured density (ha^{-1}) and basal area ($m^2 ha^{-1}$) of tree species in 4 DBH classes modified from Bell and Dilworth (1993): sapling, poletimber, small sawtimber, and large sawtimber. California black oak may be important at the microhabitat level as well as the macrohabitat level; hence, we excluded California black oak trees from tree density and basal area calculations and examined the presence of small (<33 cm DBH) and large (≥33 cm DBH) oaks separately. We recorded the presence of large (≥30 cm DBH) snags because we observed that woodrats frequently accumulate debris in the cavities of large snags. We measured tree and snag diameters using a diameter tape. We measured the diameter at root collar (DRC) of stumps using a measuring tape, and recorded the presence of large (≥30 cm DRC) stumps because these were big enough to provide a platform for debris. We measured the diameter and length of logs using calipers and a measuring tape, and the volume of each log (m^3ha^{-1}) was estimated as a frustrum paraboloid using log length and diameters at both ends (Bell and Dilworth 1993). The percent of canopy closure was quantified using a Moosehorn with an 8.5 × 8.5 cm grid viewed at eye-level (1.7 m) from the center of the plot, and the number of squares obscured by vegetation was recorded. Slope was measured using a clinometer. All ocular estimates were performed by one observer (RJI).

We also sampled, with replacement, the same vegetation and structural characteristics at paired points located a random distance (10–50 m) and a random direction from the center of each house. Random sites were constrained to lie within the same habitat type as the paired house. The distance requirement ensured that the random sites fell outside of the sampled house site, but within the estimated home range of a dusky-footed woodrat (1,942–4,459 m^2—Cranford 1977; Lynch et al. 1994).

House-site selection.—We used conditional logistic regression (CLR) to predict the odds of finding a house at a certain location given the explanatory variables. CLR can fit a model based on conditional probabilities that "condition away" or adjust out the grouped effect (Stokes et al. 2001). We considered each house-random pair to be separate strata, adjusted out subject-to-subject (i.e., house-to-house) variability and concentrated on within-subject (i.e., house-to-random) information. In this way, CLR conditions out variability due to macrohabitat differences and concentrates on variability due to microhabitat preference. Quantitative comparisons of microhabitats are possible by examining odds ratios, which indicate the increased likelihood of the outcome with each unit increase in the predictor given the covariate pattern (Keating and Cherry 2004).

Prior to CLR analyses, we examined Spearman's rank correlations between variables to identify collinearity. Variables that were highly correlated ($r_s \geq |0.7|$) and those that explained similar biological phenomena were not included together in multivariate models (e.g., sapling density and sapling basal area, $r_s = 0.98$; Hosmer and Lemeshow 1989). In addition, we performed univariate CLR using PROC PHREG in SAS 8.02 (SAS Institute 2001) to reduce the number of candidate variables for model building. We compared microhabitat variables between house and random sites and included habitat type ($n = 10$) as an interaction term in each single-variable model because we hypothesized that some variables might respond differently among habitats. We retained those variables with P-values ≤ 0.25 from log-likelihood ratio tests or variables that had significant habitat type interactions (Hosmer and Lemeshow 1989).

We then performed multivariate CLR to determine which combination of microhabitat variables best discriminated between house and random sites. We built CLR models using forward stepwise selection using the screening criteria recommended by Hosmer and Lemeshow (1989—*P* = 0.15 to enter and *P* = 0.20 to remove), so as not to exclude potentially important variables from the model. At each step, we selected the model with the lowest Akaike's Information Criterion (AIC) value, and combined this model with all other variables (Table 3); the best model was that with the lowest AIC value, and any model within 2 AIC points of the best model was considered to be a competing model (Burnham and Anderson 1998). The final model(s) were those for which all coefficients were significant. We examined model residual chi-square and residual diagnostics to further assess model goodness-of-fit (Hosmer and Lemeshow 1989; Stokes et al. 2000).

House use.—We used a reverse stepwise multiple logistic regression (MLR) no-intercept model to determine if there were combinations of microhabitat variables that best distinguished houses used and unused by adult woodrats, and to compare houses used by adults and subadults. All 21 variables were included in MLR models; in addition, we included house volume (above versus below the median of 0.3 m^3; "large" versus "small," hereafter) to determine if house size influenced use (Vestal 1938). MLR was applied using JMP IN 5.1.2 (SAS Institute 2004). Only houses used exclusively by an adult or a subadult were included in analyses; houses at which an adult and a subadult were captured at least once during the 4-day trapping session were omitted from analyses comparing adult and subadult house use, resulting in the omission of 6 houses in 2004 (4.2%) and 4 houses in 2005 (2.8%). Juvenile woodrats were excluded from all analyses. Significance level for all tests was set at $\alpha = 0.05$. All means are presented as ± standard error.

Acorn Counts.—We hypothesized that there would be a positive relationship between adult dusky-footed woodrat density and annual acorn crop; therefore acorn production of California black oak was measured on 25 and 28 trees located at woodrat study sites WR-1 and WR-2, respectively. Dusky-footed woodrat study sites WR-3 and WR-4 had insufficient densities of mature oaks to estimate mast crops at these locations. Mature (≥33 cm DBH), dominant or co-dominant California black oak trees with visible crowns in a variety of conditions (e.g., mistletoe, bole cavities, broken tops) were arbitrarily selected as sample trees without a priori knowledge of the acorn production potential of the trees and somewhat stratified to include a range of sizes (range: 33.7-75.2 cm DBH). Sample trees were permanently marked with aluminum tags for future surveys. We recorded DBH, height, crown width and condition since these factors are known to influence acorn yield (Macdonald 1969). We visually estimated acorn production in early September, just prior to acorn drop when acorns are most readily visible, using the methods developed by Garrison et al. (1998) for California black oak in Placer County, California. One observer made counts in two randomly selected parts of the tree by visually dividing the tree's live crown into a lower and upper half and further dividing each half into thirds. A random numbers table was used to select a subdivision in the lower and upper halves for counting. Binoculars were used to scan the crown and the observer counted as many apparently viable acorns as possible within 15 seconds. Visual counts of acorns for the two 15 second count periods were combined to yield a total count for a 30 second period. Visual counts of California black oak acorns using this method have been shown to be an adequate index of overall acorn production as well as the amount of acorns available as food for wildlife (Garrison et al. 1998).

RESULTS AND DISCUSSION

We have been making steady progress towards our objectives. In 2006, we completed several projects and initiated others. In addition to successfully completing an extensive (17 April-1 November) field season, our study module has produced quality peer-reviewed publications and other products. In 2006, we had 6 manuscripts either in publication or in review and several more in preparatory stages. We have chosen to present the abstracts of our published and submitted manuscripts herein as a representation of the work that we have completed to date.

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 (Publication #1, 2). 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 #5). Following the 2007 field season and the implementation of planned treatments, we will analyze data obtained at long-term grids during 2005-2007 to assess the impacts of forests management treatments on small mammal abundance and species diversity (Objective #4).

Publication #1, 2: 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 *Peromyscus maniculatus* (deer mice), whereas 69% was explained by microhabitat and year. Variation in abundance of *Tamias* sp. (long-eared and shadow chipmunk) was slightly better explained by microhabitat and year (70%) than by macrohabitat and year (67%). Red fir forests supported significantly more *Peromyscus* and *Tamias* than mixed conifer and pine-cedar forests, and more *Tamias* than mixed fir forests. Five of 6 uncommon species were significantly associated with macrohabitat type; *Spermophilus lateralis* (golden-mantled ground squirrel), *Glaucomys sabrinus* (northern flying squirrel), and *Microtus* sp. (long-tailed and mountain voles) were captured almost exclusively in red fir forests, whereas *Neotoma fuscipes* (dusky-footed woodrat) and *Spermophilus beecheyi* (California ground squirrel) 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 #5: 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 coniferous 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 *Peromyscus maniculatus* increased in 2004 (from 0.7 - 7.3 ind./ha to 65.7 - 112.7 ind./ha; Fig. 5). Numbers of *Spermophilus lateralis* 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). *Tamias quadrimaculatus* 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. *Tamias senex* remained at lower densities than *T. quadrimaculatus* except during September 2004, when populations of the former reached high densities (54.6 ± 26.8 ind./ha; Fig. 7). Survival of *P. maniculatus* was dependant on an interaction between forest type and month with additive effects of winter and 2003 fall mean cone production. *Spermophilus lateralis* survival varied by month whereas survival in both species of *Tamias* varied by an interaction of forest type and month + winter (Table 4). *Neotoma fuscipes* were present at lower elevations and reached greatest densities in ponderosa pine forests. *Glaucomys sabrinus* was uncommonly captured and found predominantly in red fir forests.

2006 Field Season

During the 2006 field season we captured and marked a total of 456 individuals of 11 species. Predominant species in the study area included dusky-footed woodrats, deer and brush mice (*Peromyscus maniculatus, P. boyleii*), long-eared and shadow chipmunks, California and golden-mantled ground squirrels (*Spermophilus beecheyi* and *S. lateralis*), red-backed voles (*Clethrionomys californicus*), Douglas squirrels (*Tamiasciurus douglasii*), montane voles (*Microtus montanus*), and northern flying squirrels. Incidental species captured included shrews (*Sorex* spp.), snowshoe hare (*Lepus americanus*), striped skunks (*Mephitis mephitis*), and birds.

We noticed a marked increase in capture rate of northern flying squirrels at long-term grids in 2006 as compared with previous years. For example, in 2006 we captured 20 northern flying squirrels at 10 long-term grids; whereas in 2005, we captured 8 individuals at 4 grids, representing a 313% increase in abundance of northern flying squirrels across all sites. This marked increase in northern flying squirrel abundance is likely the result of an improved bait mixture and arboreal trap placement, and not due to an actual increase in abundance at these sites, although we would not be able to discern whether an increase in abundance influenced our data. Also notable, northern flying squirrel trap deaths were markedly reduced in 2006 (10% mortality) as compared with

2005 (75% mortality) at long-term grids, which has contributed to a greater success at radiocollaring individuals in 2006. We recaptured 2 individuals and these were recaptured once. Flying squirrels were most commonly captured in arboreal traps (n=15), but also in ground traps (Sherman=3, Tomahawk=4) in 2006; trap type was not recorded in 2005. In addition, we captured 4 dusky-footed woodrats at 3 long-term grids. Notably, this was the first year we documented red-backed voles at long-term grids.

Landbird grids

Landbird grids were established to compliment the data collected at our long-term study grids and more fully integrate our live-trapping efforts with that of other modules. The 2006 field season marks the first year of data collection at landbird grids. We will complete data collection at landbird grids in 2007 at which time we plan to begin more detailed analyses of this data in close collaboration with the Landbird Module.

2006 Field Season

We sampled small mammals at 176 points within 24 transects located in 12 watersheds across 4 (former) treatment units. During the 2006 field season we captured and marked a total of 909 individuals of 11 species. Species captured included dusky-footed woodrats, deer and brush mice, long-eared and shadow chipmunks, California and golden-mantled ground squirrels, red-backed voles, Douglas squirrels, northern flying squirrels, and western jumping mice (*Zapus princeps*). Incidental species captured included shrews, snowshoe hare, western gray squirrels (*Sciurus griseus*), striped skunks, spotted skunks (*Spilogale gracilis*), and birds. We determined small mammal species richness at all sites sampled in 2006 (Fig. 8-11). Species richness ranged from 0-4. Mean species richness was greatest at TU-5 (2.34), followed by TU-4 (1.97), TU-3 (1.71), and TU-2 (1.66). In the future we hope to examine how landbird species richness compares to small mammal species richness at a site (i.e., are areas of high landbird species richness also areas of high small mammal species richness?).

We captured 18 northern flying squirrels (3 males, 15 females) at 10 landbird transects; two of these were recaptured. A majority (79%) of northern flying squirrels were captured in tree traps, emphasizing the importance of this trapping method. Six individuals captured at 3 landbird transects were radiocollared. In addition, we captured 39 dusky-footed woodrats (22 females, 16 males, 1 unknown) at 7 landbird transects; sixteen of these were recaptured. We measured habitat characteristics in 3.14 m^2 plots centered about trap locations at all trap locations (n=176).

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 this data for 2004-2005 and include this summary herein (Publication #7). We continued these efforts in 2006 to increase our sample size and improve our statistical power.

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

We studied the northern flying squirrel in Plumas National Forest using radiotelemetry. Fourteen squirrels from two forest types (mixed conifer and red fir) were fitted with radiocollars and were able to provide enough locations for home range calculations (Table 5). 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 (Fig. 12-13). Mean kernel home range size was 25.7 ha for all squirrels. MCP home ranges were biased towards overestimation and did not provide reliable calculations. Mean distance to the nearest nest tree did not vary throughout the night; however, females tended to travel greater distances from nest trees (Fig. 14).

2006 Field Season

In 2006, we captured 55 northern flying squirrels (long-term grids, n=20; landbird grids, n=20; flying squirrel transects, n=15). We radiocollared 19 northern flying squirrels at 6 study sites. Of these, sufficient data (≥ 50 locations) was obtained for 7 northern flying squirrels to estimate home range during 2006. Females weighed more than males ($_{fem}$ = 129.7 g, $_{male}$ = 103.6 g; P = 0.0039). Home range was only calculated for females, because of low numbers of successful male captures. Average home range size for female northern flying squirrels using 95% MCP was 12.55 ha ± 2..58 and using 95% FK was 17.56 ha ± 5.67. To evaluate den use by northern flying squirrels, we measured habitat characteristics at 39 den trees and 39 paired random points. This data will be analyzed in the near future.

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 (Publication #3, 4). In future analyses, we will present home range estimates for these animals for 2003-2006. The 2006 field season marks the final year of data collection, so that we might focus our efforts on northern flying squirrel ecology.

Publication 3, 4: Habitat selection by dusky-footed woodrats (*Neotoma fuscipes*) in managed mixed-conifer forest of the northern Sierra Nevada

Dusky-footed woodrats (*Neotoma fuscipes*) are important components of forest communities, including serving as a primary prey of the California spotted owl (*Strix occidentalis occidentalis*), 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 (*Quercus kelloggii*) 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 (Fig. 15), 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 (Table 6). 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 poletimber, 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.

2006 Field Season

In 2006, we captured 70 dusky-footed woodrats and applied radiocollars to 20 adults (male, n=7; females, n=13) and 19 subadults (male, n=7; female, n=12). Adult woodrat density was lower in 2006 than 2005 or 2004 (Table 7). Acorn productivity indices for 2005 and 2006 indicated no apparent trend or pattern; however, there is not enough data to date to truly evaluate this.

Golden-mantled ground squirrels

We captured and radiotracked golden-mantled ground squirrels during 2003-2005. Data analysis and manuscript preparation took place in 2006 and no additional data was collected at this time. The following summary (Publication #6) represents the culmination of this work and satisfies Objective #7.

Publication #6: Effects of maternal body condition on offspring dispersal in golden-mantled ground squirrels (*Spermophilus lateralis*).

Maternal body condition may play an important role in determining natal dispersal distance. We developed a trans-generational model relating maternal body condition to natal dispersal distance in male and female offspring in ground squirrels (Fig. 16). We measured the effect of maternal body condition on offspring natal dispersal in golden-mantled ground squirrels (*Spermophilus lateralis*) in the Sierra Nevada of California. Mothers were allowed to forage normally (control, n = 6) or were provided with supplemental food (treatment, n = 6) prior to hibernation, and offspring dispersal distance was measured the following year. Not surprisingly, treatment mothers gained mass more rapidly than control mothers, although the proportion of fat in mothers did not differ between treatments (Fig. 17). Additionally, offspring from treatment mothers grew at a significantly faster rate, increased fat stores, and had greater mass than control offspring. Male offspring of treatment mothers dispersed 3x farther than those of control mothers (770 m vs. 213 m), whereas female offspring of control mothers dispersed 4.8x farther than those of treatment mothers (496 m vs. 102 m; Fig 18). Dispersal distance was positively related to exploratory distance for both males and females (Fig. 19). In spite of low sample sizes, our data indicate that maternal body condition affects offspring growth, fat development, and dispersal, supporting our trans-generational model of offspring dispersal.

Chipmunks

We have live-trapped chipmunks coincident with long-term grid, landbird grid, and flying squirrel transect trapping activities since 2003. One of our objectives was to evaluate the habitat affinities of two species found commonly in the Plumas National Forests, the long-eared and shadow chipmunk, using data obtained from long-term grids during 2003-2004 (Objective #8). The following (Publication #8) is a summary of these results.

Publication #8: A multiple spatial scale perspective of the habitat affinities of sympatric *Tamias quadrimaculatus* and *T. senex.*

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 (*Tamias quadrimaculatus*) and the shadow chipmunks (*Tamias senex*) – 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 (Fig. 20). At the macrohabitat scale, both the species reached their highest mean abundance in red fir (*Abies magnifica*) forests but showed divergent secondary affinities (Fig. 21). At the microhabitat scale, however, habitat affinities differed significantly. Logistic regression models indicate that microhabitat presence of *T. quadrimaculatus* was associated positively with open canopies, cover by rocks, and multiple sapling species, and negatively with east and south facing, steep slopes (Table 8, Fig. 22). *T. senex* 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., *Ceanothus prostratus*). Affinities at micro- and macrohabitat scales varied between sampling years, indicating that these species retain a certain flexibility in habitat associations while maintaining segregation and minimizing the potential for competition (Table 9, Fig. 23).

2006 Field Season

We will continue to capture and collect chipmunks while performing live-trapping duties at long-term grids, landbird grids, and flying squirrel transects. In future analyses we hope to evaluate our technique of determining chipmunks 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 Landbird Module in 2006 by establishing temporary trapping grids at songbird census stations. 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 landbird trapping grids. We are currently coordinating an effort in which our module will provide valuable feedback to the remote sensing analyses and resultant models developed by the Fire and Fuels Module. In the near future, we hope to initiate collaborative efforts with the Spotted-owl Module by working with them to examine the diet of the spotted owl using pellets collected from nests throughout the year.

In 2006, we increased collaborative efforts with agencies and institutions outside of the PLAS. We collaborated with Janet Foley, a Professor with the University of California, Davis School of Veterinary Medicine, and her graduate student Nathan Nieto, providing them with blood and tissue from flying squirrels and western gray squirrels for a study on disease ecology. We collaborated with Mary Brooke McEachern, a post doctoral fellow at the University of California, Davis, by providing data regarding territorial bequeathal by dusky-footed woodrats, which complimented our examination of the dispersal ecology of the dusky-footed woodrat. We collaborated with Winston Smith, a Research Wildlife Biologists with the U.S.D.A. Forest Service (Region 6), by providing data on the abundance and density of flying squirrel in different habitat types for a presentation to the American Society of Mammalogist at the 2006 annual meeting in Amherst, Massachusetts. We collaborated 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 Natural History Field Museum to preserve specimens for research and educational purposes.

PUBLICATIONS

Peer-reviewed

1. Copetto, S. A. 2005. Habitat associations of small mammals at two spatial scales in the northern Sierra Nevada, California. M.S. Thesis, University of California, Davis, 39 pp.

2. 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.

3. 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.

Submitted

4. Innes, R. J., D. H. Van Vuren, D. A. Kelt, M. L. Johnson, J. A. Wilson, P. A. Stine. Submitted. Habitat selection by dusky-footed woodrats in managed, mixed-conifer forest of the northern Sierra Nevada. Journal of Mammalogy

5. Wilson, J. A., D. A. Kelt, D, H, Van Vuren, and M. Johnson. Submitted. Population dynamics of small mammals in relation to cone production in four forest types in the northern Sierra Nevada. Western North American Naturalist.

6. Wilson, J. A., D. A. Kelt, and D. H. Van Vuren. Submitted. Effects of maternal body condition on offspring dispersal in golden-mantled ground squirrels (*Spermophilus lateralis*). Oikos.

7. Wilson, J. A., D. A. Kelt, and D. H. Van Vuren. Submitted. Home range and activity of northern flying squirrels (*Glaucomys sabrinus*) in the Sierra Nevada. Southwestern Naturalist.

In Preparation

8. Coppeto, S. A., D. A. Kelt, and others. A multiple spatial scale perspective of the habitat affinities of sympatric *Neotamias quadrimaculatus* and *N. senex*. Winter 2007.

9. Innes, R. J., D. H. Van Vuren, M. B. McEachern, J. M. Eadie, D. A. Kelt, M. L. Johnson, and J. A. Wilson. In Prep. Genetic relatedness and social organization of the dusky-footed woodrat (*Neotoma fuscipes*) in mixed-conifer forests of the northern Sierra Nevada. Journal of Mammalogy. Winter 2007.

10. Mabry, K.E., and Wilson, J. A. In Prep. Trapping rodents in a cautious world: the effects of disinfectants on trap success. Journal of Wildlife Management.

PRESENTATIONS

Data from the mammal module of the Plumas-Lassen Administrative Study were used in the development of 2 posters presented at the 2006 annual meeting of the American Society of Mammalogists in Amherst, Massachusetts. James Wilson presented a poster on the home range and activity of the northern flying squirrel in the northern Sierra Nevada. Robin Innes presented a poster on the habitat relations of the dusky-footed woodrat in mixed-conifer forests of the northern Sierra Nevada. We anticipate that data from 2006 will be used in the development of 2 or more posters or oral presentations at the 2007 annual meeting of the American Society of Mammalogists in Albuquerque, New Mexico. Topics may include 1.) den use by northern flying squirrels to be presented by Jaya Smith, and 2) home range and social organization of the dusky-footed woodrat to be presented by Robin Innes. To date, the following presentations have been given.

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.

5. Innes, R. J., D. H. Van Vuren, D. A. Kelt, M. B. Johnson, J.A. Wilson. 2006. Habitat relations of dusky-footed woodrats (*Neotoma fuscipes*) in mixed-conifer forests of the northern Sierra Nevada. Poster to the American Society of Mammalogists, Annual Meeting, Amherst, MA.

6. Smith, W. 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 coordinated and supervised by Robin Innes, a University of California Davis graduate student. Sean Connelly was the field crew supervisor. Field work in 2006 was conducted by Robin Innes, Sean Connelly, Lishka Arata, Alicia Brommer, Daniel Auerbach, Sean Bogle, Scott Cohen, John Diener, Carina Port, Tiffany Russell, Jaya Smith, and Kelly Weintraub. 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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FIGURES AND TABLES

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).

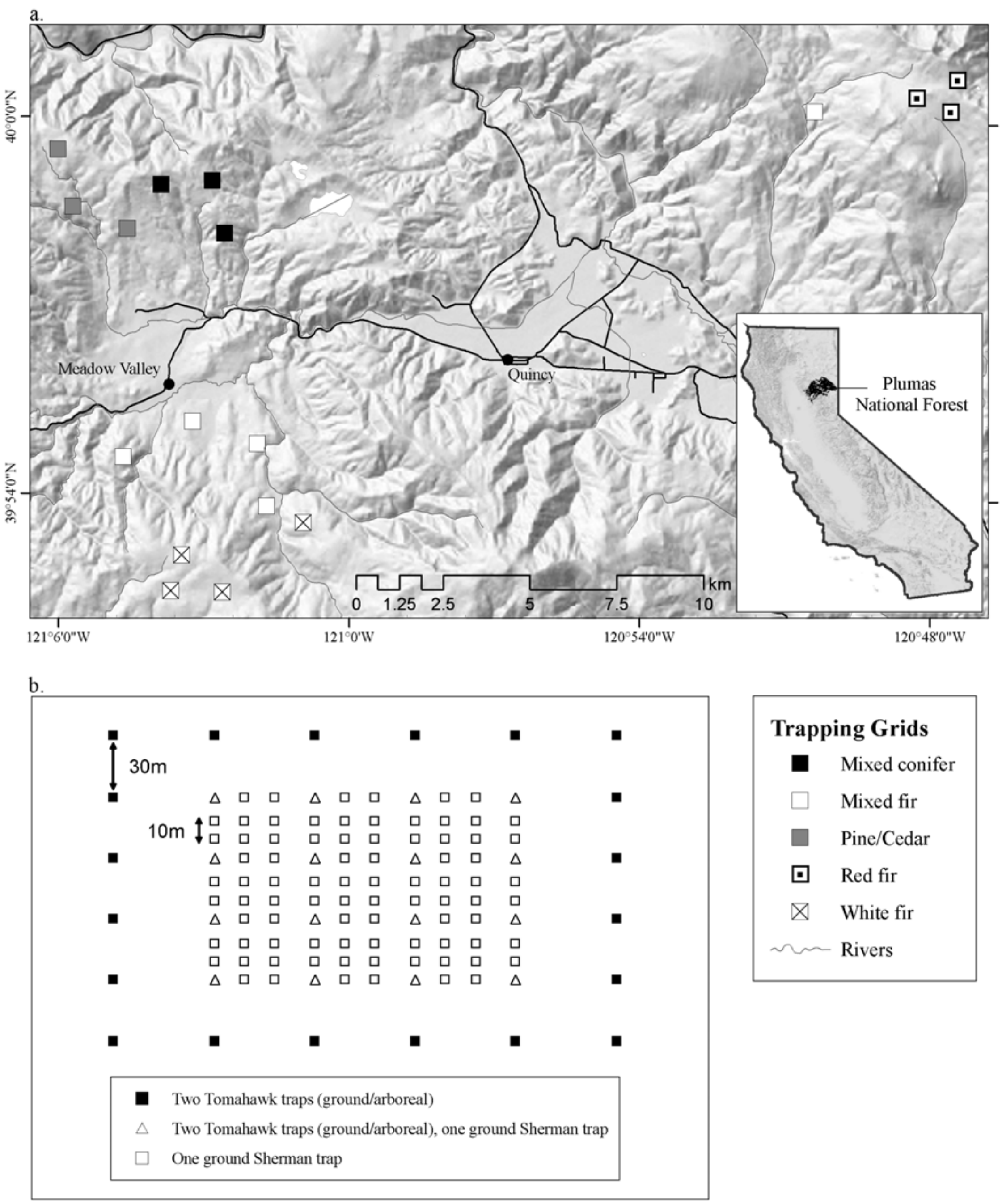
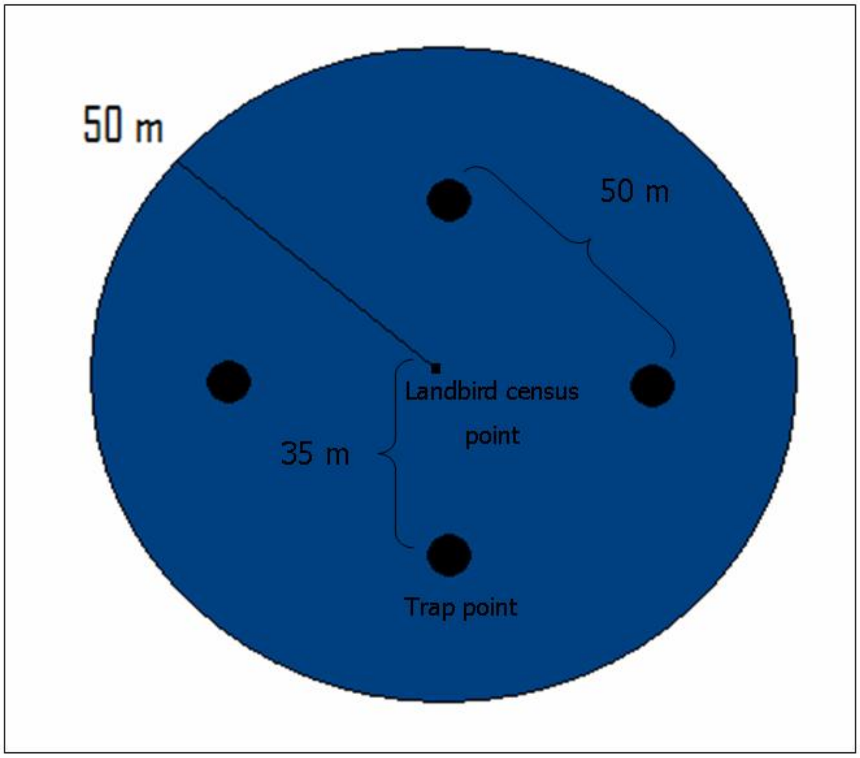


Fig. 2. — Schematic of trap configuration within a landbird grid.



1

Fig. 3. — 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.

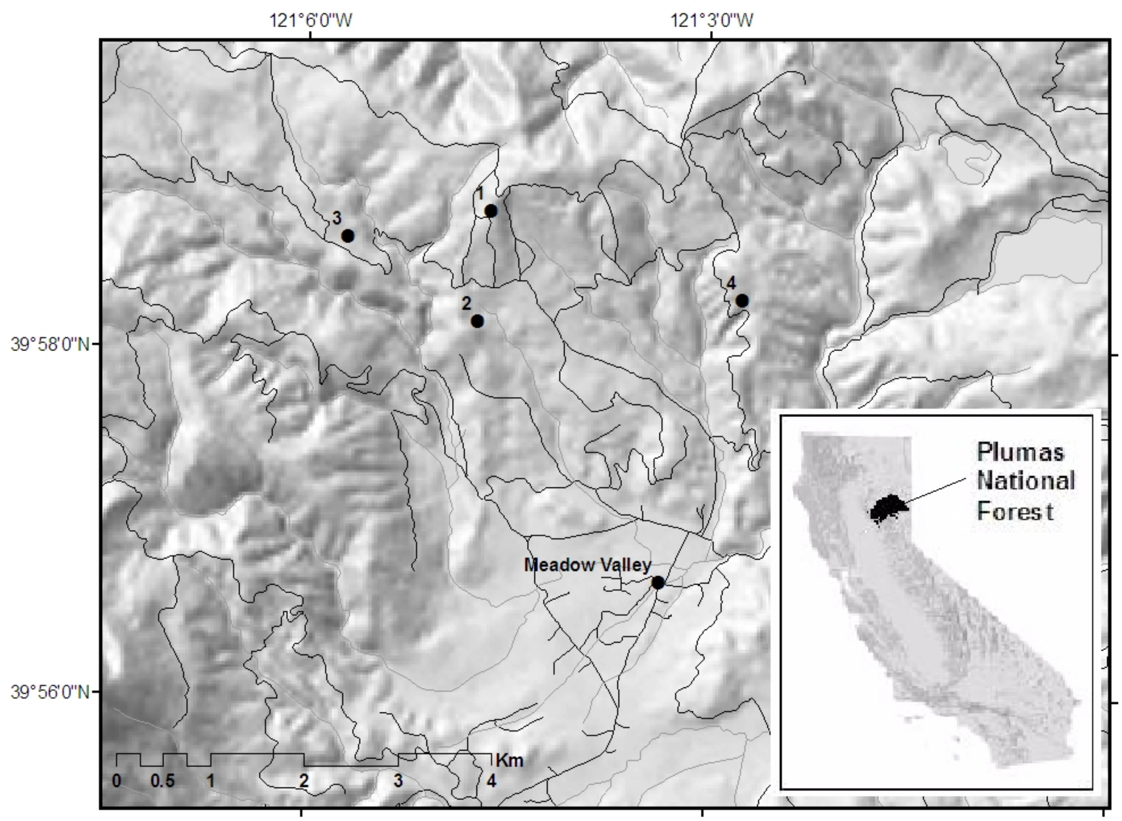


Table 1.—Description of microhabitat variables measured in 1m radius (3.14m^2) plots at all long-term grid and landbird grid trap stations. Table from Coppeto et al. (2006).

Microhabitat Variable	Description
Ground Cover (%):	
Rocks	Exposed large rocks and stones
Bare ground	Exposed soil
Forbs and grasses	Herbaceous and flowering vegetation and grasses
Litter	Dead leaves, pine needles, wood chips, sawdust-like debris
Branches	Twigs with diameter <10cm
Small logs	Logs and stumps with diameter (within plot) of 10-50cm
Large logs	Logs and stumps with diameter (within plot) of >50cm
Live shrubs	Woody vegetation not considered sapling; height ≤2m[a]
Dead shrubs	Same description as for live shrub but with no living/no foliage
Vegetation mats	Near ground surface shrub cover (*Ceanothus prostratus*)
Saplings	Small trees with height ≤2m
Non-woody perennials[b]	Shrub- and forb-like vegetation lacking woody stems
Canopy openness (%)	Percent open sky above breast height (1.4m)
Shrub species richness	Number of distinct, live shrub species
Sapling species richness	Number of distinct, live sapling species
Substrate hardness	Ground hardness averaged across 4 randomly sampled points
Slope	Degree of ground surface decline/incline
Aspect	Probable direction of water flow from center of trap station

Table 2. — Description of habitat variables measured in 4-m radius plots at 144 dusky-footed woodrat (*Neotoma fuscipes*) houses and 144 random sites in the northern Sierra Nevada, California, 2003 – 2005.

Variable	Description
Stems of woody plants	
Low shrub	Woody stems <1 m tall, excluding mat-forming shrubs
High shrub	Woody stems ≥1 m tall and <5 cm dbh
Sapling	Woody stems 5.0 – 9.9 cm dbh
Poletimber	Woody stems 10.0 – 27.9 cm dbh
Small sawtimber	Woody stems 28.0 – 53.3 cm dbh
Large sawtimber	Woody stems ≥53.4 cm dbh
Small oak	*Quercus kelloggii* stems 5.0 – 32.9 cm dbh
Large oak	*Quercus kelloggii* stems ≥33.0 cm dbh
Dead wood	
Log	Downed, dead wood ≥1 m long and ≥5 cm at the narrowest end
Large snag	Standing dead wood ≥30 cm dbh and >1.3 m tall
Large stump	Standing dead wood ≥30 cm drc and 0.1 – 1.3 m tall
Ground cover (%)	
Bare ground	Exposed soil
Rock	Exposed boulders, cobble and gravel
Mat-forming shrub	Trailing, near ground surface (<0.3 m tall) woody stem cover (e.g., *Symphoricarpos rotundifolius*)
Other	
Canopy closure	Percent closed sky at eye-level (1.7 m)
Degree slope	Degree of ground surface decline/incline

Table 3. — Frequency, mean values and standard errors (SE) for microhabitat variables in 4-m radius plots centered at dusky-footed woodrat (Neotoma fuscipes) ground houses (n = 144) and paired random sites (n = 144) in Plumas National Forest, California, 2003 – 2005. Parameter estimates, *P*-values for the Wald chi-squared statistic, and Akaike Information Criteria (AIC) are presented from a univariate conditional logistic regression.

	Mean (SE)		Parameter			
Variable	**House site**	**Random site**	**estimate (SE)**	***P***	**AIC**	
Density (ha^{-1})						
Low shrub	19,054.2 (1,656.5)	24,552.4 (1,945.9)	−0.00003 (0.00001)	0.003	186.24	*
High shrub	9,950.0 (641.8)	6,761.1 (561.7)	0.0001 (0.00002)	<0.001	189.39	*
Sapling	494.4 (51.0)	418.1 (42.9)	0.0003 (0.0002)	0.241	200.20	*
Poletimber	395.8 (41.6)	381.9 (34.2)	0.0001 (0.0003)	0.774	201.54	
Small sawtimber	123.6 (15.3)	143.1 (16.7)	−0.0005 (0.0006)	0.385	200.86	
Large sawtimber	12.5 (4.0)	16.7 (4.6)	−0.0014 (0.0022)	0.514	201.20	
Log	845.7 (77.8)	717.1 (64.2)	0.0002 (0.0002)	0.218	188.95	*
Basal area (m^2ha^{-1})						
Sapling	2.0 (0.2)	1.6 (0.2)	0.0778 (0.0549)	0.157	199.47	*
Poletimber	8.2 (0.9)	9.0 (0.8)	−0.0087 (0.0126)	0.490	201.15	
Small sawtimber	13.3 (1.7)	16.3 (2.0)	-0.0059 (0.0053)	0.266	200.36	
Large sawtimber	4.1 (1.4)	4.9 (1.4)	−0.0027 (0.0068)	0.689	201.47	
Volume (m^3ha^{-1})						
Log	124.7 (18.2)	38.5 (7.5)	0.0048 (0.0015)	0.001	171.54	*
Ground cover (%)						
Bare ground	3.5 (0.5)	5.1 (1.0)	−0.1282 (0.0543)	0.018	192.71	*
Rock	1.3 (0.2)	2.8 (0.8)	−0.0216 (0.0148)	0.144	193.65	*
Mat-forming shrub	13.9 (1.2)	19.8 (1.7)	−0.0273 (0.0091)	0.003	189.43	*
Other						
Canopy closure (%)	67.8 (2.8)	64.2 (2.8)	0.0035 (0.0036)	0.331	199.29	
Degree slope	19.3 (0.7)	16.4 (0.6)	0.1257 (0.0311)	<0.001	199.29	*
Presence (no. plots)						
Small oak	40%	30%	0.5390 (0.2746)	0.050	197.63	*
Large oak	10%	3%	1.7912 (0.7636)	0.019	193.70	*
Large snag	4%	4%	0.0000 (0.5774)	1.000	201.63	
Large stump	49%	17%	1.4191 (0.2877)	<0.001	169.44	*

*Variables with *P*-values ≤0.25 from log-likelihood ratio tests were included in multivariate models predicting house sites from random sites

Fig. 4.—Mean fall cone production by the major conifers at long-term grids. 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 (A) 2003 and (B) 2004. Statistically significant differences are represented by different letters within each species and in each year.

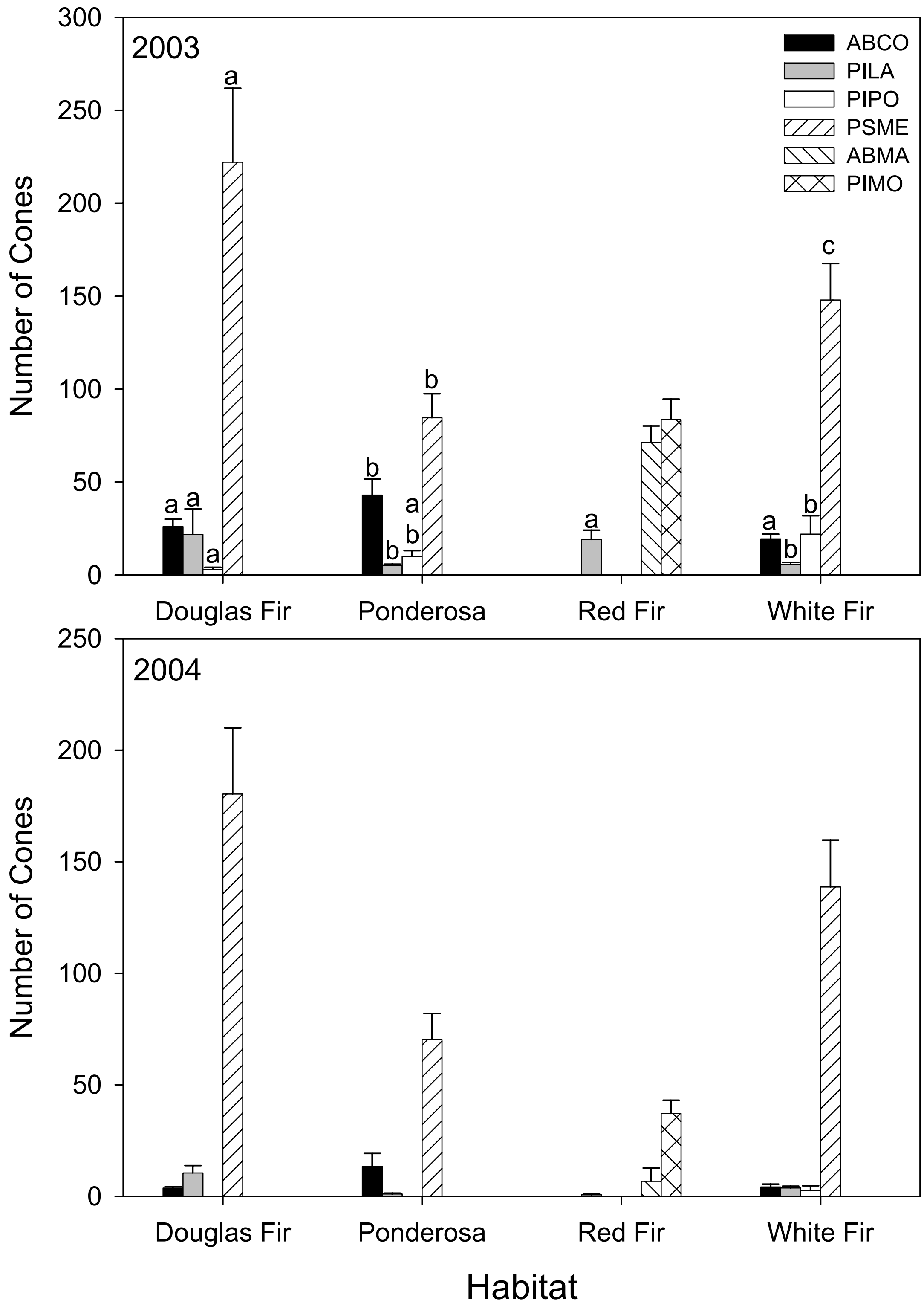


Fig. 5. — Mean monthly density (A) and survival (B) of deer mouse (*Peromyscus maniculatus*) populations inhabiting four forest types in the northern Sierra Nevada: white fir, Douglas fir, red fir, and Ponderosa pine. Population estimates were obtained using long-term grid data and program MARK. Populations were monitored from June 2003 to October 2004.

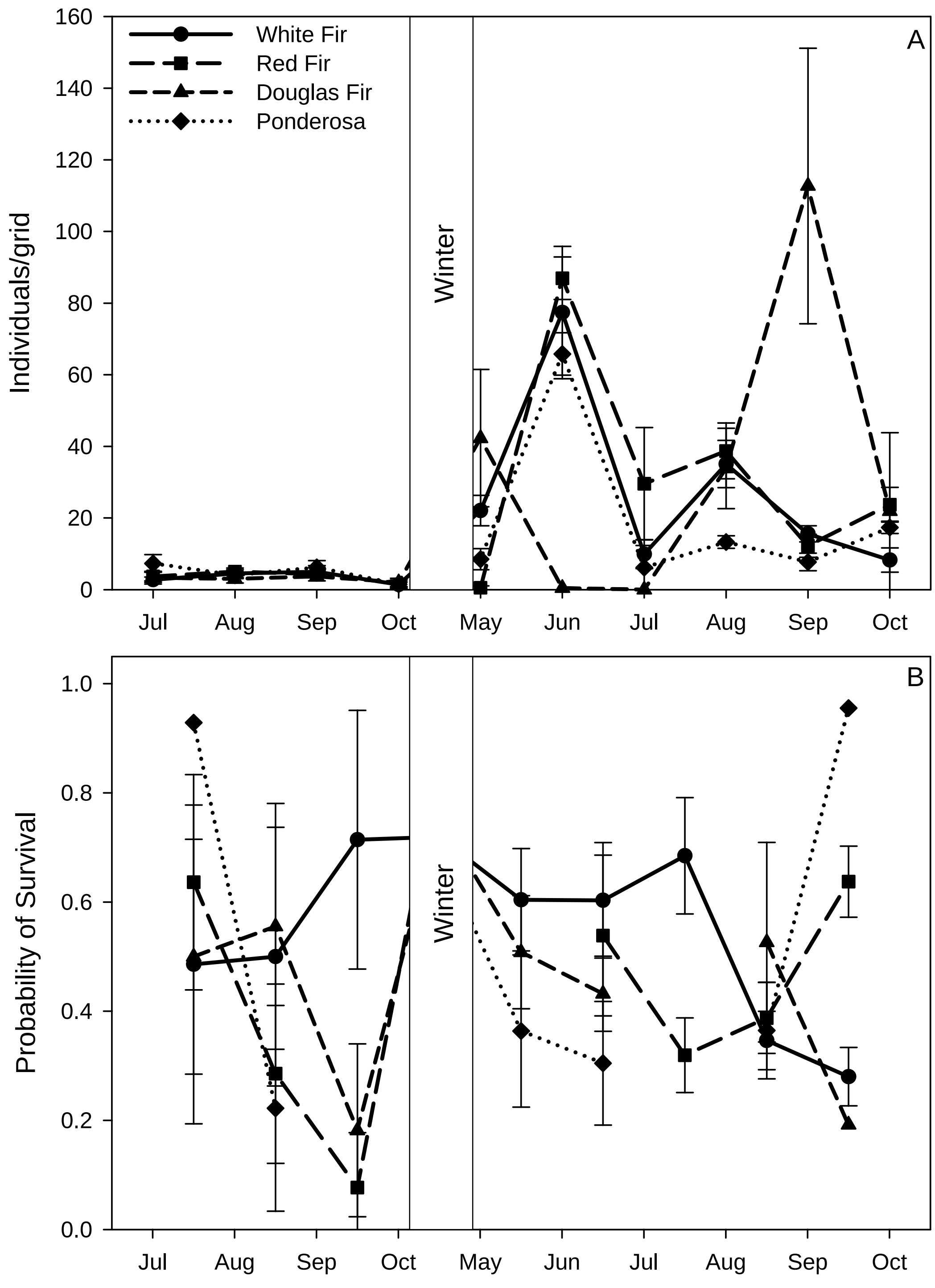


Fig. 6. — Mean monthly density (A) and survival (B) of golden-mantled ground squirrel (*Spermophilus lateralis*) populations inhabiting red fir forests in the northern Sierra. Population estimates were obtained using long-term grid data and program MARK. Populations were monitored from June 2003 to October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

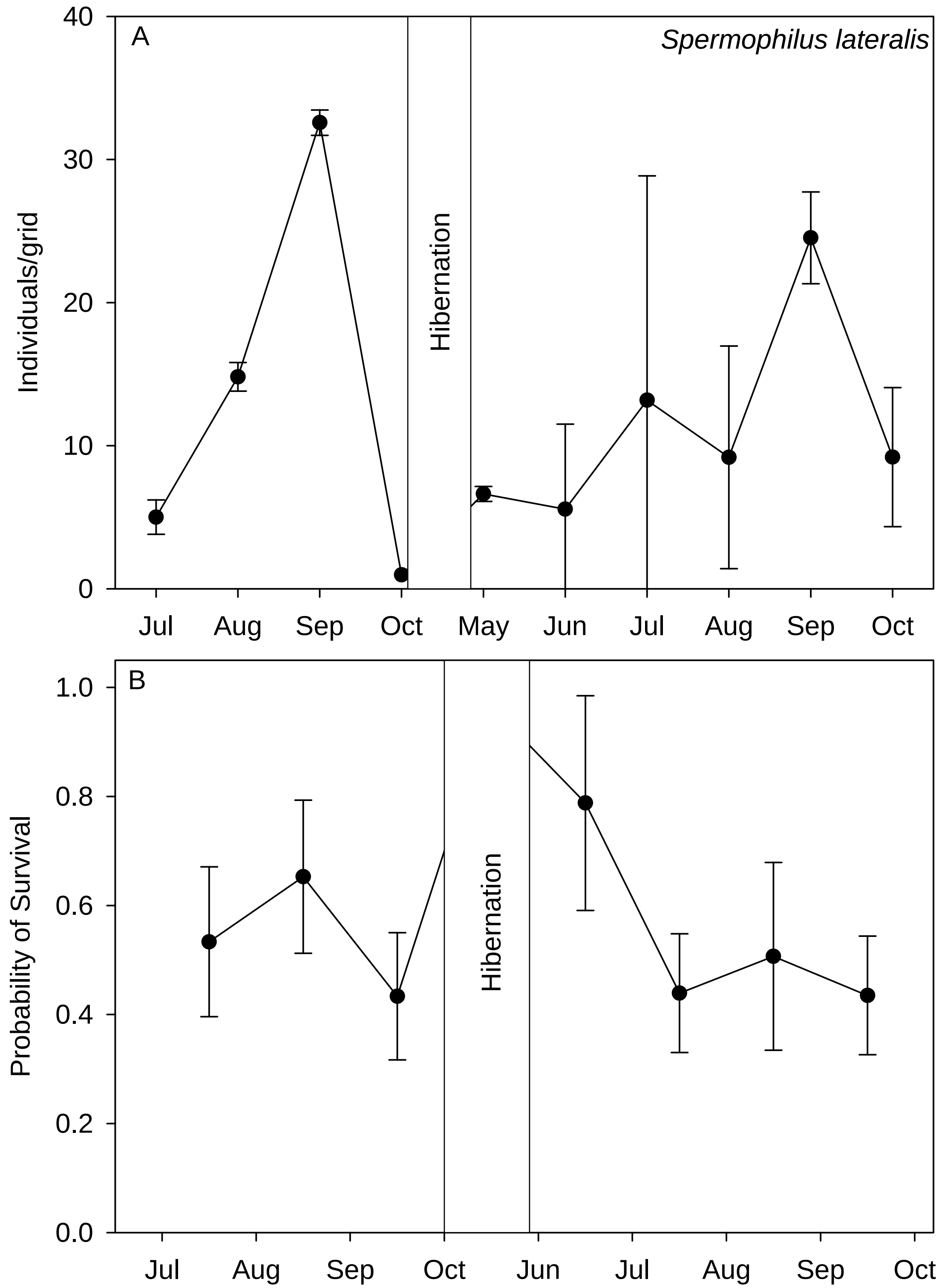


Fig. 7.—Mean monthly density of two species of chipmunk, (A) long-eared (*Tamias quadrimaculatus*) and (B) Allen's (*T. senex*) chipmunk, inhabiting three forest types (white fir, red fir, Douglas fir) in the northern Sierra. Density estimates were obtained using long-term grid data and program MARK. Populations were monitored from June 2003 to October 2004.

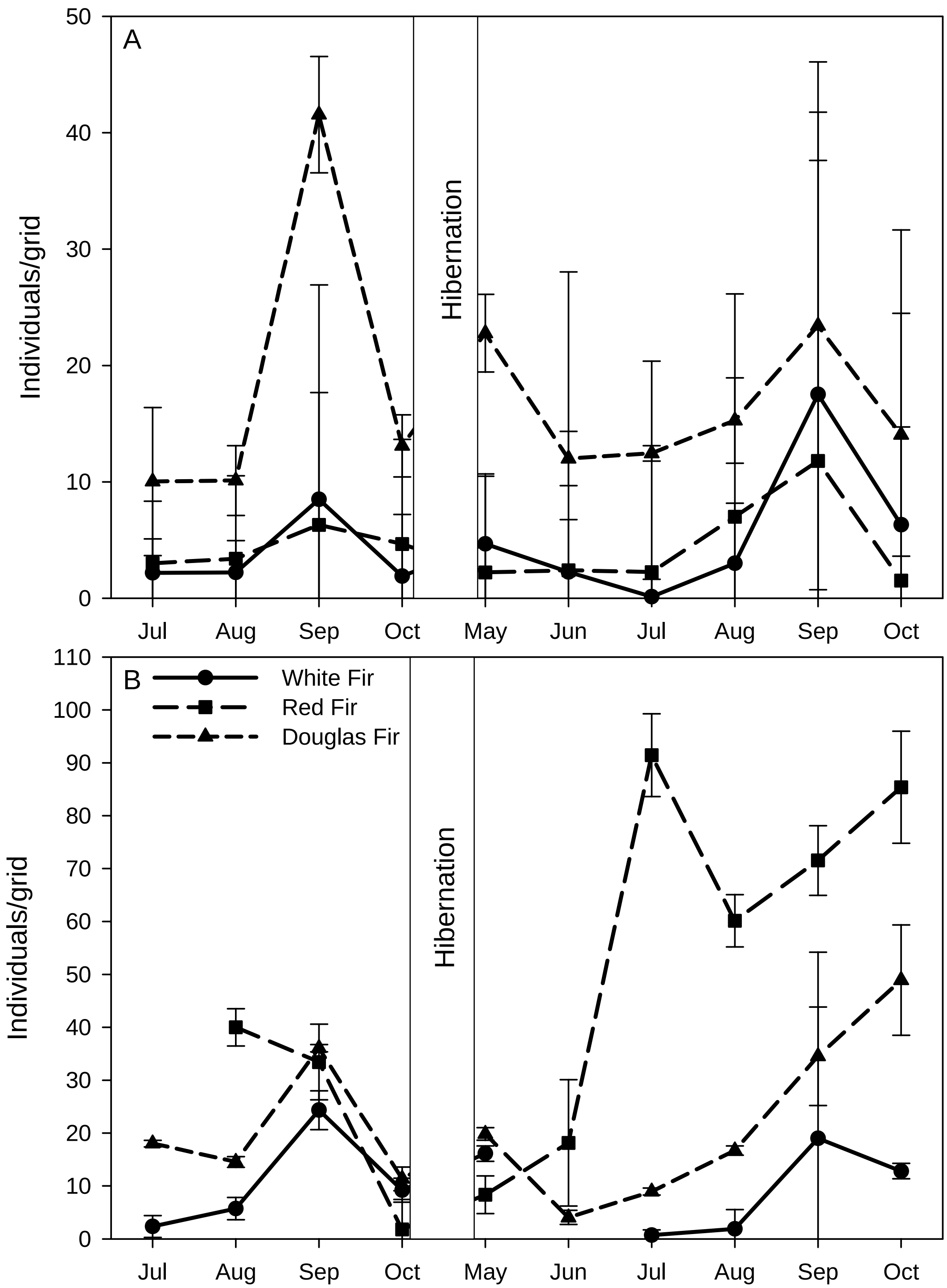


Table 4. — Results of the Program MARK analyses for 4 species of rodent in the northern Sierra Nevada. All species were analyzed individually using the Cormack-Jolly Seber data type. Best-fit models are shown for each species. Akaike's corrected information coefficient (AICc), adjusted for overdispersion, 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
Peromyscus maniculatus	Φ(habitat*t+overwinter+mean cones)p(habitat*t)	1740.6	0.99	1.85
Spermophilus lateralis	Φ(t)p(t)	358.2	0.96	1.14
Neotamias quadrimaculatus	Φ(habitat*t+overwinter+mean cones)p(habitat*t)	923.5	1.00	1.22
Neotamias senex	Φ(habitat*t)p(habitat*t)	683.2	0.60	1.23
	Φ(habitat*t+overwinter)p(habitat*t)	684.1	0.39	

Fig. 8.—Small mammal species richness in (former) treatment unit 2 of the PLAS study area in 2006.

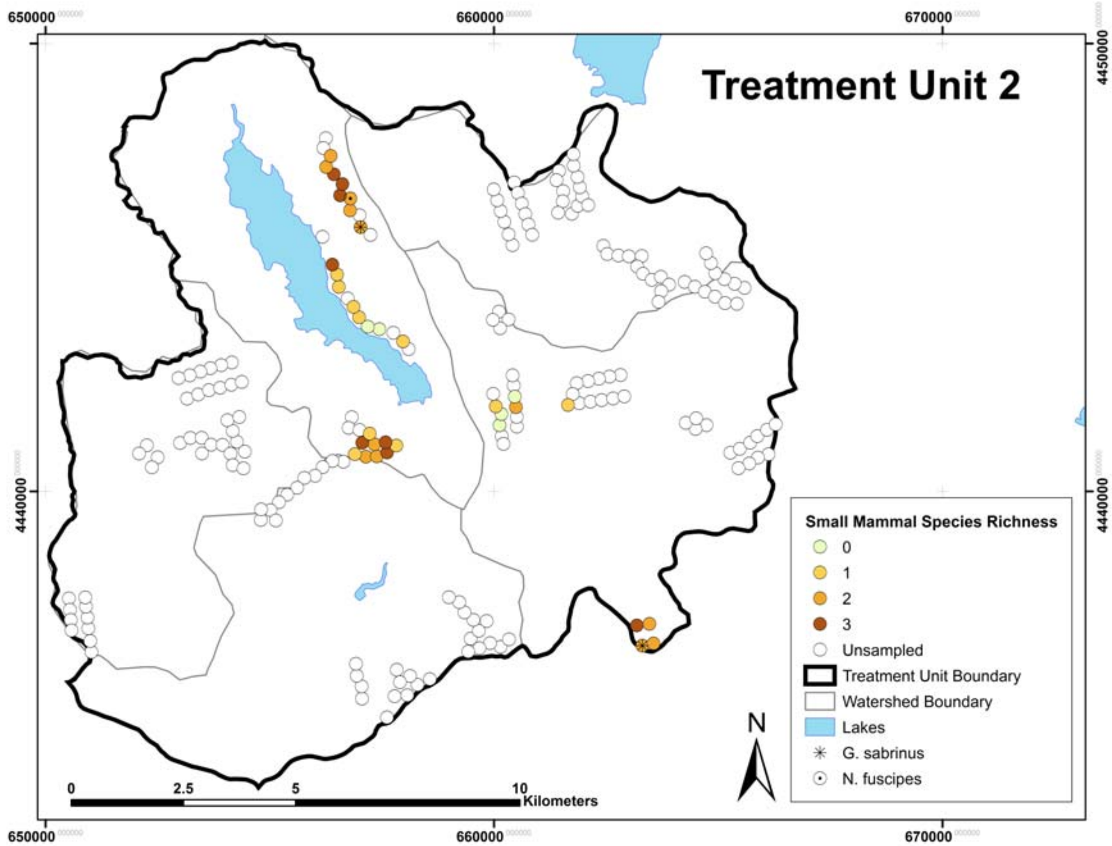


Fig. 9.—Small mammal species richness in (former) treatment unit 3 of the PLAS study area in 2006.

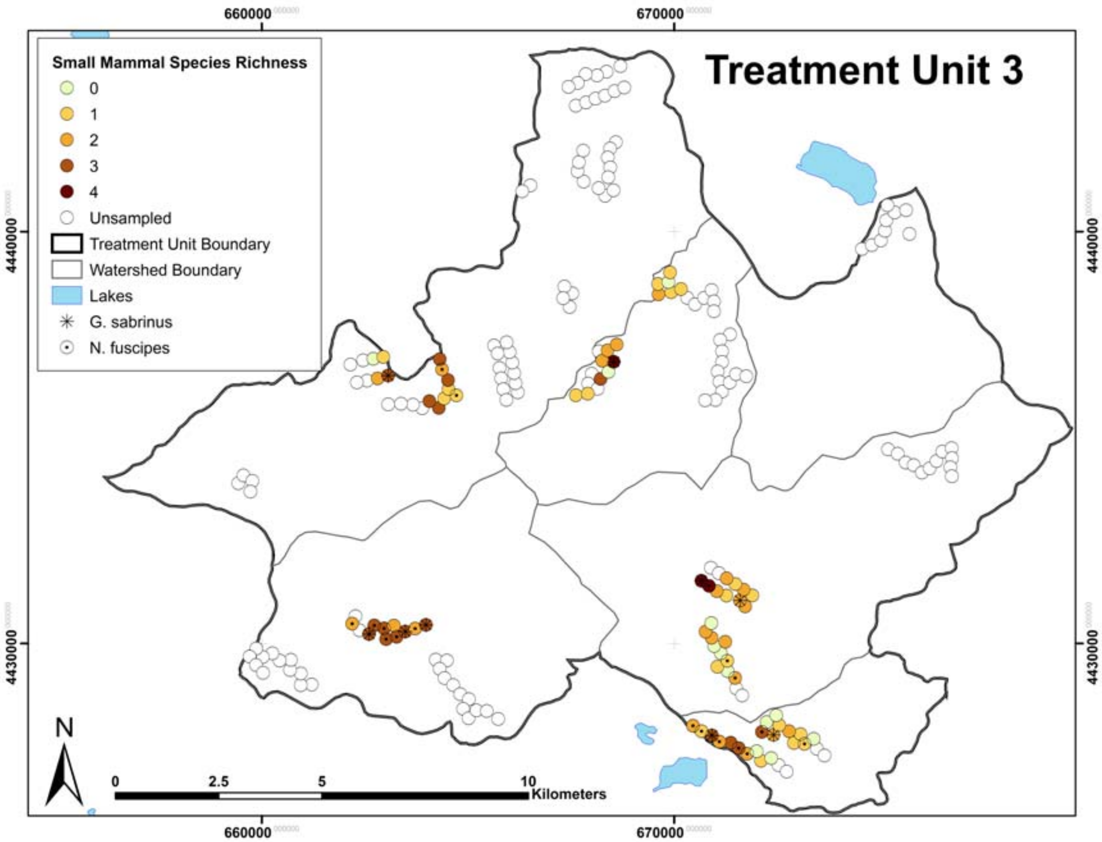


Fig. 10.—Small mammal species richness in (former) treatment unit 4 of the PLAS study area in 2006.

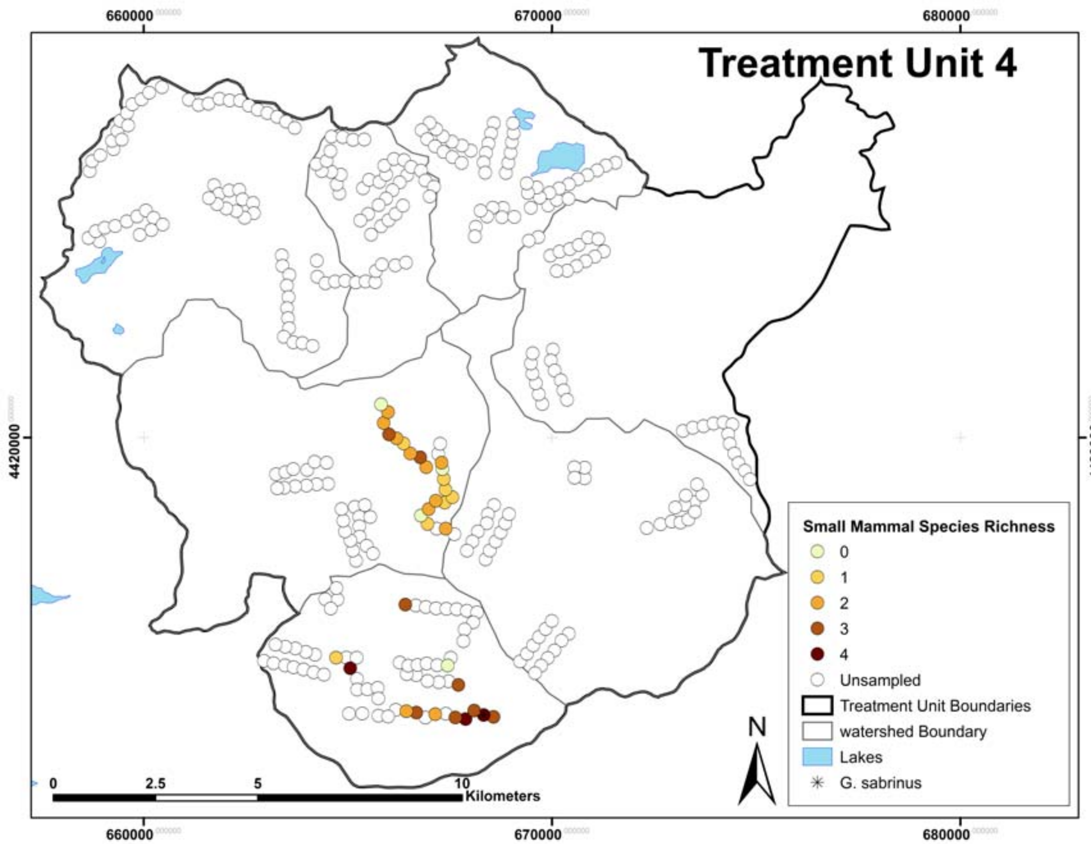


Fig. 11.—Small mammal species richness in (former) treatment unit 5 of the PLAS study area in 2006.

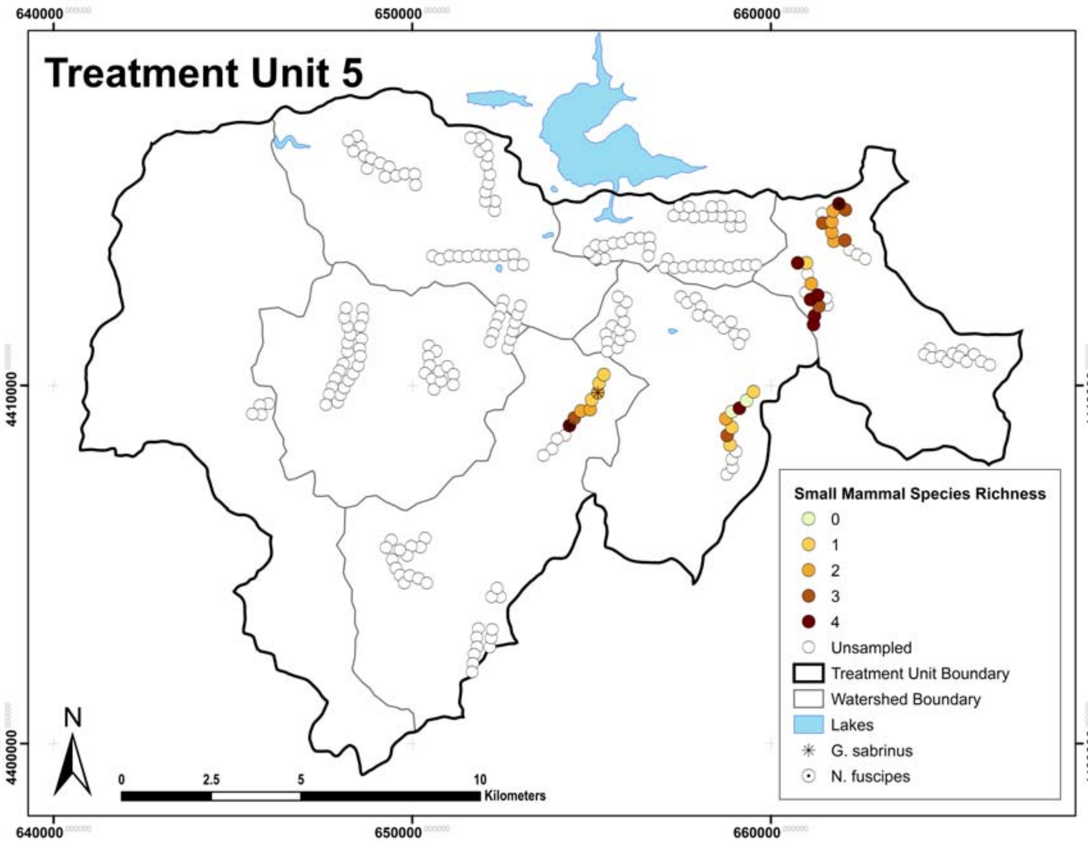


Table 5. — Home range of individual flying squirrels trapped during 2004-2005. Sex (male or female), Age (subadult or adult), mass (g), number of nests (nests), and home range size (ha) calculated with minimum convex polygon (MCP) or adaptive kernel (kernel) analyses. Unknown values are indicated by NA.

					Home Range Size (ha)	
ID	Sex	Age	Mass	Nests	95% MCP	95% Kernel
F1	F	A	125	NA	NA	NA
M1	M	A	127	3	26.1	23.0
M2	M	S	92	2	NA	NA
M3	M	A	104	2	83.4	39.8
F2	M	S	103	NA	NA	NA
F3	F	A	117	1	35.5	63.4
Archie	M	A	75	3	18.8	17.2
Brooser	M	A	75	3	19.5	24.8
Captain	M	A	91	NA	NA	NA
Delia	F	A	93	2	26.7	35.5
Emilio	M	A	96	NA	NA	NA
Feliz	M	A	104	2	24.8	39.4
Gulliver	M	J	78	3	4.5	4.7
Horatio	M	S	96	2	6.9	7.8
Isabella	F	A	99	1	25.1	31.4
Jelly	M	A	100	3	15.2	22.8
Kayto	M	A	73	NA	NA	NA
Layla	F	A	141	NA	NA	NA
Madeline	F	A	NA	1	8	13.0
Ninja	M	A	139	1	12.7	11.7

Fig. 12. — Home range extent of northern flying squirrels (*Glaucomys sabrinus*) at 2 study sites: FS-1 (red fir habitat, upper image) and FS-2 (mixed-conifer habitat, lower image). Home ranges represent the results of adaptive kernel analyses and show frequency of use with lighter shades representing areas of higher use (95, 75 and 50%).

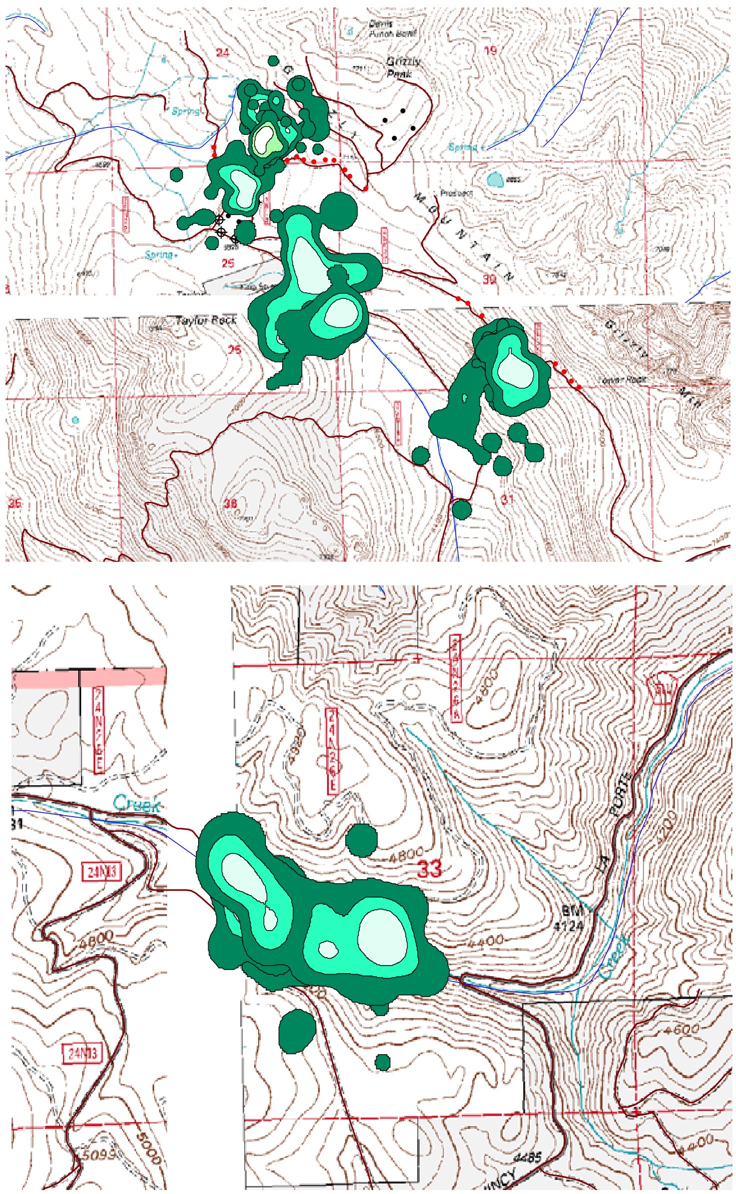


Fig. 13.— Mean home range size (ha) of male and female northern flying squirrels 2004-2005 in the northern Sierra Nevada. Mean home range size represents the 95% adaptive kernel estimates.

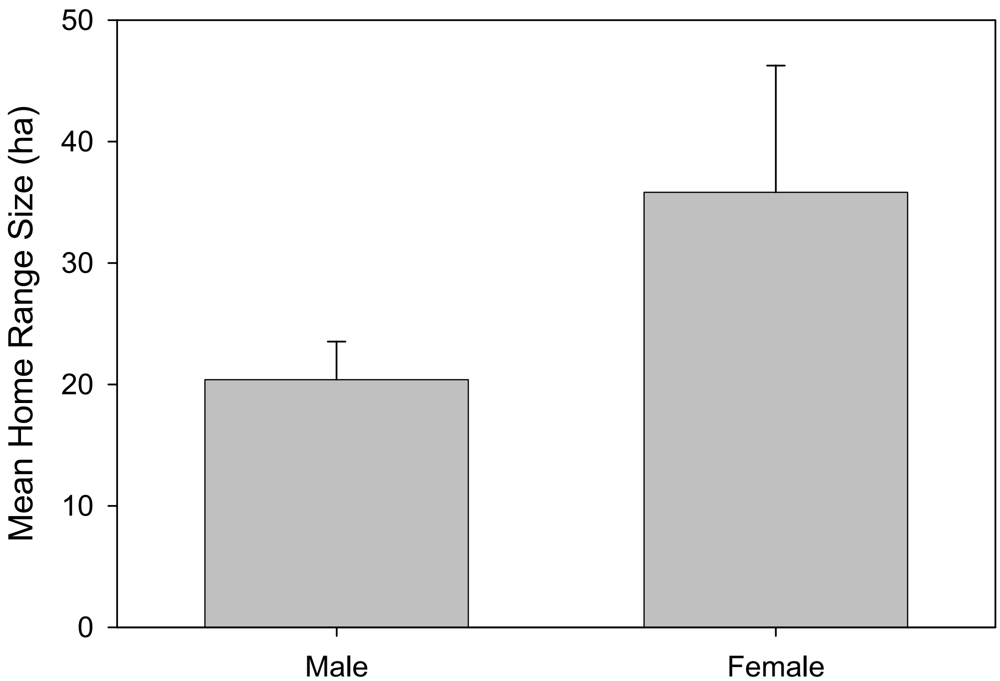


Fig. 14. — Nocturnal movement patterns of northern flying squirrels during 2004-2005. Movement patterns are represented as distance to the nearest known nest tree. Only locations between 18:00 and 06:00 were used.

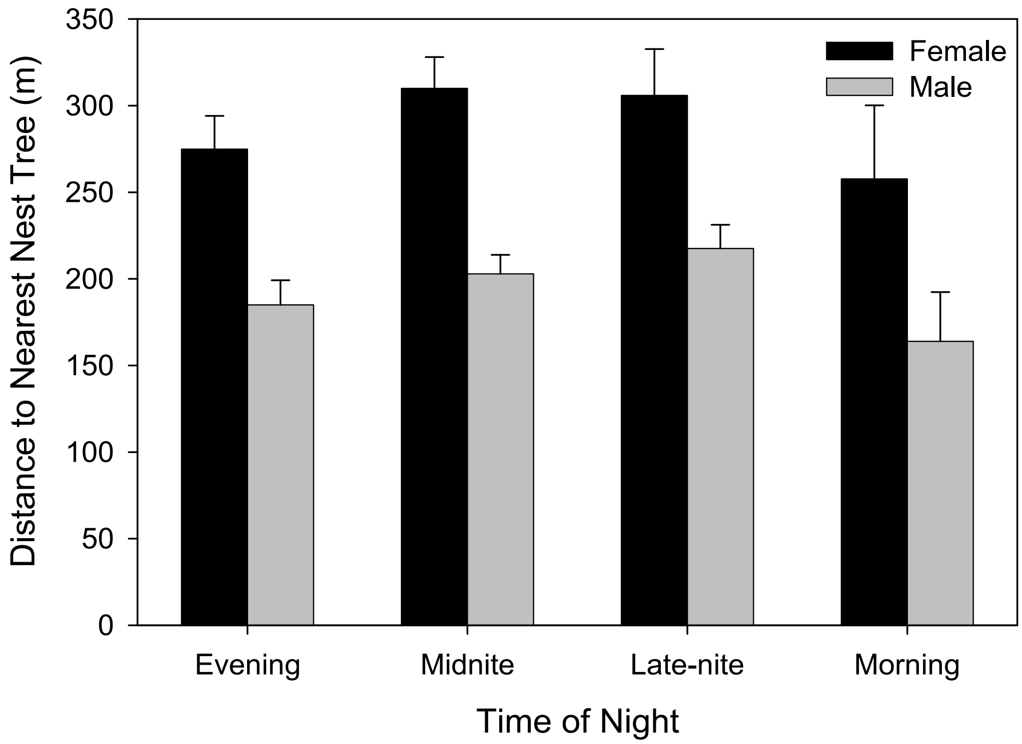


Fig. 15. — Regression of mean adult dusky-footed woodrat (*Neotoma fuscipes*) density (ha−1) on large (≥33 cm dbh) California black oak density (ha−1) in Plumas National Forest, California, 2004 – 2005.

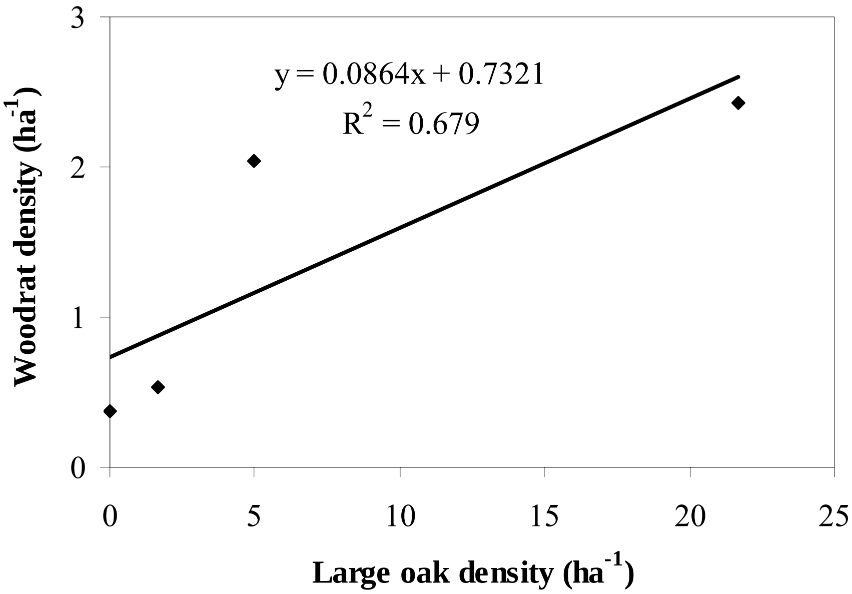


Table 6.— The best habitat model based upon the lowest Akaike Information Criterion used to explain the difference between dusky-footed woodrat (*Neotoma fuscipes*) house sites (n = 144) and paired random sites (n = 144) in the northern Sierra Nevada, California, 2003 – 2005. Parameter estimates, standard errors (SE), *P*-values for the Wald chi-square statistic, odds ratios, and 95% odds ratio confidence limits are presented from a conditional logistic regression. Odds ratios indicate the increased likelihood of the outcome with each unit increase in the predictor given the covariate pattern.

Variable	**Parameter estimate (SE)**	***P*-value**	**Odds ratio**	**95% Odds ratio confidence limits**	
Large stump presence	1.6051 (0.3779)	<0.001	4.978	2.373	10.442
Degree slope	0.1515 (0.0433)	0.0030	1.164	1.069	1.267
Log volume (m^3ha^{-1})	0.0048 (0.0016)	0.0010	1.005	1.002	1.008
Mat-forming shrub (%)	−0.0433 (0.0141)	0.0020	0.958	0.932	0.984
Bare ground (%)	−0.0527 (0.0251)	0.0360	0.949	0.903	0.997

Table 7.— Density (ha-1) of adult dusky-footed woodrats (*Neotoma fuscipes*), ground houses mean density (ha^{-1}), and density (ha^{-1}) and basal area ($baha^{-1}$) of small (< 33 cm dbh) and large (≥ 33 cm dbh) California black oak (*Quercus kelloggii*) trees, and acorn production indices at 4 study sites in the northern Sierra Nevada, California, 2004 - 2006.

		Woodrat density (ha^{-1})			Ground House	Tree House	California black oak (ha^{-1})		California black oak ($baha^{-1}$)		Acorn Production Index	
Site	Area	2004	2005	2006	Density (ha^{-1})	Density (ha^{-1})	Small	Large	Small	Large	2005	2006
1	6.18	2.91	1.94	1.46	8.90	5.83	291.67	21.67	7.78	2.71	13.11	14.82
2	3.68	2.18	1.90	1.09	11.15	3.26	142.50	5.00	2.36	0.78	9.44	3.28
3	5.60	0.54	0.54	0.36	1.96	0.36	28.33	1.67	0.49	0.48	-	-
4	6.72	0.30	0.45	0.15	1.04	0.30	207.50	0.00	2.80	0.00	-	-

Fig. 16. — Hypothesized model for offspring dispersal in ground dwelling sciurids (*Spermophilus*). Predicted offspring dispersal distance varies by offspring sex and both offspring and maternal body condition (% fat). Offspring born to mothers in better body condition (i.e., more fat) would begin life higher on the x-axis.

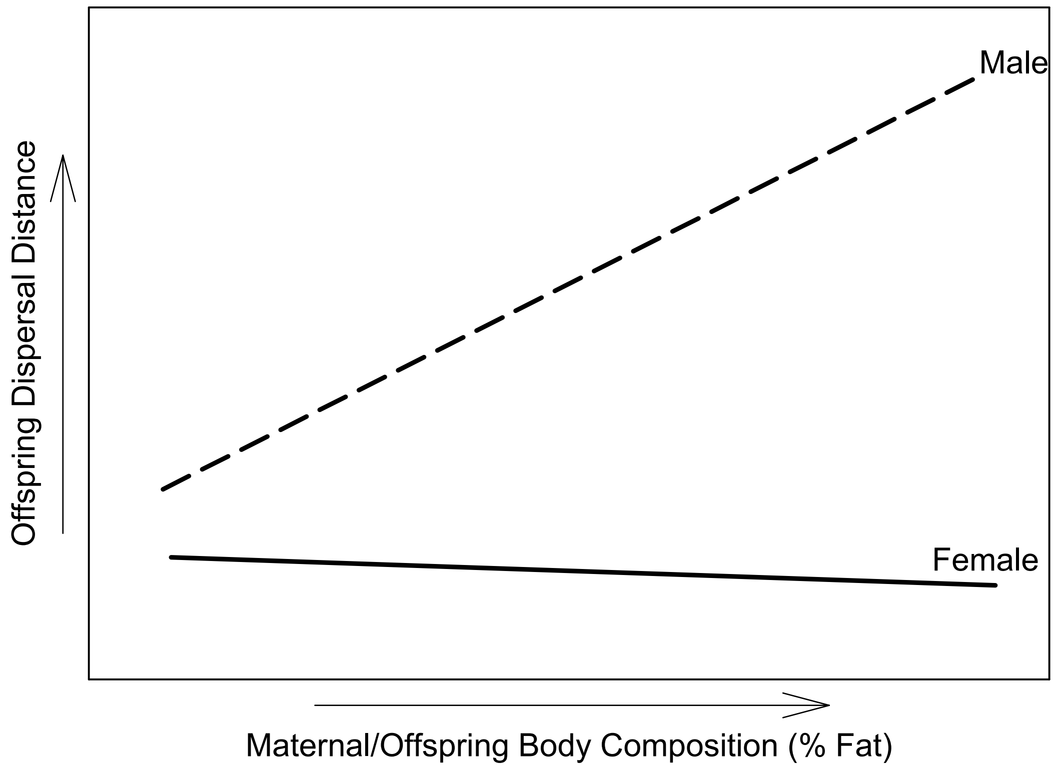


Fig. 17. — Mass of female (mother) golden-mantled ground squirrels and their offspring during 2003 – 2004. All squirrels enter hibernation during early October and emerge following snowmelt in mid May. Significance is indicated by (*).

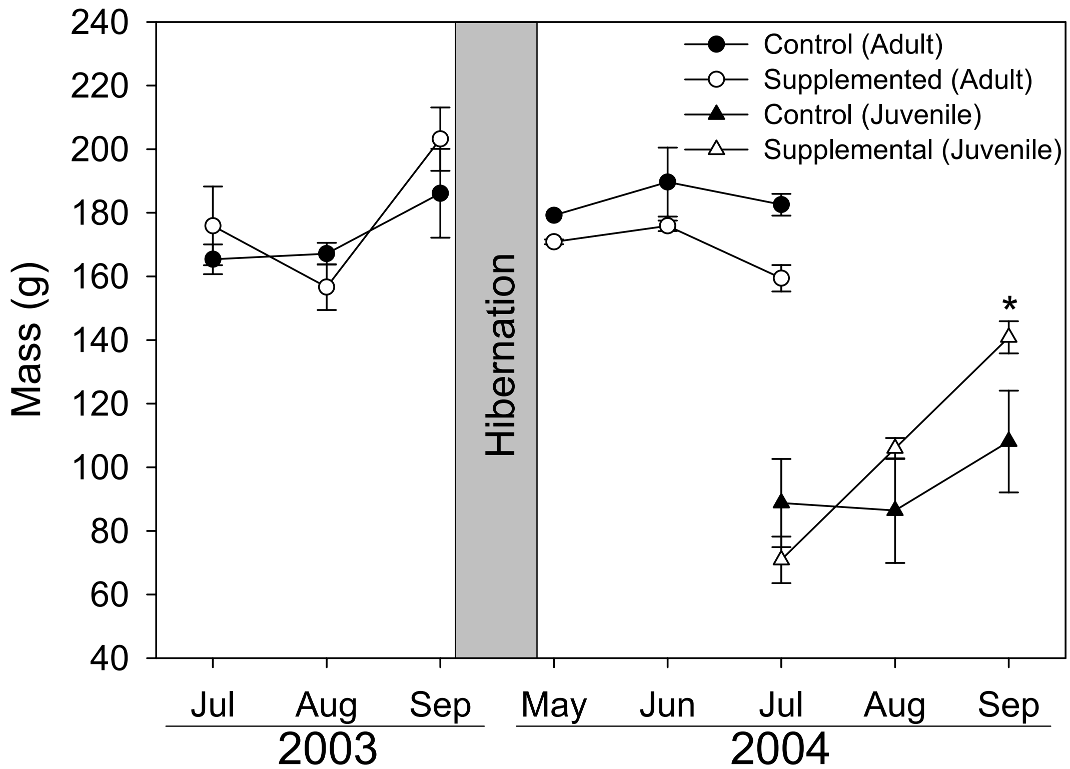


Fig. 18.— Mean exploratory distance (A) and post-natal dispersal (B) distance (m), measured as the distance between location of first capture and location of hibernation, of male (n = 13) and female (n = 10) offspring golden-mantled ground squirrels from each treatment group.

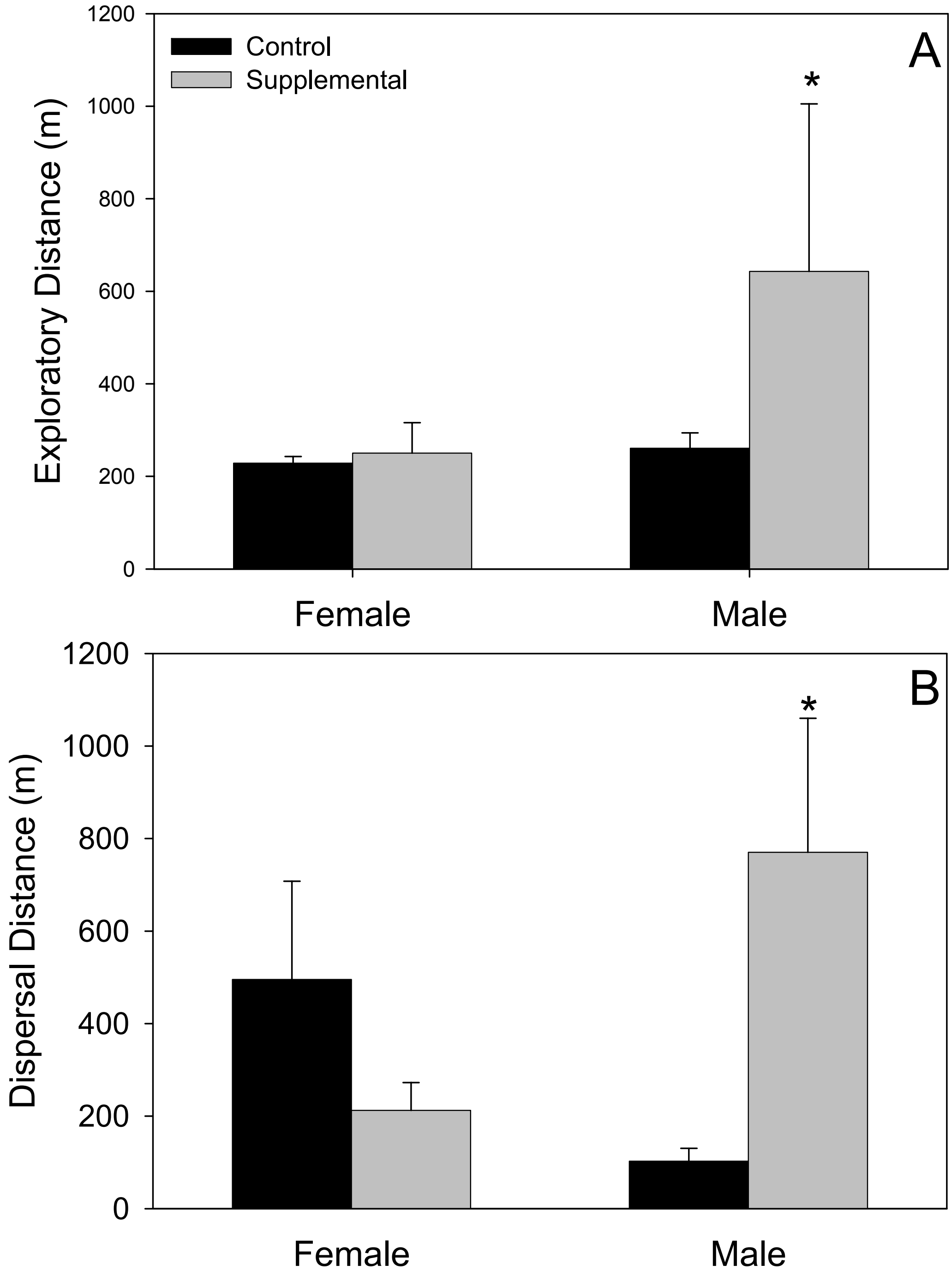
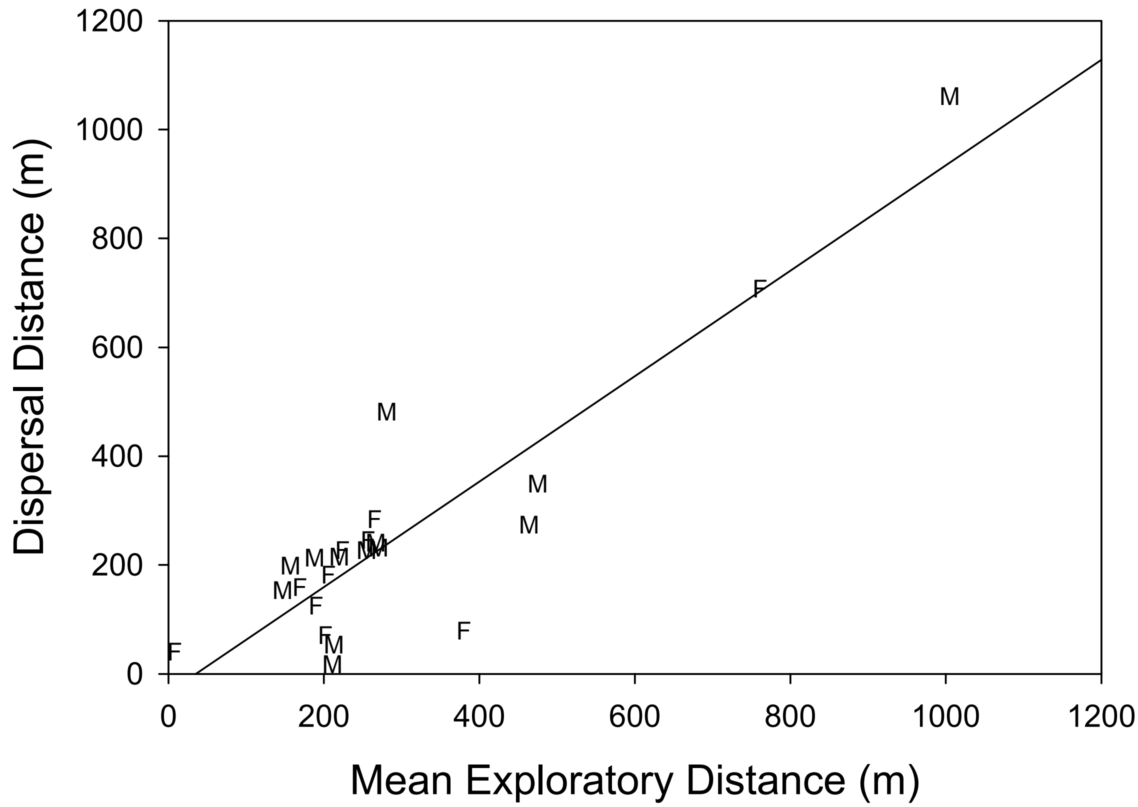
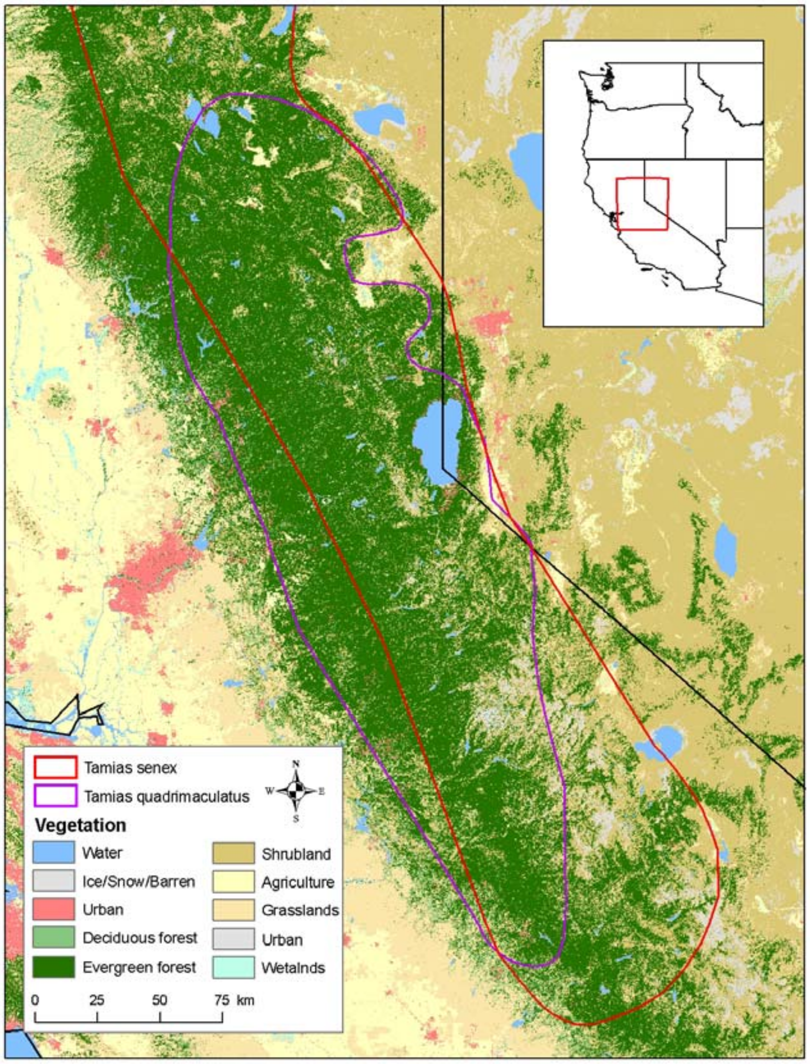


Fig. 19. — Relationship between mean exploratory distance and post-natal dispersal in male (M) and female (F) golden-mantled ground squirrel offspring.



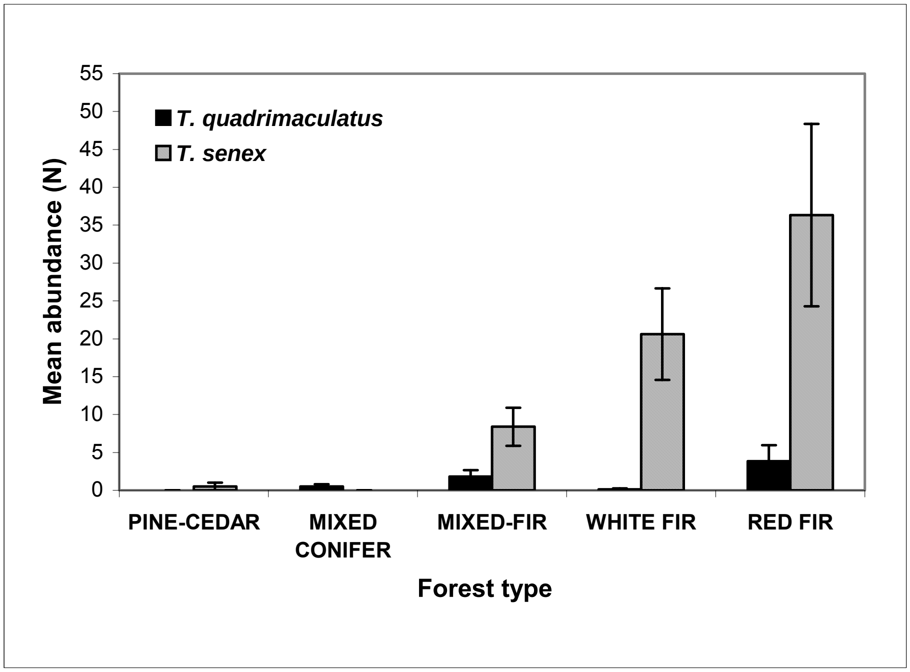
<u>Habitat Associations and Partitioning at the Landscape Spatial Scale</u>

Fig. 20. — Landscape scale map showing the geographic ranges of *T. quadrimaculatus* and *T. senex*, and associated habitat, throughout the Sierra Nevada.



Habitat Associations and Partitioning at the Macrohabitat Spatial Scale

Fig. 21. — Mean abundance (N) of *T. quadrimaculatus* and *T. senex* among five macrohabitat types of Plumas National Forest, CA (2003-2004).

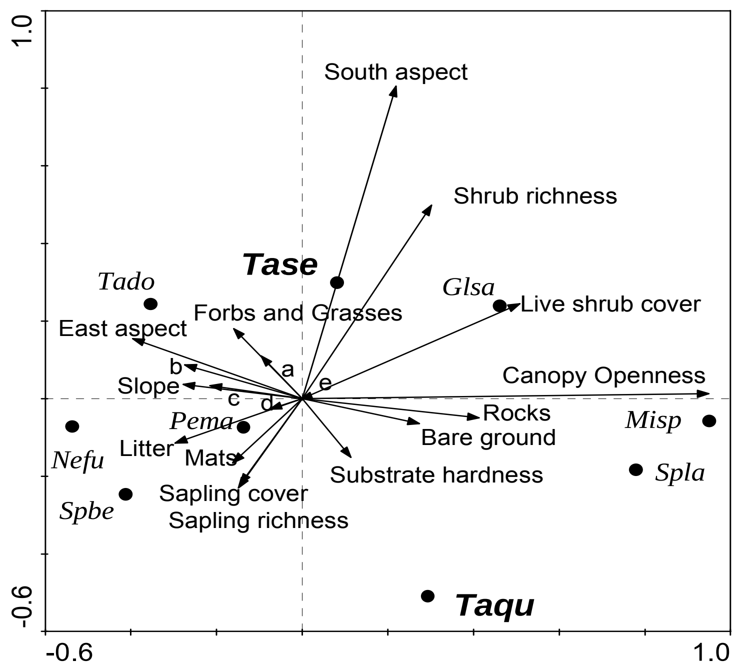


Habitat Associations and Partitioning at the Microhabitat Spatial Scale

Table 8. — Stepwise logistic regression models of Tamias quadrimaculatus and T. senex microhabitat (trap-scale) associations in Plumas National Forest, CA (2003 and 2004 pooled); variables are ordered by positive parameter estimate.

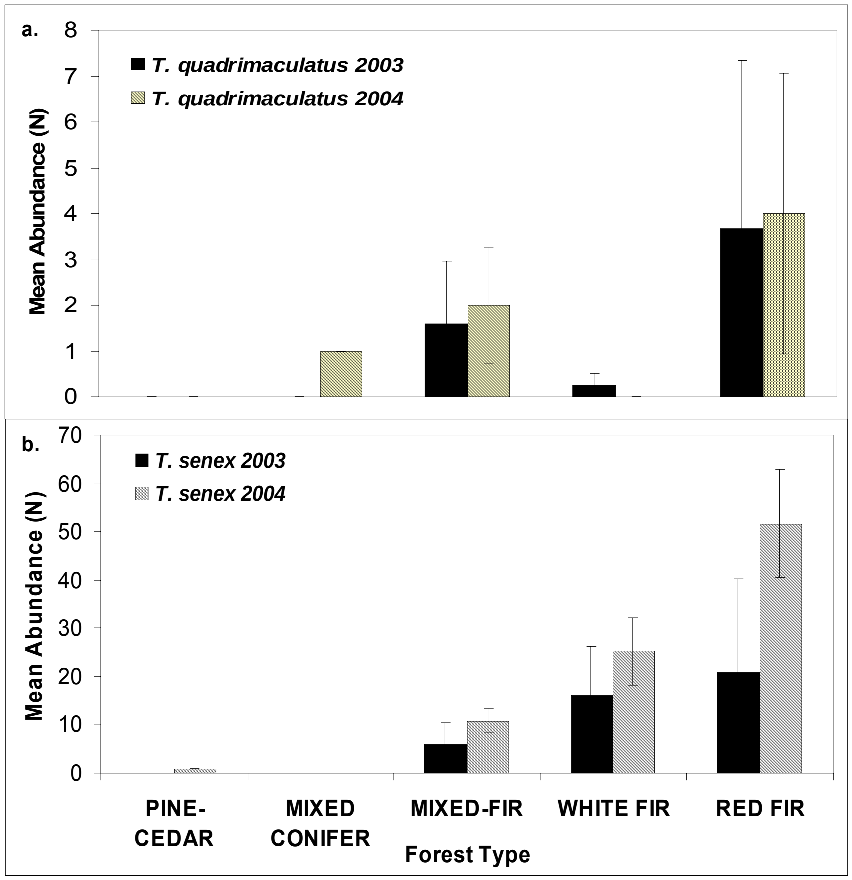
Model	Variables	Estimate	SE	Wald χ^2	P	Odds ratio	Goodness of Fit
N. quadrimaculatus							
	Canopy Openness	0.030	0.006	22.12	<0.0001	1.030 (1.018-1.043)	$P = 0.89$
	Cover by rocks	0.024	0.009	7.03	0.0080	1.025 (1.006-1.043)	
	Sapling species richness	0.018	0.007	6.00	0.0143	1.018 (1.004-1.033)	
	Slope	-0.045	0.020	4.91	0.0268	0.956 (0.918-0.995)	
	South aspect	-0.013	0.003	25.41	<0.0001	0.987 (0.982-0.992)	
	East aspect	-0.008	0.003	6.85	0.0089	0.992 (0.986-0.998)	
N. senex							
	Shrub species richness	0.623	0.086	52.94	<0.0001	1.865 (1.577-2.206)	$P = 0.24$
	Canopy Openness	0.019	0.004	26.59	<0.0001	1.019 (1.012-1.026)	
	South aspect	0.007	0.001	38.21	<0.0001	1.007 (1.004-1.009)	
	Substrate hardness	-0.460	0.121	14.30	0.0002	0.633 (0.499-0.802)	
	Cover by mats	-0.029	0.010	9.18	0.0025	0.971 (0.953-0.990)	
	Cover by litter	-0.009	0.002	14.47	0.0001	0.991 (0.987-0.996)	

Fig. 22. — Biplot of axes 1 and 2 from canonical correspondence analysis of small mammal trap-scale abundances and microhabitat variables in the Plumas National Forest, California (2003-2004). Vector length indicates the strength of correlation between variables and the canonical axes. *T. quadrimaculatus* is represented by the acronym Taqu and *T. senex* is Tase. The symbol *a* is dead shrubs, *b* is branches, *c* is non-woody vegetation, *d* is small logs, and *e* is large logs. All other species acronyms are as follows: Glsa = *Glaucomys sabrinus*, Misp = *Microtus* species, Nefu = *Neotoma fuscipes*, Pema = *Peromyscus maniculatus*, Spbe = *Spermophilus beecheyi*, Spla = *Spermophilus lateralis*, Tado = *Tamiasciurus douglasi*.



Year-to-year shifts in Habitat Preferences at the Macrohabitat Spatial Scale

Fig. 23.—Mean abundance (N) of *T. quadrimaculatus* and *T. senex*, for 2003 and 2004 data separately, among five macrohabitat types of Plumas National Forest, CA.



Year-to-year shifts in Habitat Preferences at the Microhabitat Spatial Scale

Table 9. — Stepwise logistic regression models of T. quadrimaculatus and T. senex microhabitat (trap-scale) associations in Plumas National Forest, CA (2003 and 2004 data separately); variables are ordered by positive parameter estimate. Hosmer Lemeshow goodness of fit values for each of the models include: *T. quadrimaculatus* $P > 0.33$ (2003), $P > 0.09$ (2004); *T. senex* $P > 0.08$ (2003), $P > 0.1$ (2004).

	2003			**2004**		
Model	**Variables**	**Estimate**	**P**	**Variables**	**Estimate**	**P**
N. quadrimaculatus	Cover by rocks	0.04	<0.0001	Shrub species richness	-1.72	0.0012
	South aspect	-0.02	<0.0001	Cover by live shrubs	0.02	0.0180
	Canopy Openness	0.03	**0.0009**	***Canopy Openness***	0.04	<0.0001
	Cover by large logs	0.02	0.0061	Cover by saplings	0.03	0.0002
	East aspect	-0.01	0.0412	Slope	-0.07	0.0101
N. senex	*South aspect*	0.01	<0.0001	*South aspect*	0.01	<0.0001
	Cover by large logs	0.02	0.0002	Canopy Openness	0.02	<0.0001
	Shrub species richness	*0.48*	*<0.0001*	*Shrub species richness*	*0.62*	*<0.0001*
	Cover by small logs	0.01	0.0213	Cover by Mats	-0.03	0.0060
	Cover by dead shrubs	0.03	0.0066	Cover by litter	-0.01	0.0001
	Sapling species richness	0.27	0.0427	Substrate hardness	-0.39	0.0029
	Cover by non-woody perennials	0.02	0.0085			

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

2006 Annual Report

Submitted February 2007

Ryan D. Burnett and Nadav Nur

PRBO Conservation Science
3820 Cypress Drive # 11
Petaluma, CA 94954

PRBO Contribution # 1550

EXECUTIVE SUMMARY

In this document we report on the avian module of the Plumas-Lassen Area Study (PLAS). In 2006 we conducted our fifth year of monitoring. Information presented herein includes updated species richness and total bird abundance for all sites surveyed, final results from our analysis of avian community composition within several measures of Spotted Owl (SPOW) habitat, and analysis of population trends for 25 species in the study area from 2003 – 2006.

Species richness and total bird abundance in 2006 – when pooled across all sites – was the second lowest recorded between 2002 and 2006 and was similar to the lowest year for these indices, recorded in 2004. In contrast, in 2005 we recorded the highest richness and abundance indices of the five years.

Analysis of avian community composition in relation to SPOW habitat showed avian species richness and total bird abundance significantly higher outside of SPOW Core Areas. Nineteen of 25 species analyzed had a statistically significant relationship with at least one of the three measures of SPOW habitat. Thirteen of these were negative and six were positive. Five of the thirteen species were negative with all three measures and two of the six were positive with all three measures. The majority of those negatively associated with SPOW habitat areas are shrub or open forest dependent species.

Analysis of population trends from 2003 – 2006 showed that 14 of the 25 species analyzed were decreasing while eleven were increasing. Of these, six decreasing and four increasing trends were statistically significant. Four of the six species with significant declining population trends had a significant negative association with at least one measure of SPOW habitat. Decreasing species included: Hammond’s Flycatcher, Mountain Chickadee, Red-breasted Nuthatch, Fox Sparrow, and Spotted Towhee. Three of the four species with increasing trends had a significant positive association with at least one measure of SPOW habitat. Increasing species included: Dusky Flycatcher, Golden-crowned Kinglet, Brown Creeper, and Hermit Warbler. The species with the largest per year population decline was the Pileated Woodpecker – a species strongly correlated with SPOW habitat. However, due to very small sample sizes this trend was not significant.

In 2006, we increased our outreach efforts and integrating with forest managers. We presented results at several conferences, created white papers on managing important Sierra Nevada habitats for birds, and worked on several forest service efforts to provide data for the new management indicator species direction. We have also updated our interactive GIS tool – for use by forest managers – with 2006 data.

INTRODUCTION

The Sierra Nevada is one of the most important ecosystems for birds in California (Siegel and DeSante 1999, CalPIF 2002). A century of intensive resource extraction and forest management practices here have put at risk the ecological stability and continued functionality of the system as a whole (SNEP 1996). Loss of habitat to intensive logging operations and human development, lack of replacement of old-growth stands due to harvest rotations of insufficient duration, changes in forest structure and species composition due to fire suppression, and removal of snags and dead trees are among the most detrimental impacts (SNEP 1996, CalPIF 2002). Birds and other wildlife populations have subsequently been altered by such changes; significant population declines have been observed in a number of species, some of which are now afforded special status at the federal or state level.

The Record of Decision (ROD) for the Sierra Nevada Forest Plan Amendment (SNFPA) and subsequent supplemental ROD (SNFPA 2001, SNFPA 2004) direct the Forest Service to maintain and restore old forest conditions that provide crucial habitat for a number of plant and animal species. The decision focuses attention and directs actions towards both protecting and creating habitat with old forest attributes, while providing substantial amount of harvestable timber. Simultaneously, the Forest Service is taking steps to reduce risks of catastrophic fire by reducing fuel loads in overstocked forests. Achieving all of these potentially competing goals will, at the very least, be a challenging task.

Here we report on the landbird study module of the Administrative Study, one of an integrated series of research efforts intended to evaluate land management strategies designed to reduce wildland fire hazard, promote forest health, and provide economic benefits within the area covered by the Herger-Feinstein Quincy Library Group Forest Recovery Act Pilot Project (HFQLG Pilot Project; see Stine et al. 2004).

Valuable feedback can be gained by determining how the full complement of the avian community responds to different forest management regimes, particularly at the landscape scale. If forest management practices encourage old forest development and forests across landscapes trend towards larger trees and higher canopy cover, how will birds other than the SPOW respond to these conditions?

The primary objective of the landbird module is to assess the impact of forest management practices in sustaining a long-term ecologically stable forest ecosystem at the local and landscape scales. We know, *a priori*, that the avian community is comprised of species that are associated with a wide range of forest seral stages, vegetative composition, and structures (SNEP 12996, CALPIF 2002, Burnett and Humple 2003). This habitat, and hence avian diversity, is due in large part to the natural ecological dynamics of these forest systems. Though humans have altered these systems, they continue to undergo non-human mediated changes through biological, geological, and stochastic processes. Therefore, it is imperative for managers to consider how these changes influence management actions temporally and spatially, and how ecological balance can be achieved in an inherently dynamic system.

In order to meet our primary objective of assessing the impacts of forest management practices on landbirds at local and landscape scales, we are addressing the following:

(1) Determine landbird habitat associations at the local scale.

(2) Determine landscape effects on bird habitat associations.

(3) Based on the results of objectives 1 and 2, develop predictive bird models to forecast how individual species may respond to forest management, particularly those planned as part of the HFQLG Pilot Project.

(4) Quantitatively assess the impacts of forest management treatments on avian abundance and species diversity.

(5) Identify population trends for landbirds to determine if populations are changing temporally.

(6) Evaluate population trends to assess factors responsible for observed trends.

This multiple-objective approach will allow us to interpret both the effects of specific management practices, the extent to which they influence the greater landscape (in the short-term), and the integrated effects of treatments and natural processes over time.

In addition to this study, PRBO has been monitoring songbird populations in the Northern Sierra Nevada since 1997. Since 2001, these efforts have aimed to complement the avian research of the Administrative Study within the HFQLG area. Specifically, these efforts have focused on avian response to meadow restoration and cessation of grazing, the viability of clear-cut regenerations in providing habitat for shrub dependent bird species, and avian response to aspen and black oak habitat enhancement (see Burnett et al. 2005a). Working closely with the project planners from Forest Service ranger district staff, these studies are being implemented as adaptive management experiments. This work should be seen as not only providing valuable data to guide forest management but also as models of effective collaboration between science and managers in administering public lands in the Sierra Nevada and beyond (Burnett *in press*).

METHODS

Avian Surveys

We are using standardized five-minute multiple distance band circular plot point count censuses (Buckland et al. 1993, Ralph et al. 1993, Ralph et al. 1995) to sample the avian community in the study area. In this method, points are clustered in transects, but data is only collected from fixed stations, not along the entire transect.

Point count data allow us to measure secondary population parameters such as relative abundance of individual bird species, species richness, and species diversity. This method is useful for making comparisons of bird communities across time, locations, habitats, and land-use treatments.

All birds detected at each station during the five-minute survey are recorded according to their initial distance from the observer. These detections are placed within one of six categories: within 10 meters, 10-20 meters, 20-30 meters, 30-50 meters, 50-100 meters, and greater than 100 meters. The method of initial detection (song, visual, or call) for each individual is also recorded. Using a variable radius point count allows us to conduct distance sampling. Distance sampling should enable us to provide more precise estimates of density and detectability of individual birds as well as account for some of the observer variability inherent in the point count sampling method (Buckland et al. 1993).

Counts began around local sunrise, were completed within four hours, and did not occur in inclement weather. Each transect was visited twice during the peak of the breeding season from mid May through the first week of July in each year.

Treatment Unit and Transect Nomenclature

In this report we use the former treatment units (TUs) – those defined in the original Administrative Study plan – as functional units to analyze bird indices across aggregations of watersheds (see Appendices 1-7). These aggregations of watersheds no longer have any planned treatment in common; they are simply used here as a tool to describe geographically linked portions of the study area.

Transect naming protocols were different in 2002 than in 2003 and 2004. Transects established in 2002 under the previous study design are numbered transects (e.g., 222). The first number is the TU and the second and third numbers are the cover and size class, respectively, of the randomly-generated starting point (e.g. 214 is in TU-2, ands starts in forest designated as having cover class 1, and size class 4. In 2003 and 2004, under the existing study plan, new transects were named after the CalWater Planning Watershed (CalWater 1999). For example, SNK1 is in the Snake Lake watershed and is the first transect established there, while CHG3 is in the China Gulch watershed and was the third transect established there. The numeric ending is simply for designating between the different transects in the same watershed and does not have any additional significance.

2006 Survey Effort

In 2006 we surveyed 92 transects of 12 points each as well as the 72 additional owl territory points for a total of 1176 points (Table 1). Each site was surveyed twice for a total of 2352 point visits. All 72 owl points were surveyed in both 2005 and 2006. Of the remaining 1104 points, 348 have been surveyed consecutively since 2004, and 756 have been surveyed consecutively since 2003.

Field Crew Training

Point count crew members all have had previous experience conducting avian fieldwork and undergo extensive training onsite for two weeks prior to conducting surveys. Training consists of long hours in the field studying bird identification and conducting simultaneous practice point counts with expert observers. Each crew member is given an audio compact disc with the songs and calls of all of the local avifauna two months prior to their arrival at the study site to begin the training process early. Each person uses the CD to study the local birds and is then given quizzes each evening designed to test their knowledge of the songs and calls of the local birds. All observers must pass these tests and be 95% accurate on double observer point counts (compared to R. Burnett) before being allowed to begin surveying alone. Significant time is also given to calibrating each person in distance estimation. In addition each observer uses a laser range finder to calibrate distances at each point before starting an actual survey. Distance and bird identification calibration continues throughout the field season.

Statistical Analysis

We present the mean by point (average per point per visit) index for all analyses presented herein. For community indices we used a restricted list of species that excluded those that do not breed in the study area (Rufous Hummingbird, House Wren, Orange-crowned Warbler) or are not accurately censused using the point count method (e.g., raptors, waterfowl, grouse, nightjars, swallows, crows, ravens).

Species Richness

We define species richness as the total number of species detected within 50 meters of each point in a year divided by the number of visits to the site (two in all cases).

Diversity

We define species diversity as the mean number of species detected within 50 meters (species richness) weighted by the mean number of individuals of each species. A high diversity score indicates high ecological (species) diversity, or a more equal representation of the species. Species diversity was measured using a modification of the Shannon-Wiener index (Krebs 1989). We used a transformation of the usual Shannon-Weiner index (symbolized H′), which reflects species richness and equal distribution of the species. This transformed index, introduced by MacArthur (1965), is N_1, where $N_1 = 2^{H'}$. The advantage of N_1 over the original Shannon-Weiner metric (H′) is that N_1 is measured in terms of species instead of bits of information, and thus is more easily interpretable (Nur et al. 1999).

Abundance

The index of abundance is the mean number of individuals of all species detected per station per visit. This number is obtained by dividing the total number of detections within 50 meters by the number of visits.

Table 1. Extensive and DFPZ point count transects surveyed in the Plumas – Lassen Study in 2006.

Treatment Unit	Watershed	Code	Extensive Survey Points	DFPZ Survey Points	Owl Nest Stand Points
5	Grizzly Forebay	GRZ	41	0	2
5	Frazier Creek	FRC	45	0	4
5	China Gulch	CHG	36	0	0
5	Bear Gulch	BEG	41	0	5
5	Haskins Valley	HAV	38	0	2
5	Red Ridge	RED	31	5	0
5	**Unit Total**		**232**	**5**	**13**
4	Silver Lake	SIL	49	10	2
4	Meadow Valley Creek	MVY	47	3	2
4	Deanes Valley	DVY	36	4	4
4	Snake Lake	SNK	37	11	0
4	Miller Fork	MIL	39	25	4
4	Lower Knox Flat	LKF	36	0	2
4	Pineleaf Creek	PLC	31	12	0
4	**Unit Total**		**283**	**65**	**14**
3	Soda Creek	SOD	36	0	0
3	Rush Creek	RUS	50	5	12
3	Halsted Flat	HAL	36	0	0
3	Lower Spanish Creek	SPC	31	5	0
3	Black Hawk Creek	BLH	24	0	0
3	Indian Creek	IND	12	0	3
3	**Unit Total**		**189**	**0**	**15**
2	Mosquito Creek	MSQ	43	0	6
2	Butt Valley Reservoir	BVR	36	0	0
2	Ohio Creek	OHC	39	3	1
2	Seneca	SEN	57	5	8
2	Caribou	CAR	25	10	0
2	**Unit Total**		**200**	**18**	**15**
1	Upper Yellow Creek	UYC	24	22	7
1	Grizzly Creek	GCR	29	19	5
1	Butt Creek	BCR	24	13	3
1	Soldier Creek	SCR	0	12	0
1	**Unit Total**		**77**	**66**	**15**
	Grand Total		**959**	**145**	**72**

Spotted Owl Habitat Avian Community Analysis
Using the full set of point count locations – where treatment has not yet occurred – we compared the abundance of 25 avian species and several measures of avian community with three measures

of SPOW habitat. The three measures of SPOW habitat were: inside vs. outside of Core Areas (Core), inside of Protected Activity Centers (PACs) vs. outside of Core, and direct line distance from the nearest known owl nest. For the purposes of this analysis and discussion we define the Core as the 1000-acre protected area around the nest, which includes the 300-acre PAC and the additional 700 acre Core. We used existing digitized PAC, Core, and SPOW nests locations - provided by the Plumas and Lassen National Forest - in a GIS environment to delineate each of our point count locations as being inside or outside of PAC and/or Core and to calculate distance from nests (ESRI 2000). We only used known SPOW nest locations from 2002 – 2004 in the PLAS study area as documented by the Plumas Lassen SPOW admin study and the Lassen Demography Study.

Dependent variables included the twenty most abundant species in the study area (based on point count detections), five uncommon to rare species of special interest, species richness, Shannon-Weiner index of diversity, total bird abundance, and the total abundance of individuals within each of the three primary nesting guilds (tree, shrub, and cavity; see table 2). Ground nesting species were not included in the nesting guild analysis.

Table 2. The abundance of the twenty most abundant species (based on per point detections) and five species of special interest and their respective nesting location in the PLAS study area in 2005 and 2006 (mean per point per year across visits).

Species	Mean Abundance Per Point	Nesting Guild
Hermit Warbler	1.34	Tree
Oregon Junco	0.72	Ground
Nashville Warbler	0.62	Ground
Audubon's Warbler	0.61	Tree
Dusky Flycatcher	0.60	Shrub
Mountain Chickadee	0.57	Cavity
Golden-crowned Kinglet	0.55	Tree
Western Tanager	0.42	Tree
Fox Sparrow	0.29	Shrub
Red-breasted Nuthatch	0.29	Cavity
Brown Creeper	0.26	Cavity
Hammond's Flycatcher	0.25	Tree
Cassin's Vireo	0.19	Tree
Warbling Vireo	0.18	Tree
MacGillivray's Warbler	0.17	Shrub
Stellar's Jay	0.13	Tree
American Robin	0.11	Tree
Black-headed Grosbeak	0.10	Tree
Spotted Towhee	0.09	Shrub/Ground
Calliope Hummingbird	0.08	Shrub
Species of Special Interest		
Red-breasted Sapsucker	0.04	Cavity
Olive-sided Flycatcher	0.04	Tree
Western Wood - Pewee	0.03	Tree/Snag
Chipping Sparrow	0.03	Tree/Shrub
Pileated Woodpecker	0.01	Cavity

We used 2005 and 2006 raw point count detections from within 50 meters of the observer for analysis of both community indices and the 20 most abundant species. For the five species of management concern, we used detections within 100 meters to increase power to detect differences. Using detections within 100 meters increased mean per point abundances for each of these five species to 0.10 – approximately the same as the mean per point abundance of the least common of our 20 most abundant species.

We examined the relationship between each dependent variable with three measures of SPOW habitat using negative binomial regression (Stata Corp 2005). This procedure can be used to model count data when Poisson estimation is inappropriate due to overdispersion (Cameron and Trivedi 1998). Negative binomial regression was preferred over Poisson regression based on a Poisson Goodness of Fit test for all but one species, Pileated Woodpecker (Stata Corp. 2005).

We examined interactions with year by including a year term in each model and then comparing those to models with only the main effect using a Likelihood Ratio test (Stata Corp 2005). We found significant interactions with year for a number of species, however, in each case the relationship with the independent variable (measure of SPOW habitat) was significant in the same direction in both years with only the magnitude of the relationship (i.e. slope of the line) being different. Thus we felt it was appropriate to consider both years together. For community indices we used linear regression instead of negative binomial and then followed the same procedure listed above.

Comparing SPOW PAC and Core to outside of Core we generated a binomial response variable coded (1 for inside of PAC or Core and 0 for outside of PAC and Core). For the analysis of distance from known SPOW nest we used a transformed index of continuous distance from known nest – the natural log of the inverse distance [$\ln(1 \div \text{distance})$]. Since negative binomial regression log transforms dependent variables we log transformed distance from known nest to make them comparable scales. Graphs of all significant relationships are presented with mean per distance interval and best fit line. Probability statistics presented on graphs are those generated from negative binomial regression. In several cases we fit trends using second or third order polynomials as they better represented the apparent relationship with abundance and distance from nest for those species. Note that graphs show mean abundance per distance bin and that not all bins are of equal distance intervals. We assumed statistical significance at the 0.05 alpha level for all analyses though for PAC and Core analyses we presented the probability statistic for all values of alpha <0.15; all other values are represented as NS (non-significant).

Four Year Trend Analysis

We analyzed annual linear trends (annual rate of change) for the twenty most abundant species (based on point count detections) and the five species of special interest discussed above. We generated estimates of annual rate of change using the incident rate ratio option with negative binomial regression (Stata Corp. 2005). Statistical significance was assumed at an alpha level of 0.05. For all species showing a significant trend, graphs of estimated trend lines are presented. While several trends appear to deviate from linear (non-constant rate of change), with only four years of data, we did not attempt to fit higher order models for these species even if the data appeared to support one. Each graph also contains the mean abundance per year (summed across visits) with standard error bars.

RESULTS

Overview

We determined breeding bird species richness and abundance at all sites surveyed in 2006 (Table 3), and included indices for these same transects from all previous years they were surveyed (2002-2005). For the location of each transect we refer you to the supplemental GIS project available on compact disc from the authors. In 2006, total bird abundance ranged from 1.54 on the 422 transect to 6.46 on RED 2. Species richness ranged from 2.17 on the D409 transect to 8.83 on the RED 2 transect. Mean species richness and total bird abundance for all extensive transects combined in 2006 was 5.09 and 3.60, respectively. Overall total bird abundance and species richness across all years (2003 – 2006) was highly correlated (r^2= 0.76, p<0.001).

Table 3. Mean abundance and species richness for all point count transects surveyed by PRBO in the Plumas/Lassen area study, 2002-2006. NS stands for not surveyed. Locations of all transects can be obtained in the CD supplement.

Transect	Unit	Abundance					Richness				
Extensive		**2006**	**2005**	**2004**	**2003**	**2002**	**2006**	**2005**	**2004**	**2003**	**2002**
114	1	3.54	6.38	5.67	3.58	7.63	4.67	6.50	6.00	4.58	8.42
BCR1	1	3.63	4.54	2.41	NS	NS	5.33	6.33	3.73	NS	NS
UYC1	1	2.71	3.58	5.18	NS	NS	4.25	5.41	6.33	NS	NS
GCR1	1	3.67	5.00	2.75	NS	NS	5.67	5.83	4.17	NS	NS
GCR2	1	2.83	3.71	3.71	NS	NS	4.17	5.58	4.92	NS	NS
HSRF	1	2.92	6.00	3.88	NS	NS	4.67	8.16	5.75	NS	NS
Subtotal	**1**	**3.22**	**4.87**	**3.93**			**4.79**	**6.30**	**5.06**		
213	2	3.88	4.54	2.38	5.13	1.89	5.00	6.17	2.92	6.17	2.29
214	2	2.21	4.71	1.42	1.63	3.92	3.50	6.42	2.08	2.25	5.58
222	2	3.88	3.95	3.50	5.25	4.46	5.50	5.25	5.17	7.58	6.08
223	2	5.54	5.83	3.63	6.29	6.04	6.25	6.25	4.50	7.33	8.58
224	2	2.50	3.92	2.67	3.21	4.50	3.50	4.83	4.17	4.33	6.08
MSQ1	2	3.17	4.75	2.17	2.79	NS	4.83	5.58	3.16	4.08	NS
MSQ2	2	4.13	3.67	2.17	2.75	NS	4.92	4.50	3.33	3.50	NS
BVR1	2	4.67	4.83	4.08	5.17	NS	6.17	6.50	5.42	5.42	NS
BVR2	2	4.25	5.96	5.96	3.63	NS	6.25	7.33	7.17	5.33	NS
BVR3	2	2.71	4.92	3.54	4.67	NS	4.08	6.25	4.75	6.25	NS
OHC1	2	4.38	6.88	3.17	3.00	NS	5.92	7.67	4.00	4.33	NS
OHC2	2	2.38	4.13	1.64	4.08	NS	4.08	6.33	2.55	5.58	NS
SEN1	2	2.92	2.88	2.25	3.00	NS	3.92	4.08	3.75	4.08	NS
CAR1	2	3.46	5.75	4.17	3.42	NS	4.08	6.50	5.67	4.42	NS
CAR2	2	3.54	5.54	3.63	2.50	NS	5.17	7.00	5.33	3.83	NS
CAR3	2	1.88	4.17	1.91	NS	NS	2.58	4.50	2.82	NS	NS
Subtotal	**2**	**3.47**	**4.78**	**3.02**	**3.77**		**4.73**	**5.95**	**4.17**	**4.97**	
313	3	5.75	5.50	6.08	7.58	3.67	8.42	7.50	8.25	10.00	5.08
314	3	2.67	5.17	3.88	4.42	4.08	4.00	6.50	5.50	6.42	3.75
322	3	4.83	5.25	5.58	3.38	4.63	6.58	7.67	7.00	5.17	6.58
323	3	2.79	3.92	2.46	2.79	5.33	4.08	5.67	4.00	4.67	7.92
324	3	3.29	5.21	4.63	3.83	4.54	4.92	6.00	5.25	5.17	6.83
BLH1	3	3.00	3.92	2.09	2.42	NS	3.42	5.08	3.36	3.25	NS
BLH2	3	2.25	2.71	3.55	NS	NS	3.58	4.00	4.73	NS	NS

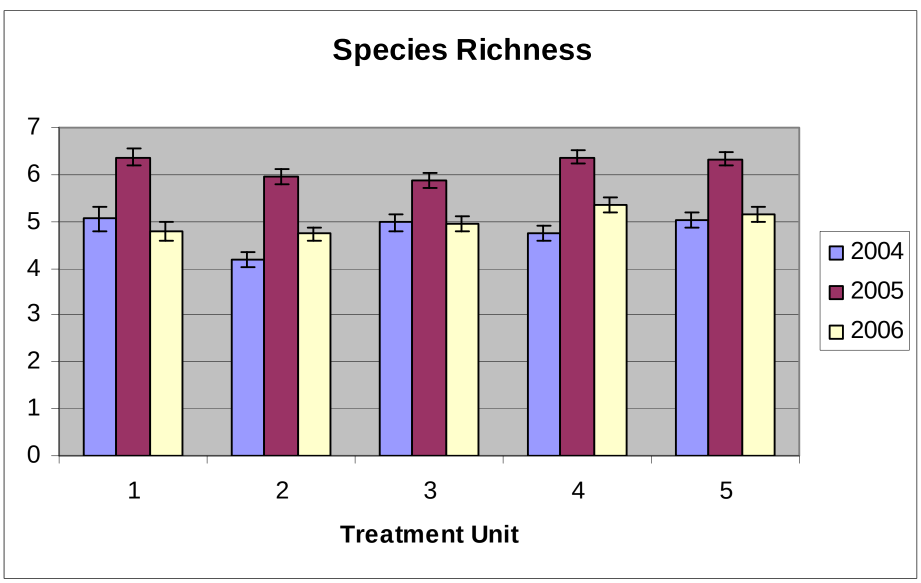
HAL1	3	3.67	4.08	2.50	3.46	NS	5.67	5.83	3.92	5.58	NS
HAL2	3	5.00	4.50	3.00	3.92	NS	5.58	5.08	3.58	5.17	NS
HAL3	3	2.96	7.33	3.25	6.96	NS	4.83	8.17	4.67	7.67	NS
IND1	3	2.29	4.96	2.83	4.13	NS	3.83	6.83	4.50	5.50	NS
RUS1	3	4.00	5.04	5.79	5.83	NS	5.75	6.42	6.92	7.75	NS
SOD1	3	2.63	3.67	3.92	NS	NS	4.25	4.83	5.75	NS	NS
SOD2	3	5.17	4.04	2.75	NS	NS	6.67	6.58	4.17	NS	NS
SOD3	3	2.42	1.38	0.63	NS	NS	3.83	2.16	1.17	NS	NS
SPC1	3	3.42	3.79	3.13	3.29	NS	4.58	5.08	4.33	4.75	NS
SPC2	3	3.33	5.04	2.21	4.25	NS	4.25	6.00	3.50	5.75	NS
Subtotal	**3**	**3.50**	**4.47**	**3.43**	**4.33**		**4.96**	**5.88**	**4.74**	**5.91**	
413	4	5.21	5.29	4.83	2.83	5.83	7.17	6.83	6.33	2.58	7.83
414	4	6.13	4.42	4.75	4.38	6.79	7.17	6.25	6.08	6.50	8.58
422	4	1.54	5.36	3.71	4.54	4.29	2.50	6.42	4.58	5.42	5.92
423	4	4.88	5.04	3.58	3.29	4.58	6.33	5.92	4.92	4.50	6.75
424	4	4.96	4.25	3.54	5.46	5.75	6.75	5.75	5.33	7.42	8.00
MIF1	4	4.17	5.79	3.29	4.00	NS	6.08	6.75	4.25	5.50	NS
MIF2	4	6.25	5.50	3.00	5.67	NS	8.67	7.50	4.25	7.42	NS
MIF3	4	4.33	7.21	3.54	5.21	NS	5.42	7.25	4.50	6.17	NS
D404	4	4.21	5.00	3.35	6.50	4.96	5.67	6.25	5.00	8.33	7.08
D405	4	4.21	4.67	3.35	4.79	4.46	6.17	6.50	4.90	7.00	6.50
LKF1	4	4.54	5.04	2.96	NS	NS	6.50	6.58	3.42	NS	NS
LKF2	4	1.67	3.42	3.83	NS	NS	2.75	4.50	4.92	NS	NS
LKF3	4	3.25	4.21	5.13	NS	NS	5.00	5.58	6.75	NS	NS
MVY1	4	3.13	6.08	3.29	4.75	NS	4.50	7.42	4.33	6.92	NS
MVY2	4	4.00	5.92	3.79	5.58	NS	5.83	6.83	5.17	7.08	NS
PLC1	4	3.21	5.46	3.71	NS	NS	4.83	7.25	5.67	NS	NS
SIL1	4	5.79	6.96	3.08	5.17	NS	7.50	8.00	4.42	6.67	NS
SIL2	4	2.92	6.04	6.83	5.13	NS	3.75	7.17	7.08	7.17	NS
SIL3	4	2.00	3.25	2.46	2.29	NS	2.75	4.25	3.17	3.75	NS
SNK1	4	4.25	5.04	2.38	4.25	NS	4.92	6.58	3.75	5.50	NS
SNK2	4	3.04	4.08	2.33	4.54	NS	4.58	5.17	3.33	6.33	NS
SNK3	4	2.63	5.25	1.71	NS	NS	4.08	6.17	2.67	NS	NS
Subtotal	**4**	**3.92**	**5.15**	**3.57**	**4.61**		**5.41**	**6.41**	**4.77**	**6.13**	
513	5	3.63	4.79	6.79	3.00	5.38	4.25	6.58	7.67	4.33	6.92
514	5	3.71	4.38	4.08	5.75	2.46	5.58	6.58	5.58	5.17	4.25
522	5	2.29	5.25	3.17	5.63	5.50	3.50	6.00	4.42	7.25	7.67
523	5	2.29	5.50	2.42	3.33	3.54	3.92	7.00	4.00	5.75	5.25
524	5	3.75	5.17	3.04	2.79	4.42	5.58	6.33	4.92	4.08	6.42
BEG1	5	2.04	4.21	1.96	3.42	NS	3.17	5.75	3.25	4.42	NS
CHG1	5	4.00	3.58	2.46	3.46	NS	6.08	4.92	3.58	5.08	NS
CHG2	5	4.38	4.88	3.17	6.67	NS	6.08	6.08	4.33	8.25	NS
CHG3	5	2.58	4.38	5.79	3.54	NS	4.00	6.00	7.25	5.17	NS
FRC1	5	4.00	4.88	2.96	5.25	NS	6.25	6.50	4.67	7.08	NS
GRZ1	5	2.33	3.29	2.58	3.92	NS	3.50	4.25	3.50	4.92	NS
GRZ2	5	3.88	4.25	3.96	3.58	NS	5.33	5.75	5.75	5.67	NS
GRZ3	5	3.21	6.96	3.38	4.71	NS	4.83	6.00	5.08	7.08	NS
RED1	5	3.50	4.96	4.42	4.75	NS	5.00	6.83	5.67	5.92	NS
RED2	5	6.46	5.58	3.38	3.00	NS	8.83	7.50	4.92	5.08	NS
RED3	5	4.17	4.71	3.92	4.13	NS	6.75	7.00	5.83	6.25	NS

D501	5	4.96	5.50	2.35	4.21	NS	7.08	6.67	3.40	5.75	NS
HAV1	5	2.96	5.17	3.42	5.75	NS	5.00	7.00	4.92	7.67	NS
HAV2	5	3.38	4.33	3.42	4.92	NS	4.92	6.92	5.08	7.25	NS
Subtotal	**5**	**3.55**	**4.83**	**3.51**	**4.31**		**5.24**	**6.30**	**4.94**	**5.90**	
Extensive Total		**3.60**	**4.83**	**3.50**	**4.25**		**5.09**	**6.17**	**4.77**	**5.73**	
DFPZ											
D102	1	3.29	5.08	2.42	3.54	5.29	4.92	6.42	2.75	5.00	5.92
D107	1	5.63	5.83	3.63	3.50	4.25	7.25	6.92	5.50	5.25	6.17
D108	1	2.67	5.25	6.09	NS	5.89	4.42	6.83	7.25	NS	4.67
D110	1	4.63	4.63	2.79	NS	NS	7.00	6.25	4.08	NS	NS
D111	1	4.29	4.88	3.42	NS	NS	5.75	6.58	5.33	NS	NS
D112	1	3.92	4.58	5.46	NS	NS	4.50	5.67	7.08	NS	NS
Subtotal	**1**	**4.07**	**5.04**	**3.97**	**3.52**	**5.14**	**5.64**	**6.45**	**5.33**	**5.13**	**5.59**
D401	4	4.58	6.04	2.30	4.21	6.79	6.58	7.67	3.33	5.00	8.75
D402	4	4.63	4.26	3.05	4.13	4.71	7.08	5.83	4.50	5.58	6.75
D403	4	5.13	4.21	1.85	3.79	3.71	7.25	5.75	2.45	5.58	5.42
D407	4	4.25	6.04	3.00	3.46	4.42	6.58	7.75	4.83	5.33	6.33
D408	4	3.63	4.67	3.70	5.88	4.50	5.42	6.08	5.08	7.58	6.75
D409	4	1.79	3.38	2.00	1.92	NS	2.17	4.42	2.73	3.00	NS
DFPZ	**4**	**4.00**	**4.77**	**2.65**	**3.90**	**4.83**	**5.85**	**6.25**	**3.82**	**5.35**	**6.80**

Species Richness by Treatment Unit

We compared species richness between treatment units and years (Figure 1). In 2006 richness ranged from 4.73 species detected per point in Unit Two to 5.35 in Unit Four.

Figure 1. Avian species richness (mean per point per visit) by treatment unit in 2004 – 2006 in the Plumas Lassen Study Area (± standard error).



All five units showed a significant decrease ($p<0.05$) in mean richness between 2005 and 2006. However, richness was not significantly lower in any unit in 2006 compared to 2004, though it was significantly higher in Unit Two. Richness declined 25% in Unit One between 2005 and 2006; the largest decline of any of the five units.

Four Year Trends in Species Abundance

Of the 25 species for which we analyzed linear trends in abundance from 2003 to 2006, 14 had a decreasing trend while 11 were increasing (Table 4). Six of the 14 decreasing trends and three of the 11 increasing trends were statistically significant ($p<0.05$). Three additional species, two positive and one negative, had trends significant at the alpha = 0.10 level. Species with significant negative trends ($p<0.05$) from 2003 – 2006 were: Hammond's Flycatcher, Mountain Chickadee, Red-breasted Nuthatch, Audubon's Yellow-rumped Warbler, Spotted Towhee, and Fox Sparrow. Species with significant increasing trends were: Dusky Flycatcher, Golden-crowned Kinglet, Brown Creeper, and Hermit Warbler.

Table 4. Estimated annual linear trends in abundance for the twenty five species in the Plumas Lassen Study area from 2002 – 2006. Species are listed in taxonomic order (AOU 2006).

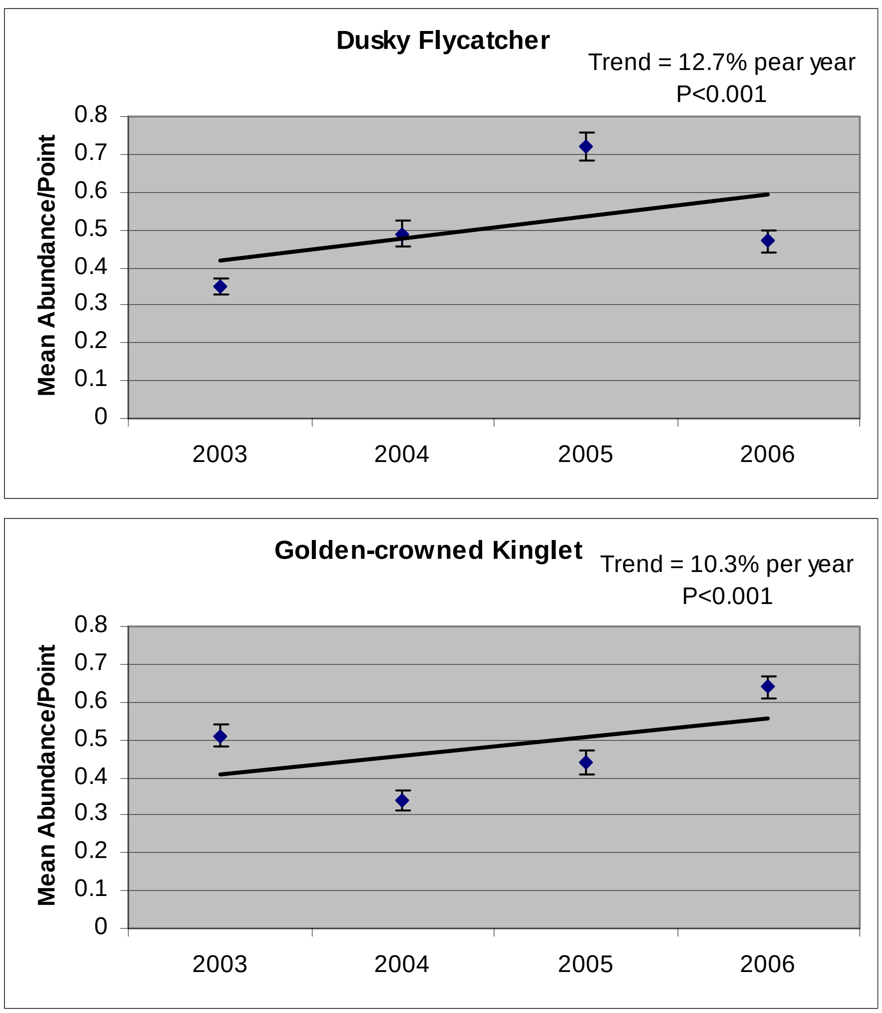
		95% Confidence Interval	
Species	**Trend (%)**	**Low**	**High**
Hairy Woodpecker	-10.1	-22.8	4.7
Red-breasted Sapsucker	-6.6	-20.6	9.8
Pileated Woodpecker	-26.2+	-45.9	0.8
Hammond's Flycatcher	-19.4***	-25.8	-12.5
Dusky Flycatcher	12.7***	6.2	19.6
Western Wood-Pewee	10.8	-9.7	35.9
Olive-sided Flycatcher	-8.8	-23.7	8.9
Cassin's Vireo	2.6	-5.2	11.0
Warbling Vireo	2.4	-7.2	13.1
Steller's Jay	0.2	-10.1	11.7
Mountain Chickadee	-9.2***	-14.0	-4.1
Red-breasted Nuthatch	-19.9***	-25.1	-14.3
Brown Creeper	6.4+	-0.6	13.9
Golden-crowned Kinglet	10.3***	5.6	16.3
American Robin	-1.1	-10.1	10.0
Nashville Warbler	4.2	-1.4	10.0
Audubon's Warbler	-7.4***	-11.6	-3.1
Hermit Warbler	11.7***	6.5	15.0
MacGillivray's Warbler	-4.4	-11.9	7.7
Western Tanager	-0.6	-6.0	5.2
Spotted Towhee	-14.0*	-23.8	-2.9
Chipping Sparrow	27.8+	-4.06	70.0
Fox Sparrow	-10.5**	-17.7	-2.8
Oregon Junco	2.7	-1.8	7.4
Black-headed Grosbeak	-4.2	-14.7	7.5

***** = p<0.05, ** = p<0.01, *** = p<0.001, + = p<0.1

Of the five species of special interest included here, two showed an increasing trend (Chipping Sparrow, Western Wood-Pewee) and three a decreasing trend (Pileated Woodpecker, Red-breasted Sapsucker, and Olive-sided Flycatcher).

Annual rate of change (% per year) ranged from -26.2% for Pileated Woodpecker to +27.8% for Chipping Sparrow; due to low sample sizes – for both these species – their trends were only significant at the alpha = 0.10 level. For species with significant trends, it ranged from a -19.9% decline for Red-breasted Nuthatch, to 11.8% increase for Hermit Warbler (Table 4 and Figures 2 & 3). Abundance of all decreasing species was lower in 2006 than any of the previous three years; for several species - Hammond's Flycatcher, Red-breasted Nuthatch, and Mountain Chickadee - 2006 was solely responsible for the decreasing population trend (Figure 3).

Figure 2. Linear trends for species with significant (p< 0.05) population increases in the PLAS study area from 2003 – 2006.



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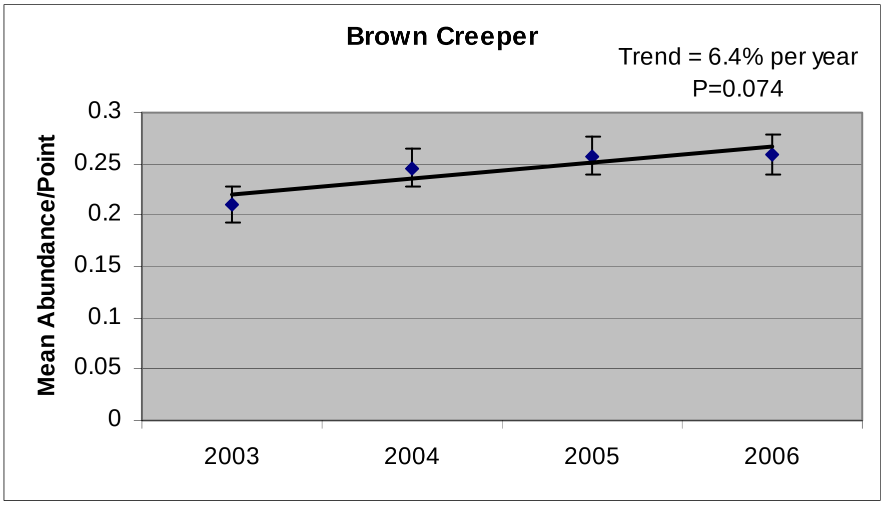


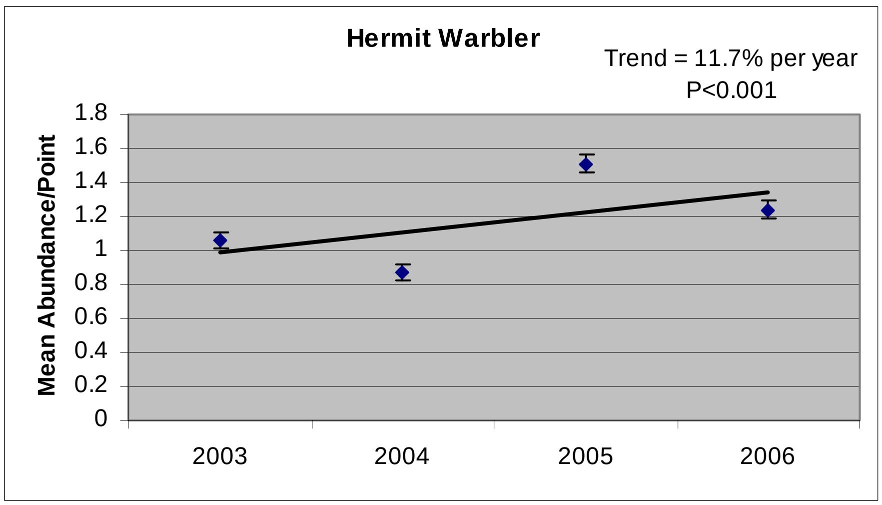
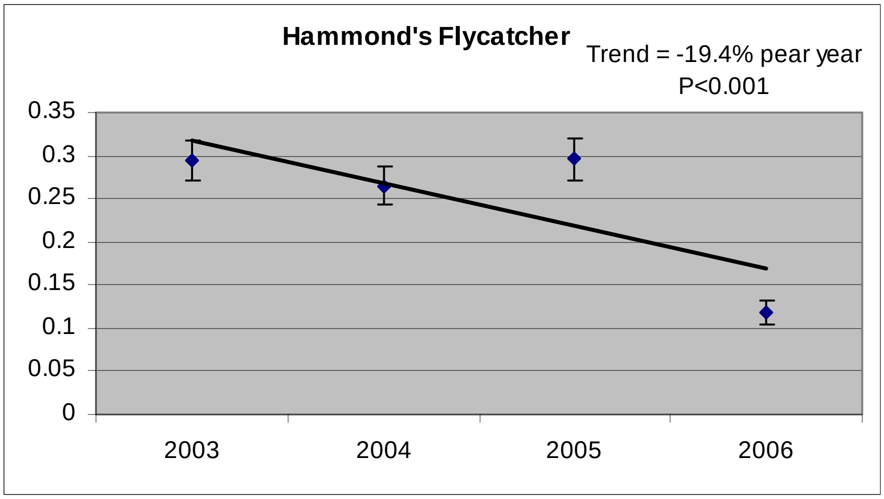
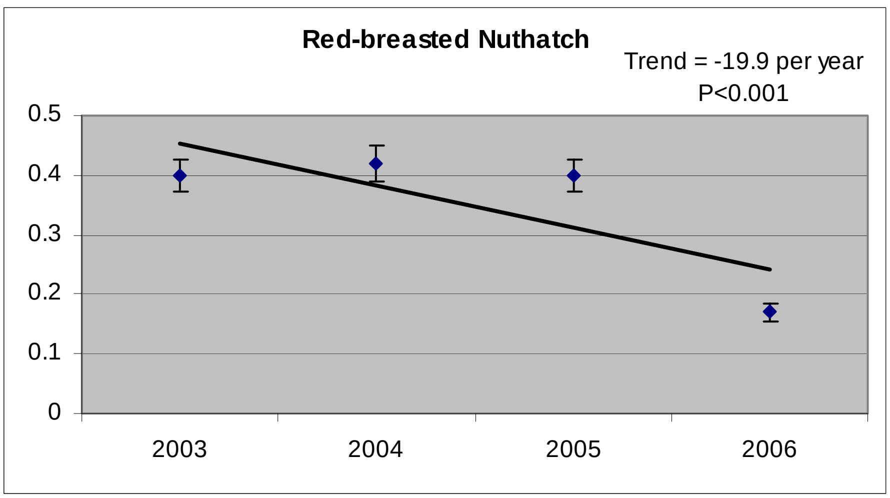


Figure 3. Linear trends of species showing significant (p< 0.05) population declines in the PLAS study area from 2003 – 2006.





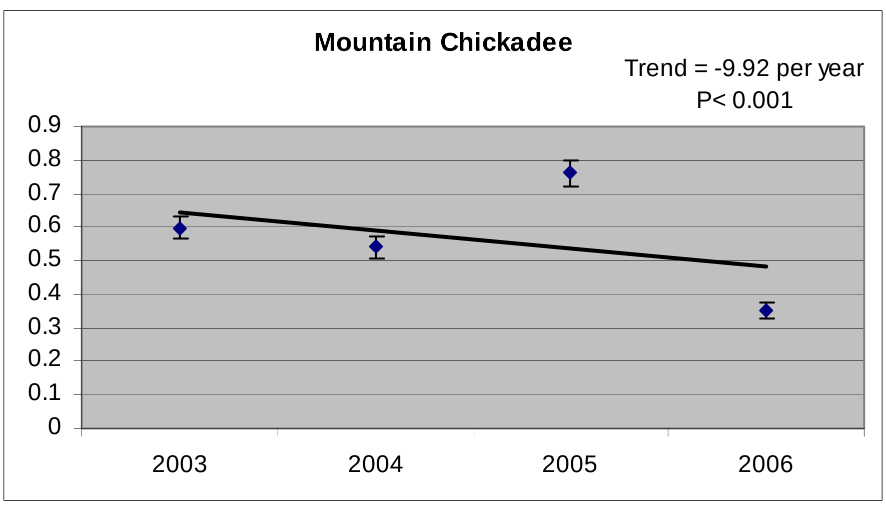
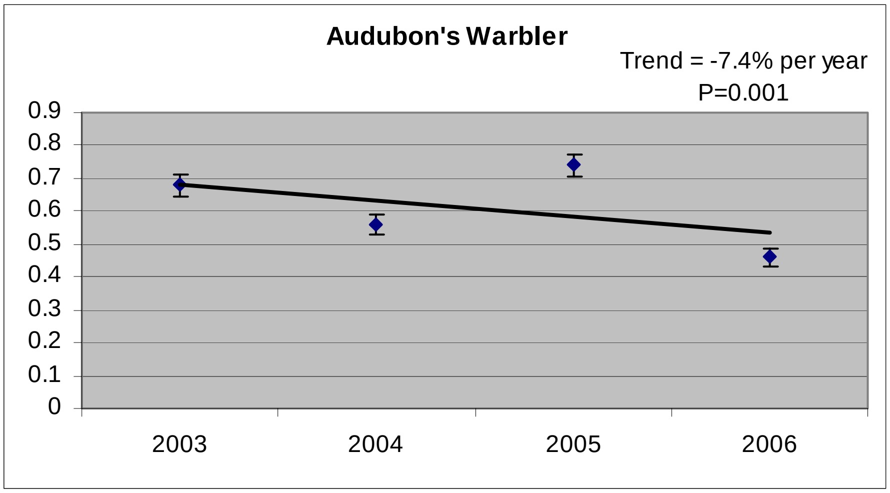
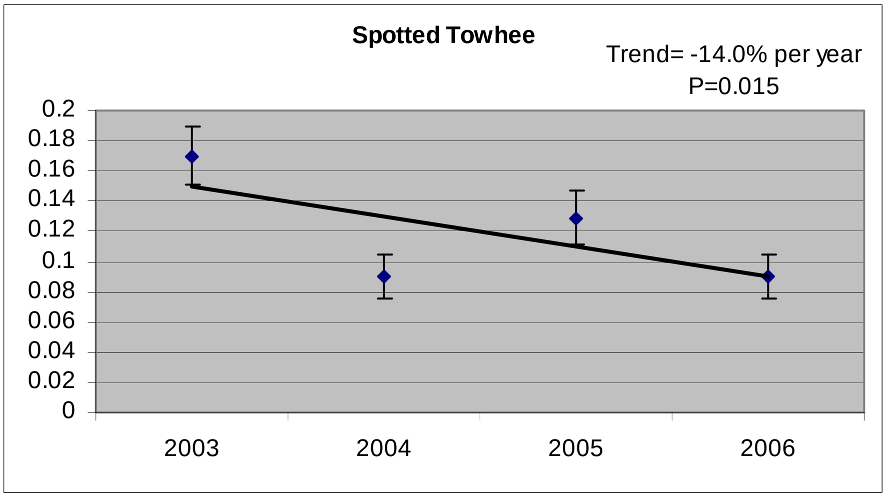
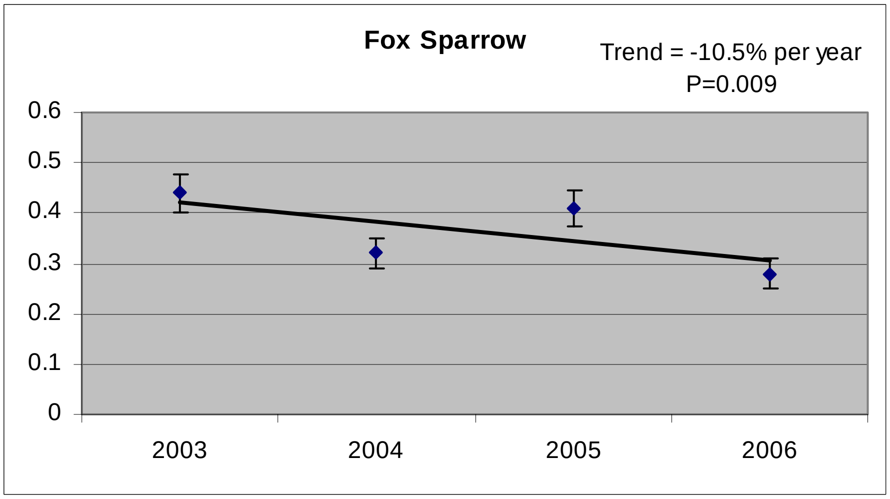


Figure 3 continued.







Avian Community Composition in Relation to Spotted Owl Habitat

Overview

19 of the 25 species and all six community indices analyzed showed a statistically significant relationship with at least one measure of SPOW habitat. Thirteen species had a negative association while six were positive. Five species were negative with all three measures, while two were positive with all three. All six community indices were significantly different with at least one measure of SPOW habitat, five negative and one positive.

Community Indices

Avian species richness, Shannon-Wiener index of diversity, and total bird abundance were all significantly higher outside of SPOW Core (see definition of Core in methods). Comparing the abundance of birds in each of three nesting guilds, the abundance of members of the tree nesting guild were significantly higher inside of Core while both shrub and cavity nesters were significantly more abundant outside (Table 5).

Comparing outside of Core to inside of PAC, species richness, diversity, total bird abundance, and abundance of cavity nesters were similar (ratios $\leq$ 1.04) with no statistically significant differences. Shrub nesters were still significantly more abundant outside of Core than inside PAC and tree nesters were still significantly more abundant inside of PAC, with ratios of 2.07 and 1.30 respectively.

Table 5. Six avian community indices in relation to Spotted Owl Core Areas in the PLAS study area in 2005 and 2006.

Index	Outside Core	Inside Core	Ratio	P
Species Richness	5.85	5.47	1.07	<0.001
Shannon Index of Diversity	5.36	4.99	1.07	<0.001
Total Bird Abundance	8.70	8.20	1.06	0.001
Shrub Nesters	1.79	0.86	2.08	<0.001
Cavity Nesters	1.37	1.24	1.10	0.026
Tree Nesters	3.90	4.63	0.84	<0.001

Species Abundance related to Pac and Core

Nine species were significantly more abundant outside of Core Areas than inside Core Areas (Table 6). Eight of these nine species showed the same relationship when comparing outside Core to inside PAC only (Table 7). Six species were significantly more abundant inside of Core; these same six species were also significantly more abundant inside of PAC. The highest ratios (abundance outside:inside) for species negatively associated with Core were: Fox Sparrow (4.18), Calliope Hummingbird (2.80), and Spotted Towhee (2.76). The highest ratios for species positively associated with Core (inside:outside) were: Hammond's Flycatcher (1.69), Hermit Warbler (1.64), Brown Creeper, and Pileated Woodpecker (both 1.59). Of the five species of special interest, three (Olive-sided Flycatcher, Western Wood-Pewee, and Chipping Sparrow) were negatively associated with Core, while Pileated Woodpecker was the only one with a positive association. The fifth species, Red-breasted Sapsucker, was equally abundant inside and outside of Core.

Table 6. The mean abundance per point per year of 25 avian species inside and outside of 1000 acre Spotted Owl Core Areas in the PLAS study area in 2005 & 2006. Ratios are the higher abundance divided by the lower abundance.

More Abundant Outside	Outside Core	Inside Core	Ratio	P
Fox Sparrow	0.460	0.110	4.18	<0.001
Calliope Hummingbird	0.112	0.040	2.80	<0.001
Spotted Towhee	0.127	0.046	2.76	<0.001
Olive-sided Flycatcher	0.208	0.103	2.02	<0.001
Dusky Flycatcher	0.769	0.411	1.87	0.001
Western Wood-Pewee	0.137	0.079	1.73	<0.001
MacGillivray's Warbler	0.202	0.130	1.55	<0.001
Mountain Chickadee	0.671	0.452	1.48	<0.001
Chipping Sparrow	0.099	0.074	1.34	0.076
Western Tanager	0.456	0.388	1.18	0.014
American Robin	0.118	0.105	1.12	NS
Audubon's Warbler	0.638	0.577	1.11	0.080
Steller's Jay	0.137	0.123	1.11	NS
Nashville Warbler	0.639	0.595	1.07	NS
Red-breasted Sapsucker	0.100	0.090	1.11	NS
Oregon Junco	0.740	0.695	1.06	NS
Red-breasted Nuthatch	0.294	0.289	1.02	NS
More Abundant Inside				
Pileated Woodpecker	0.022	0.035	1.59	0.023
Hammond's Flycatcher	0.185	0.313	1.69	<0.001
Hermit Warbler	1.028	1.682	1.64	<0.001
Brown Creeper	0.202	0.322	1.59	<0.001
Golden-crowned Kinglet	0.473	0.626	1.32	<0.001
Cassin's Vireo	0.177	0.214	1.21	0.002
Black-headed Grosbeak	0.091	0.110	1.21	NS
Warbling Vireo	0.172	0.179	1.04	NS

The analysis examining the differences between inside PAC vs. outside Core produced similar results to the inside versus outside of Core. For almost all species the difference in abundance was greater when we limited the measure of owl habitat to just the PAC. For example, Fox Sparrow went from 4.18 to 5.06 times more abundant outside while Pileated Woodpecker went from 1.59 to 2.17 times more abundant inside.

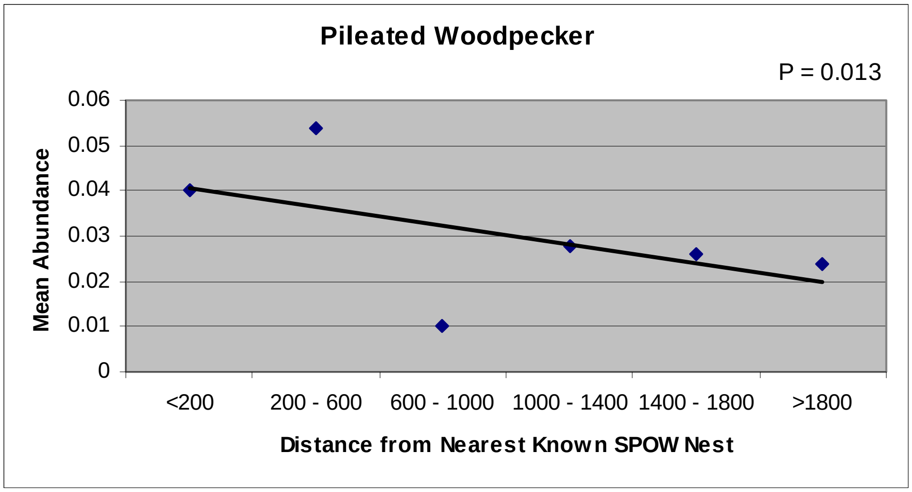
Table 7. The mean abundance per point per year of 25 avian species inside of 300 acre Spotted Owl Protected Activity Centers vs. outside of 1000 acre Core Areas in the PLAS study area in 2005 & 2006. Ratios are the higher abundance divided by the lower abundance.

More Abundant Outside	Outside Core	Inside Pac	Ratio	P
Fox Sparrow	0.460	0.091	5.06	<0.001
Spotted Towhee	0.127	0.030	4.23	<0.001
Calliope Hummingbird	0.112	0.048	2.33	0.001
Western Wood-Pewee	0.137	0.063	2.18	<0.001
Olive-sided Flycatcher	0.208	0.123	1.69	<0.001
Dusky Flycatcher	0.769	0.461	1.67	<0.001
American Robin	0.118	0.078	1.51	0.045
MacGillivray's Warbler	0.202	0.136	1.49	0.012
Mountain Chickadee	0.671	0.452	1.49	<0.001
Chipping Sparrow	0.099	0.067	1.48	0.117
Steller's Jay	0.137	0.102	1.34	0.130
Western Tanager	0.456	0.407	1.12	NS
Oregon Junco	0.740	0.669	1.11	NS
Nashville Warbler	0.639	0.597	1.07	NS
Audubon's Warbler	0.638	0.610	1.05	NS
Red-breasted Nuthatch	0.289	0.289	1.00	NS
More abundant inside				
Pileated Woodpecker	0.018	0.039	2.17	0.016
Hammond's Flycatcher	0.185	0.346	1.87	<0.001
Hermit Warbler	1.028	1.910	1.86	<0.001
Brown Creeper	0.202	0.396	1.96	<0.001
Golden-crowned Kinglet	0.473	0.688	1.46	<0.001
Cassin's Vireo	0.177	0.260	1.47	<0.001
Black-headed Grosbeak	0.091	0.123	1.35	NS
Warbling Vireo	0.172	0.199	1.16	NS
Red-breasted Sapsucker	0.100	0.106	1.06	NS

Distance from Known Spotted Owl Nests

Fewer species were significantly associated with distance from known SPOW nests than with either of the two measures of SPOW habitat discussed above (Figures 4 & 5). Two species, Pileated Woodpecker and Hermit Warbler, increased in abundance as you approached the nearest nest site, while the abundance of eight species significantly decreased. For four species – Olive-sided Flycatcher, Western Wood-Pewee, Chipping Sparrow, and Fox Sparrow – the relationship with distance appeared to be driven by a large increase in abundance beyond 1800 meters from nests (Figure 5). For all other species a linear relationship appeared to accurately portray the relationship.

Figure 4. Mean abundance per point count station across five distance intervals from SPOW nests, and fitted line of predicted values for species whose abundance significantly increases (p<0.05) as you approach SPOW nest sites in the PLAS study area in 2005 & 2006.



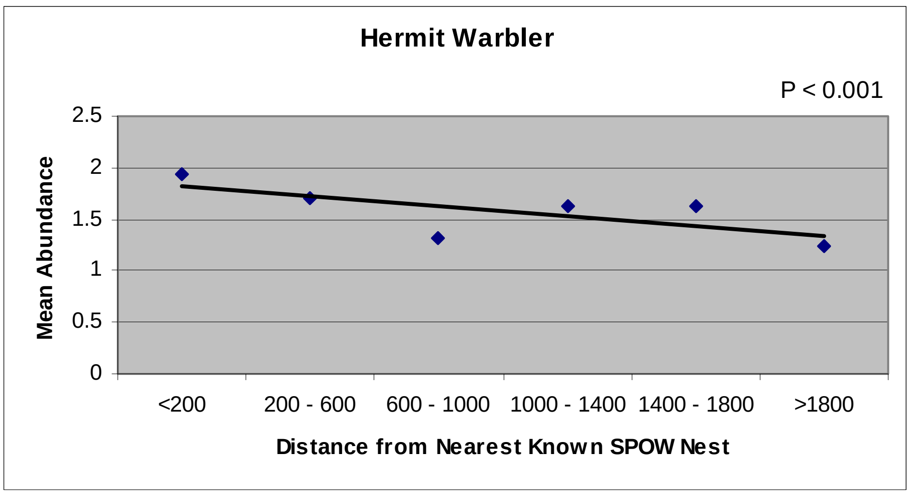
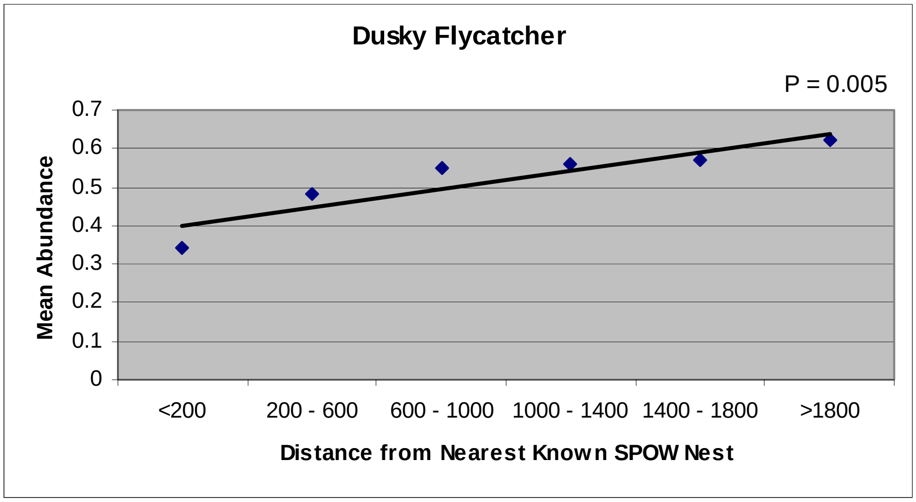
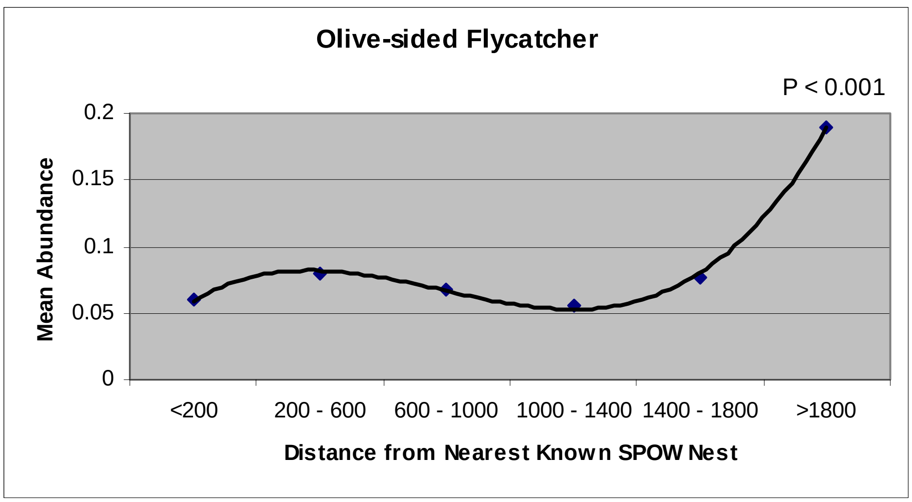
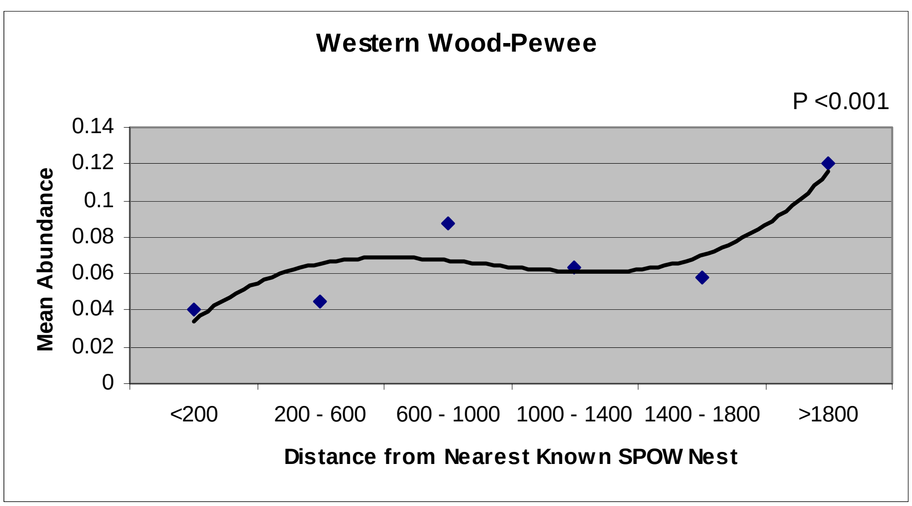


Figure 5. Mean abundance per point count station across five distance intervals, from SPOW nests, and fitted line of predicted values for species whose abundance significantly increases (p<0.05) as you move away from SPOW nest sites in the PLAS study area in 2005 & 2006.







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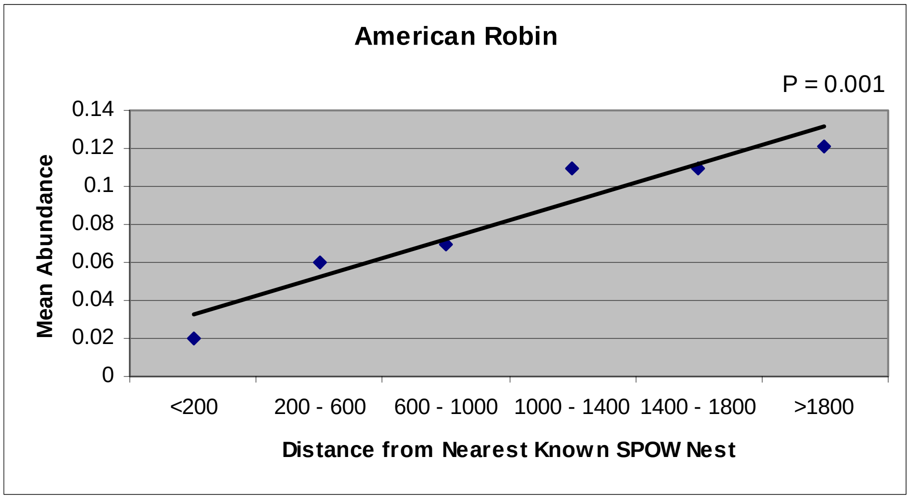

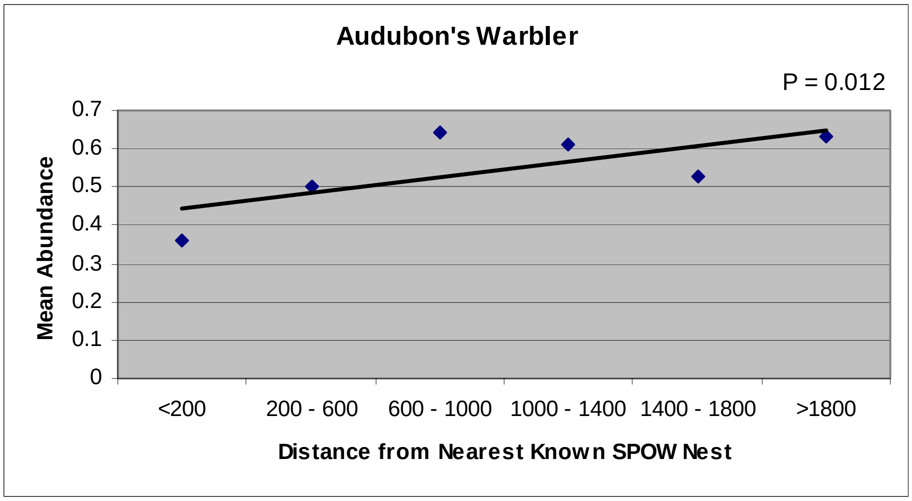

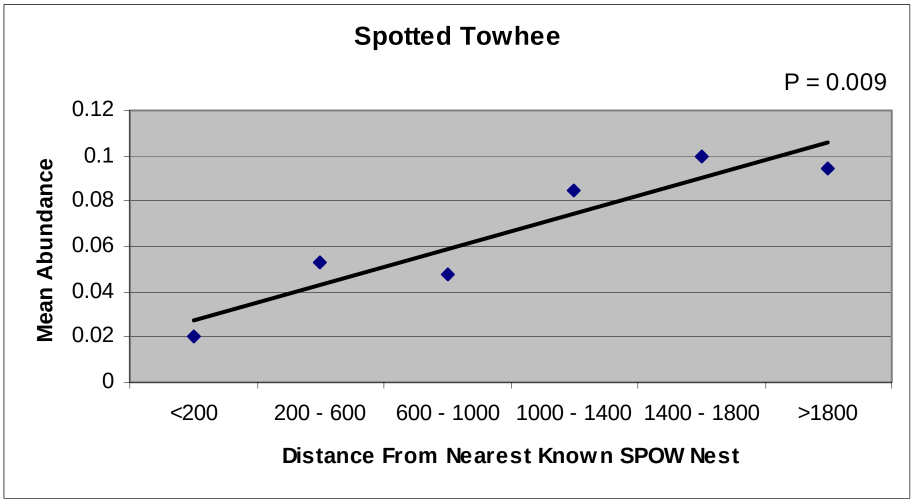

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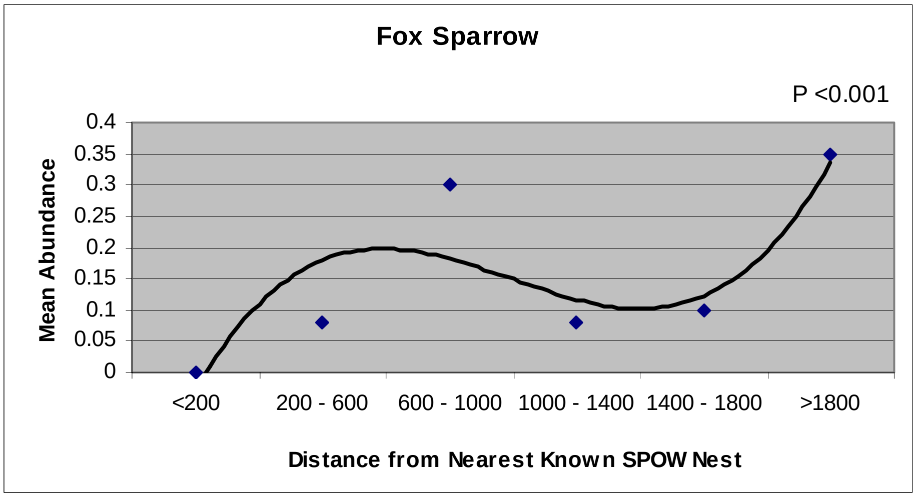
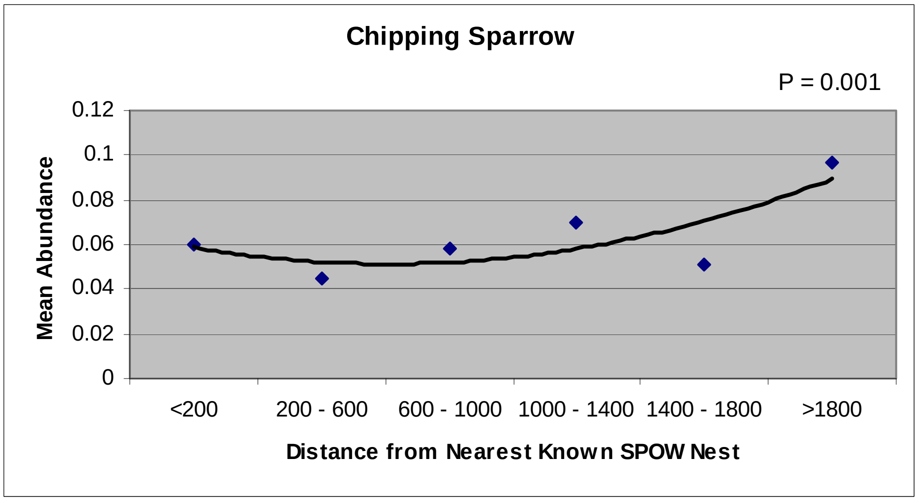
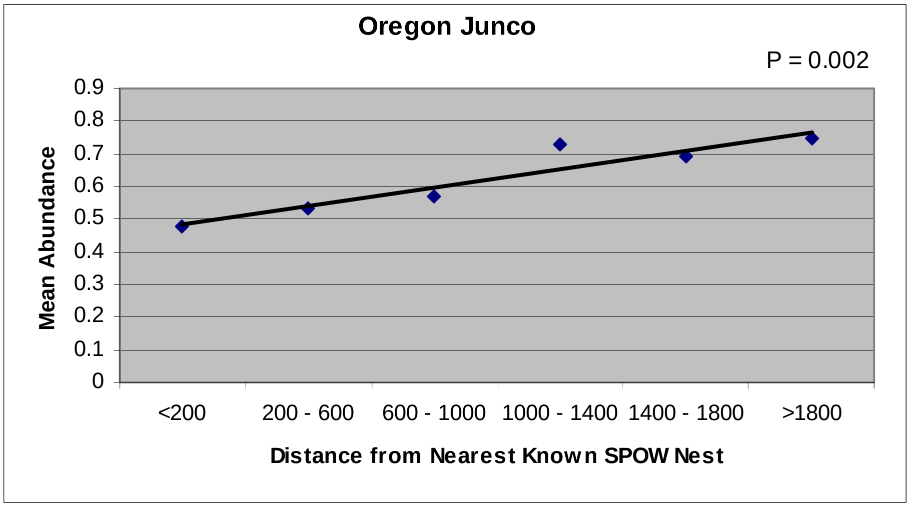


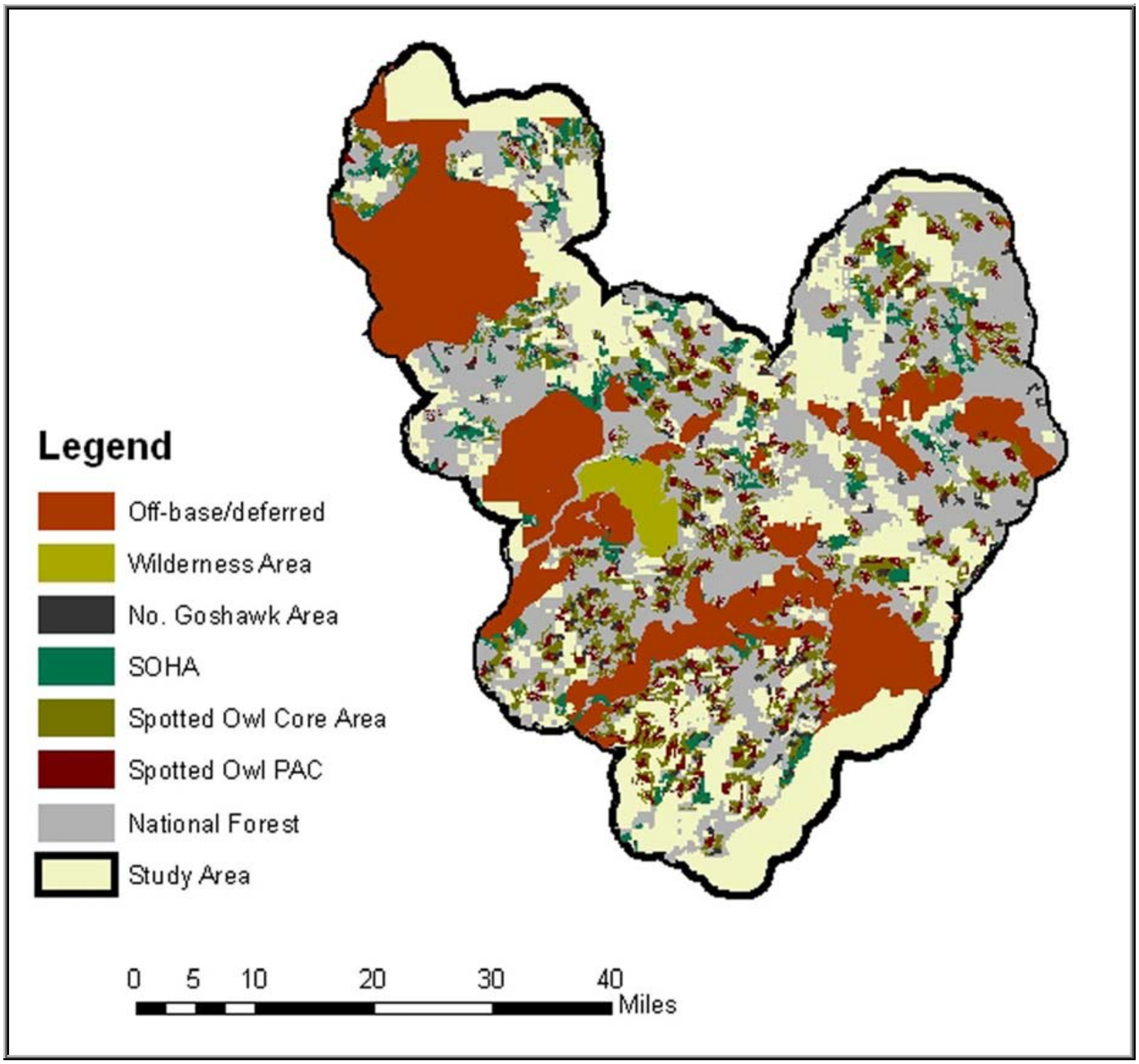




Management Land Allocations in the PLAS Study Area

In order to understand the significance of the analysis of avian species composition associated with SPOW habitat we investigated land allocations in the PLAS study area. We identified six separate allocations that have restrictions on timber harvest, fuel reductions, and other significant forest management activities that would result in canopy reductions or change towards younger seral stages (Figure 6).

Figure 6. Land allocations with restrictions on timber harvest activities on National Forest lands in the PLAS study area as of 2005.



Eleven and a half percent of the National Forest land in the PLAS study area is currently designated as SPOW PACs, with an additional 19.95% in Core Areas, and 9.62% in Spotted Owl Habitat Areas. In the HFQLG project area the 700 additional acres of Core surrounding the PAC is no longer a recognized allocation (though few Core Areas have been treated under this direction). However, unlike the rest of the Sierra Nevada Spotted Owl Habitat areas are recognized here (HFQLG FEIS 1999). Additional land allocations with restricted activities include: Northern Goshawk PACs – 3.07%; Wilderness Areas – 2.31%; and the HFQLG recognized Off-base and Deferred that encompass 28.42% of the landscape (HFQLG FEIS 1999). Accounting for non-duplication where these designations overlap, a total of 56.62% of the National Forest land in the study area is set aside in these restricted areas. If Core Areas are subtracted from this total (since the HFQLG does not recognize them), the total is 44.13% of the total study area (Table 8).

Table 8. Total acres and percent of National Forest lands in each of six conservation land allocations in the PLAS study area as of 2005.

Land Allocation	Acres of USFS Land in Study Area	% of total USFS Land in Study Area
Spotted Owl PAC	117,966	11.49
Spotted Owl Core	204,939	19.95
Spotted Owl Habitat Areas	98,812	9.62
Northern Goshawk PAC	31,481	3.07
Wilderness	23,738	2.31
Off-base/Deferred	291,884	28.42
Total - overlap	581,459	56.62
Total - Core	453,185	44.13

GIS Project for Creating Species Maps

We updated the interactive GIS project incorporating all bird data collected from 2003-2006 (CD Supplement A). This tool can be used by land managers to generate distribution maps for all species breeding within the PLAS study area (see Appendices 9 and 10 for examples). In addition the project can be queried to produce avian species richness, total bird abundance, and the abundance of any species by point. These data are then presented on a map with relevant habitat and treatment layers. Appendix 11 outlines directions for creating additional maps for any species of interest or for bird community indices, and describes all aspects of this GIS project and associated database tables. In future years we will continue to update this project to incorporate the most current and relevant information on the distribution and abundance of birds in the study area. If you do not have a copy of the GIS project CD and would like one please contact the author at rburnett@prbo.org.

DISCUSSION

Species Richness and Total Bird Abundance

Total bird abundance is highly correlated with species richness in our study area, thus in years with fewer total birds; species richness is likely to decline as well. It may be that in years with ample resources, or following a highly productive year, species will occupy sub-optimal habitat. In years with scarcer resources, or following a poor reproductive year it is likely only the highest quality sites are occupied. Thus, statistically significant annual fluctuations in species richness and total bird abundance across the entire study area are likely a result of population fluctuations not directly tied to changes in available habitat between years. However, it is critical to identify the key habitat features for each species that are instrumental in a site providing high quality habitat. Using a suite of avian species as management indicators, we can develop habitat models to determine the most important habitat features, monitoring their population trends over time, and determine their response to treatments. With this information one can then understand what species – or, more importantly, what habitat types and features – are underrepresented and then modify direction to ensure a balanced approach to future forest management.

Avian Community Composition in Relation to Spotted Owl Habitat
In the Sierra Nevada, considerable attention – and now management direction – is being influenced by the California SPOW (e.g., HFQLG FEIS 1999, SNFPA 2001). With this management direction the need exists to understand how these changes in forest management will impact the rest of the avian community. Understanding the composition and abundance of the avian community inside and outside of the key management areas for SPOW in the Sierra Nevada may allow managers to take a proactive ecosystem based approach to future management direction.

The California SPOW is a habitat specialist in the Sierra Nevada (Gutierrez et al. 1992). Due to these specific habitat requirements, it appears to be a poor candidate as an umbrella species, for more than a handful of avian species, in this habitat diverse ecosystem. Avian species richness and total bird abundance were significantly lower inside of Core Areas and substantially more of the twenty most abundant species were significantly less abundant inside of both PAC and Core Areas than outside. However, it should be noted that the disparity in species richness, total bird abundance, and diversity was mitigated when comparing outside Core to PACs alone. PACs appear to support more total birds and a greater diversity of species than the surrounding 700 acres of the Core, however PACs have significantly lower abundance for most shrub and open forest dependent species.

Five of the nine species significantly more abundant outside of PAC and Core Areas are shrub dependent birds, while two others, are known to have strong affinities for open forest and edge habitats conditions. The Large-billed subspecies of Fox Sparrow is unique to the mountains of southern Oregon and interior California (Rising & Beadle 1996, Weckstein et al. 2002). Evidence suggest that this subspecies is in fact one of four distinct species of Fox Sparrow (Zink & Kessen 1999). With the Sierra Nevada comprising the majority of this subspecies (or species) range managing, for its needs here is vital to its existence. Fox Sparrows were five times less abundant inside of Pac and Core areas than they were outside. This species may be the most at risk from a management strategy that will result in significant increases in SPOW like habitats.

The Olive-sided Flycatcher, another species negatively correlated with all three measures of SPOW habitat, is a Forest Service sensitive species in California. According to the Breeding Bird Survey, it has experienced a nearly 4% per year decline in the Sierra Nevada over the past 40 years (Sauer et al. 2005). This Neotropical migrant flycatcher is quite uncommon in the study area with 0.04 detected within 50 meters of observers per point count station between 2002 and 2006. For comparison, the most abundant species in the study area – Hermit Warbler – averaged 1.17 detections within 50 meters. Olive-sided Flycatcher has also experienced an 8.8% per year decline in the study area over the past four years – though this trend was not significant due to our small sample size. This species has strong affinities for forest edges, burned habitat, and snags (Altman and Sallabanks 2000). If forests continue to trend towards more homogenous

PAC-like habitat, the Olive-sided Flycatcher's decline in the Sierra will likely continue if not accelerate in coming decades.

Trending towards a PAC-like Forest

Approximately 50% of National Forest lands in the PLAS study area are currently set aside in areas where little if any forest treatments will occur. In a fire suppression dominated management regime, tree size and densities will continue to increase, in areas where no forest treatments occur. Furthermore, many forest treatments now being planned – including Defensible Fuel Profile Zones (DFPZ) and Strategically Placed Area Thinnings – are retaining a minimum of 40% canopy cover in order to minimize potential impacts to late seral associated species (HFQLG FEIS 1999, SNFPA 2001). With half the forest in restricted areas and the other half being managed for high canopy retention and larger trees, it appears inevitable that the majority of the Northern Sierra forests will become Core like habitat. In fact, analysis conducted for each of the two current management strategies for the Northern Sierra forests – SNFPA and HFQLG Pilot Project – predicted significant increases in canopy cover and tree sizes in the coming decades (HFQLG FEIS 1999, SNFPA 2001).

DFPZ treatments may not only be ineffective in creating open forest and shrub dominated habitats but they are likely having a detrimental effect on shrub nesting bird species. At least in Treatment Unit Four, managers appear to be targeting shrub dominated sites for DFPZ placement. Pre-treatment DFPZs in Unit Four had significantly higher abundance of Dusky Flycatcher and Fox Sparrow – two shrub-dependent birds that were negatively associated with SPOW habitat – compared to non-DFPZ sites (Burnett et al. 2006). The three species significantly less abundant within proposed DFPZs were Hermit Warbler, Brown Creeper, and Hammond's Flycatcher – three species strongly correlated with SPOW habitat. Based on our observations over the past four years, treatments in shrub dominated areas involves partial to wholesale mastication of shrubs. The majority of shrub nesting bird species select for sites with very high shrub cover. In the Lassen National Forest, four shrub-dependent species (including Fox Sparrow and Dusky Flycatcher) nesting in 15 to 20 year old plantations – with shrub cover averaging 50% – chose nest sites with significantly higher shrub cover than random sites (Burnett et al. 2005a). For each of these species, shrub cover within five meters of nests averaged over 60%. Thus, it is not likely that shrub-dominated habitats treated under fuel reduction projects will support these shrub-nesting species.

In the HFQLG area of the Northern Sierra, group selections are being used as an additional management tool. Groups involve removal of almost all of the overstory and therefore are a potential source of open forest and shrub dominated habitat. However, group selection treatments as they are prescribed under HFQLG are two acres or less in size (HFQLG FEIS 1999). Densities of shrub nesting birds in the Lassen National Forest; including Dusky Flycatcher, MacGillivray's Warbler, Green-tailed Towhee, and Fox Sparrow averaged over two acres per territory (PRBO unpublished data). Thus even the largest groups – if they were managed for dense shrub cover – are too small to support a single shrub nesting bird territory.

Private lands are a potential source of early succesional open forest habitat in the Sierra Nevada. Timber harvest practices on these lands are often more intensive resulting in larger forest openings with suitable conditions for shrub establishment. However, based on our observations in the Northern Sierra, many of these sites are densely replanted with conifers and shrubs are actively inhibited or removed through mastication and herbicide treatments. The resulting early succesional habitat is unlikely to support species such as Dusky Flycatcher, Fox Sparrow, MacGillivray's Warbler, or Spotted and Green-tailed Towhee.

It is evident that managing for an increase in PAC- and Core-like habitat may result in significant changes to the avian community in the Northern Sierra Nevada. While it is important to manage for SPOW and other late seral associated species, it is essential to strike a balance with the needs of all the other species dependent upon this system. Our analysis of avian community composition in relation to SPOW habitat has led us to ask several questions: Should late seral habitat be emphasized in all forest treatments? Are Sierra Nevada forests limited in the amount of high canopy cover forest or the amount of high quality late seral habitat? The current approach to forest management appears to be focused on converting more of the forest to closed canopy to meet the needs of late seral species. While this approach may or may not benefit late seral species in the coming years it is fairly clear that it will negatively impact a number of other Sierra Nevada birds and undoubtedly other organisms. Shrub-dominated and open forest habitat conditions are a critical component of the Sierra Nevada ecosystem and are likely to decline under a late seral dominated management regime.

Four Year Trends in Species Abundance

It is important to note that four years is not enough time to confidently ascertain long-term trends in avian populations. However, analyzing trends over this timeframe can provide meaningful information on the status of avian populations and alert one to species that may be in need of more management attention.

We found an interesting correlation between species with significant population trends from 2003 – 2006, and the association of those species with SPOW habitat. Three of the four species significantly increasing were positively correlated with SPOW habitat, while four of six declining were negatively associated with SPOW habitat. Brown Creeper, Golden-crowned Kinglet, and Hermit Warbler were all positively correlated with at least two of the three measures of SPOW habitat. The fourth significantly increasing species, Dusky Flycatcher, was negatively associated with all three measures of SPOW habitat. Two of the species showing declines – the shrub-dependent Spotted Towhee and Fox Sparrow – showed strong negative associations with all three measures of SPOW habitat. The Mountain Chickadee was significantly more abundant outside of Core and PACs and Audubon's Warbler's abundance increased away from SPOW nests. Hammond's Flycatcher, on the other hand, was significantly more abundant inside of Pac and Core. The Red-breasted Nuthatch showed no affinity for or against any of the three measures of SPOW habitat.

The only two species that did not fit the correlation of increasing species being positively associated with SPOW habitat and decliners being negatively associated were Hammond's and Dusky Flycatcher. Dusky Flycatcher is an early seral shrub dependent species (Sedgwick 1993). It was negatively associated with owl habitat areas and showed a significant increasing trend. Hammond's Flycatcher is a late seral closed canopy associated species (Sedgwick 1994) that was positively correlated with owl habitat areas and showed a significant population decline. These two species are very difficult to separate in the field during point count surveys. In some years observers were more conservative and many birds were only identified to the species pair, while in other years almost all individuals were identified to the species. For our analysis purposes we had to discard these unidentified detections. For the analysis of abundance associated with SPOW habitat this is probably not an issue, for analysis of population trends this may be a confounding factor. The number of unidentified flycatcher detections in 2006 was higher than any of the previous three years. It may be many of these detections were Hammond's Flycatcher thus explaining the precipitous decline observed in this species in 2006. However, it does not explain the significant increasing trend in Dusky Flycatcher. It is important to be aware of these potential confounding factors when analyzing data of these two species.

Population trends for avian species can be influenced by factors other than available breeding habitat or habitat quality. These species may be limited by wintering habitat or other factors such as widespread disease (e.g. West Nile Virus, Avian Influenza). However, the list of species showing significant population trends have a wide range of life history strategies and includes, permanent residents (e.g. Mountain Chickadee and Golden Crowned-Kinglet), short-distance migrants (Oregon Junco, Audubon's Warbler), and neotropical migrants (Hermit Warbler and Dusky Flycatcher). In fact, all of the declining species are either permanent residence or short-distance migrants, suggesting declines are at least in part due to factors on the breeding grounds. The strongest and most plausible link between these species appears to be their relationship to SPOW habitat.

Results from the four year trend analysis highlight the need to continue to collect data for several more years to conclusively determine the true magnitude of these population rates. Should the Forest Service be focusing more management actions on the needs of Fox Sparrow and Red-breasted Nuthatch? Should we be unconcerned with Hermit Warblers and Golden-crowned Kinglets? Will these trends change as more treatments are implemented?

CONCLUSION

Long-term, landscape-based ecological monitoring will be critical to determining when an acceptable balance has been struck with the full compliment of habitat conditions. Avian monitoring is one of the only practical tools capable of providing the necessary feedback to make these complex and difficult decisions before the scale has been tipped too far and regulatory hurdles significantly limit management options. In the last century, fire suppression and timber harvest practices (among others) have tipped the balance of these systems towards overstocked forests with small to medium sized shade tolerant trees. In response to this, current management direction has emphasized retaining and creating more late-seral habitat. However, results presented in this report highlight the need to balance the requirements of the whole suite of species and ecological conditions that exist in the Sierra Nevada in order to avoid significant impacts to a number of avian species.

OUTREACH AND PUBLICATIONS

Accepted Publications
Integrating Avian Monitoring into Forest Management: Pine-Hardwood and Aspen Enhancement on the Lassen National Forest. Accepted as part of a PSW General Technical Report.

Presentations
Avian Community Composition in the Context of Spotted Owl Management in the Sierra Nevada – oral presentation at:

Plumas Lassen Study Symposium in Quincy, California 3/31/06.
The Western Section of the Wildlife Society in Monterey, California 2/2/07.

Integrating Avian Monitoring into Forest Management on the Lassen and Plumas National Forests – oral presentation at:

Forest Forum in Westwood, California 1/19/2006.

Pine-Oak Habitat Enhancement on the Lassen National Forest – poster presented at:

The 6th California Oak Symposium in Rohnert Park, California 10/10/06.

Outreach
"Birds in the Park" – presentation on managing coniferous forest for birds and bird banding demonstration in collaboration with Lassen Volcanic National Park – over 200 park visitors participated 7/23/06.

Pine-Oak Habitat Enhancement Field Trip – invited to participate on Lassen National Forest tour of QLG Pine-Oak project in the Almanor Ranger District. Gave a presentation on our monitoring results and produced a "white paper" handout summarizing our results. 7/14/06.

Mono Lake Bird Chataqua – led a field trip on bird identification and overview of Plumas-Lassen Study and all of PRBO's work in the Northern Sierra. 6/19/2006

We have been in regular contact with several members of the Quincy Library Group and the Plumas Audubon Society.

Integration with Management
We provided input to several important Forest Service projects in 2006 in an effort to integrate our results to help guide forest management in the Sierra Nevada:

1. Updated the "Interactive GIS Project" with 2006 avian monitoring data. This product can be used by forest planners in the region to determine the presence/absence or abundance of all species detected in the study area.

2. Created an interactive GIS CD for the Almanor Ranger District (ARD) with presence/absence data of each woodpecker species at every point count station ever

surveyed by PRBO in the district. We also conducted a tutorial of its application and use with ARD biologist Mark Williams.

3. Provided data from all PRBO avian survey sites from across all National Forest lands in the Sierra Nevada in coordination with Diana Craig in the Region 5 office for use in MIS analysis.

4. Provided input on Sierra National Forests Kings River Project Biological Evaluation, including reviewing the pilot analysis using the new MIS direction from Region 5. A collaboration between PRBO, John Robinson of On My Mountain, and the Sierra National Forest.

5. Produced and distributed four white papers integrating avian monitoring data into science based recommendations for managing four important Sierra habitat types for birds. These papers have now been distributed to all QLG area forest service staffs, the QLG, private timber companies in the Northern Sierra, and other interested parties.

PERSONNEL

This project is coordinated and supervised by PRBO staff biologist Ryan Burnett. Eric Wood was the field crew supervisor in 2006. Field work in 2006 was conducted by those listed above as well as Jeff Birek, Jeremy Russell, Elizabeth Summers, Alyson Webber, and Jared Wolfe. Computer programs used to manage and summarize data were created by PRBO staff biologists Grant Ballard and Diana Humple. Diana Humple and Nadav Nur provided helpful editing and statistical advice respectively. The study is carried out under the guidance of PRBO Terrestrial Ecology Division Director Geoffrey R. Geupel.

ACKNOWLEDGEMENTS

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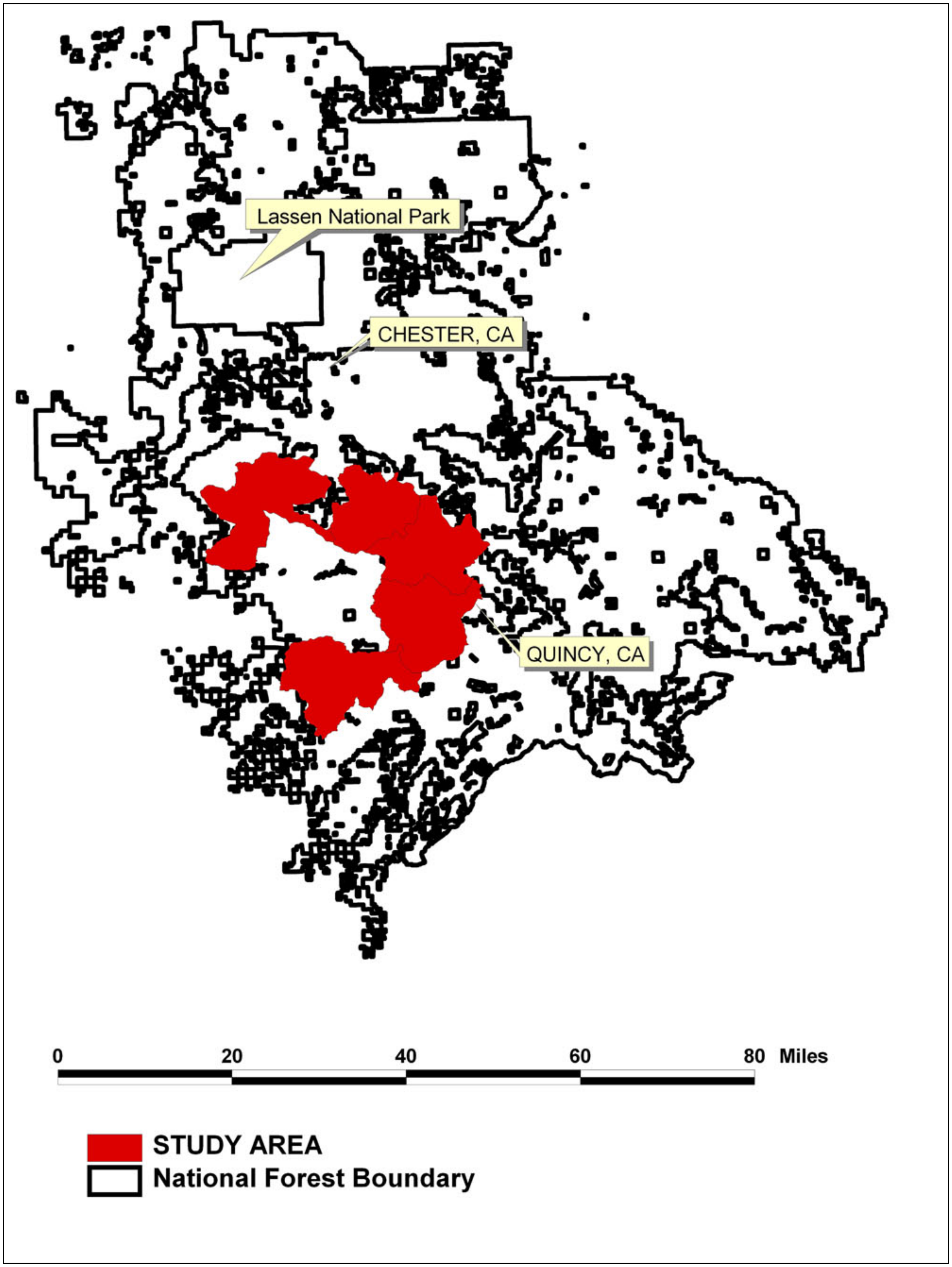
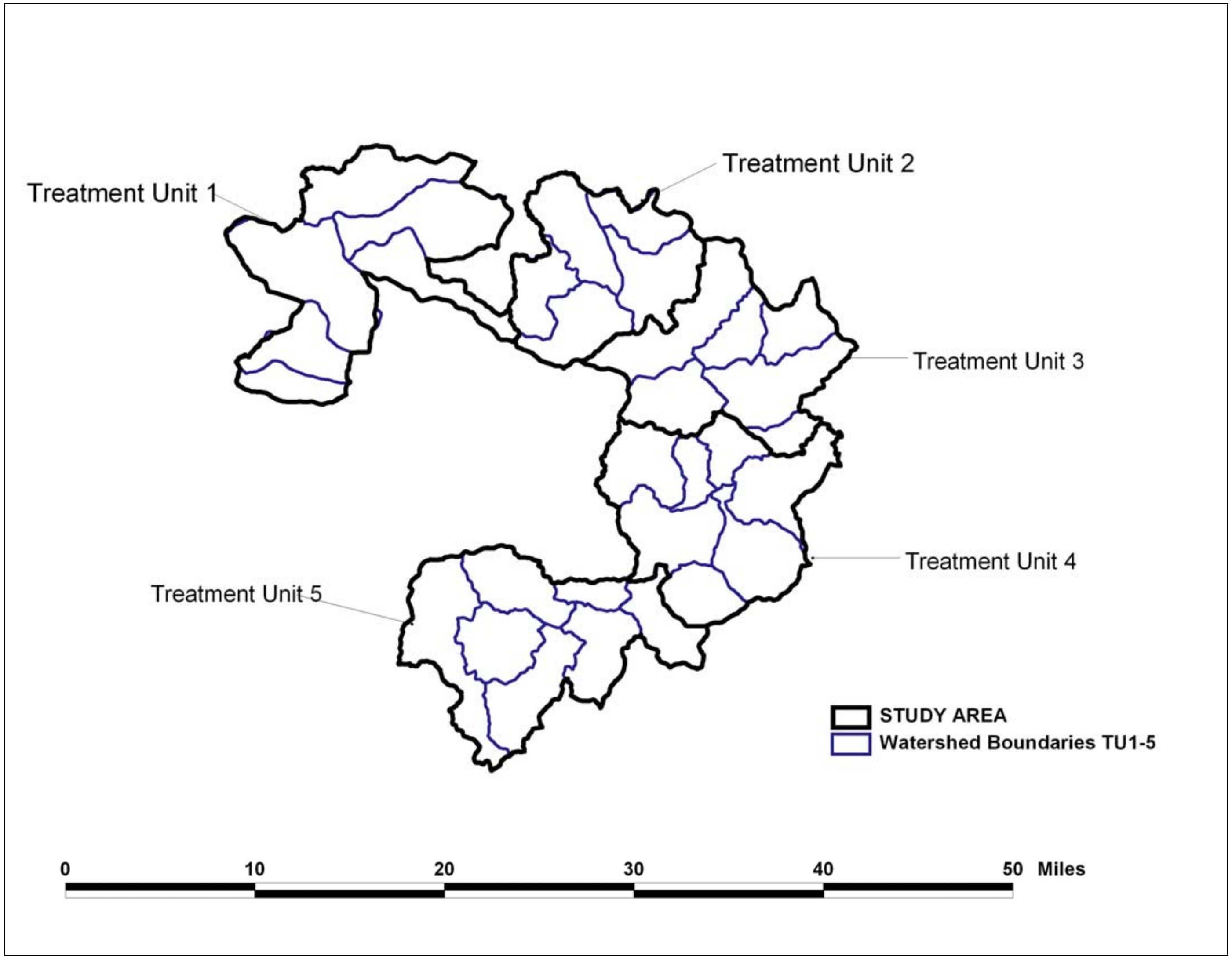
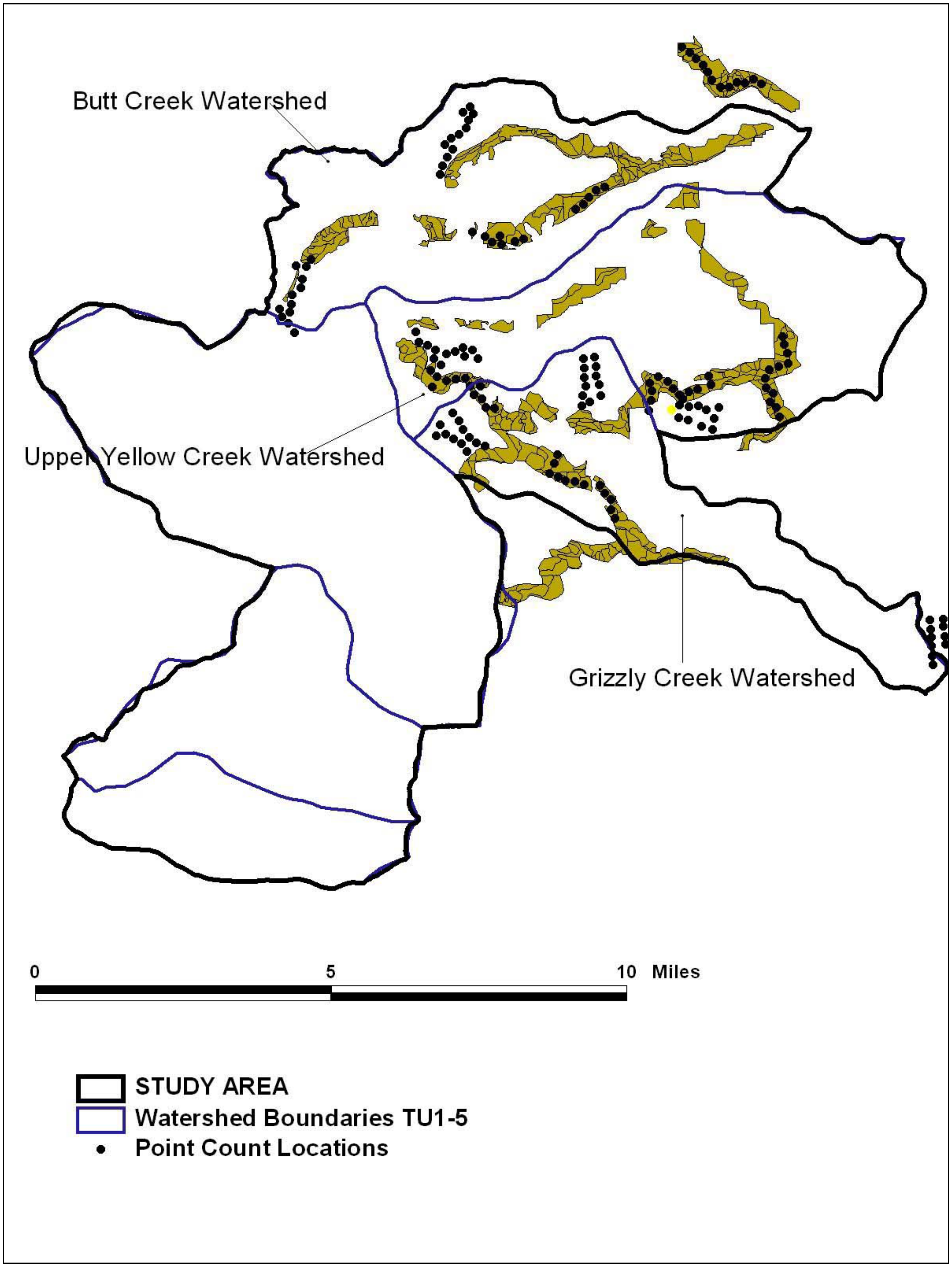
Appendix 1. Study area overview map of the PRBO Plumas-Lassen module of the Administrative Study.



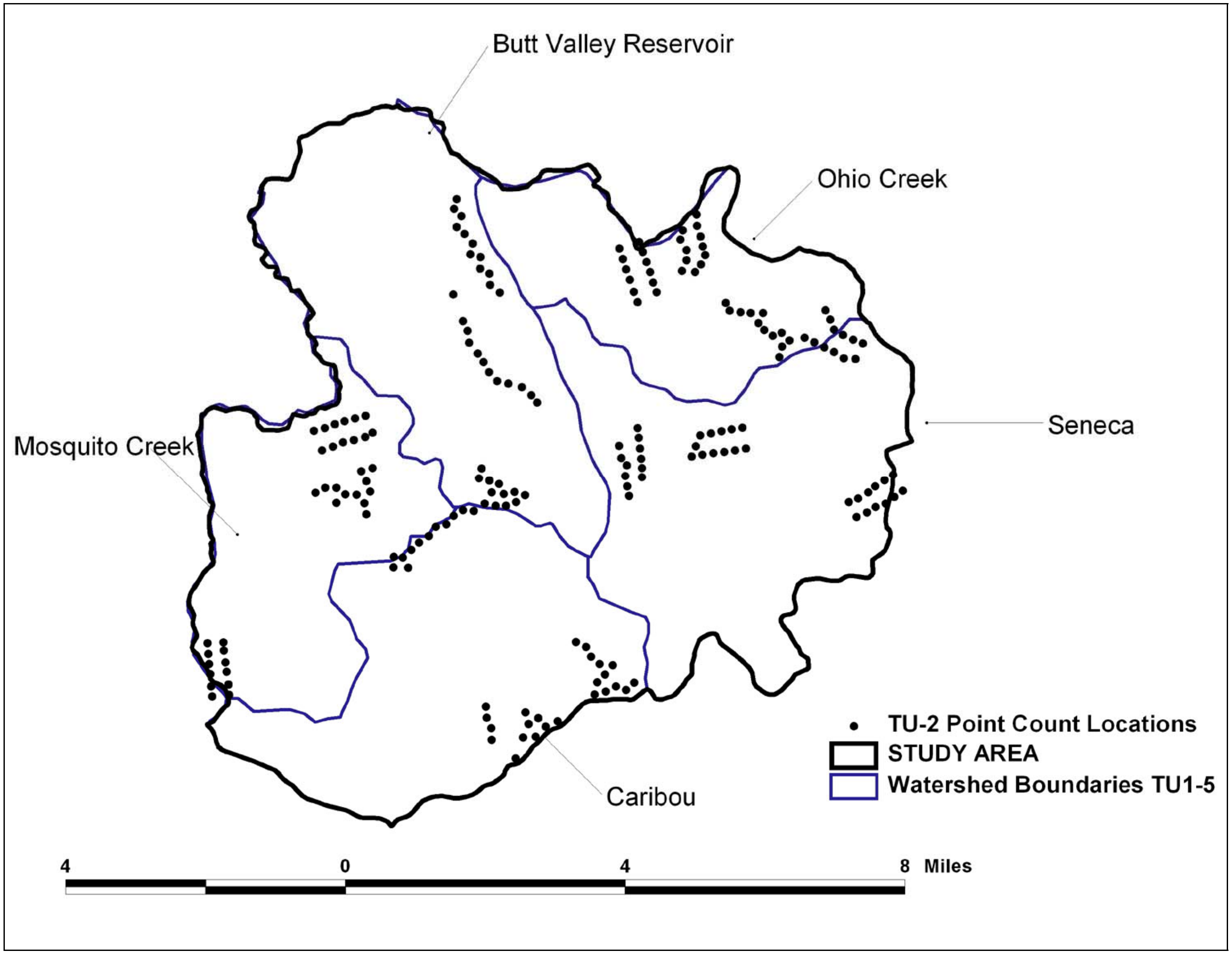
Appendix 2. Treatment Units and Watershed boundaries of the PRBO Plumas-Lassen Avian Study Area.



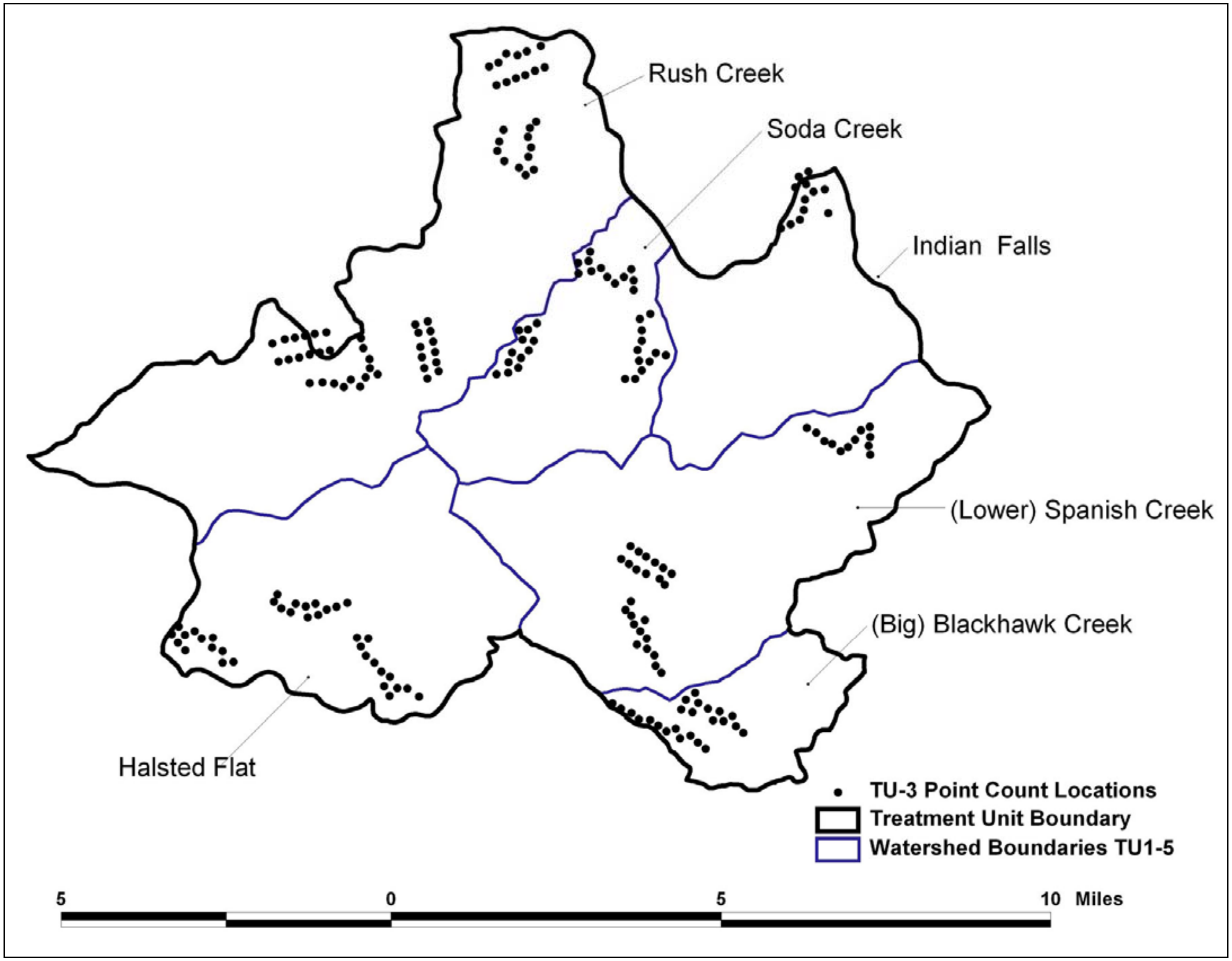
Appendix 3. Treatment Unit 1 Map with watersheds, DFPZ outlines, and locations of point count transects surveyed in 2006 for the PRBO Plumas-Lassen Administrative Study.



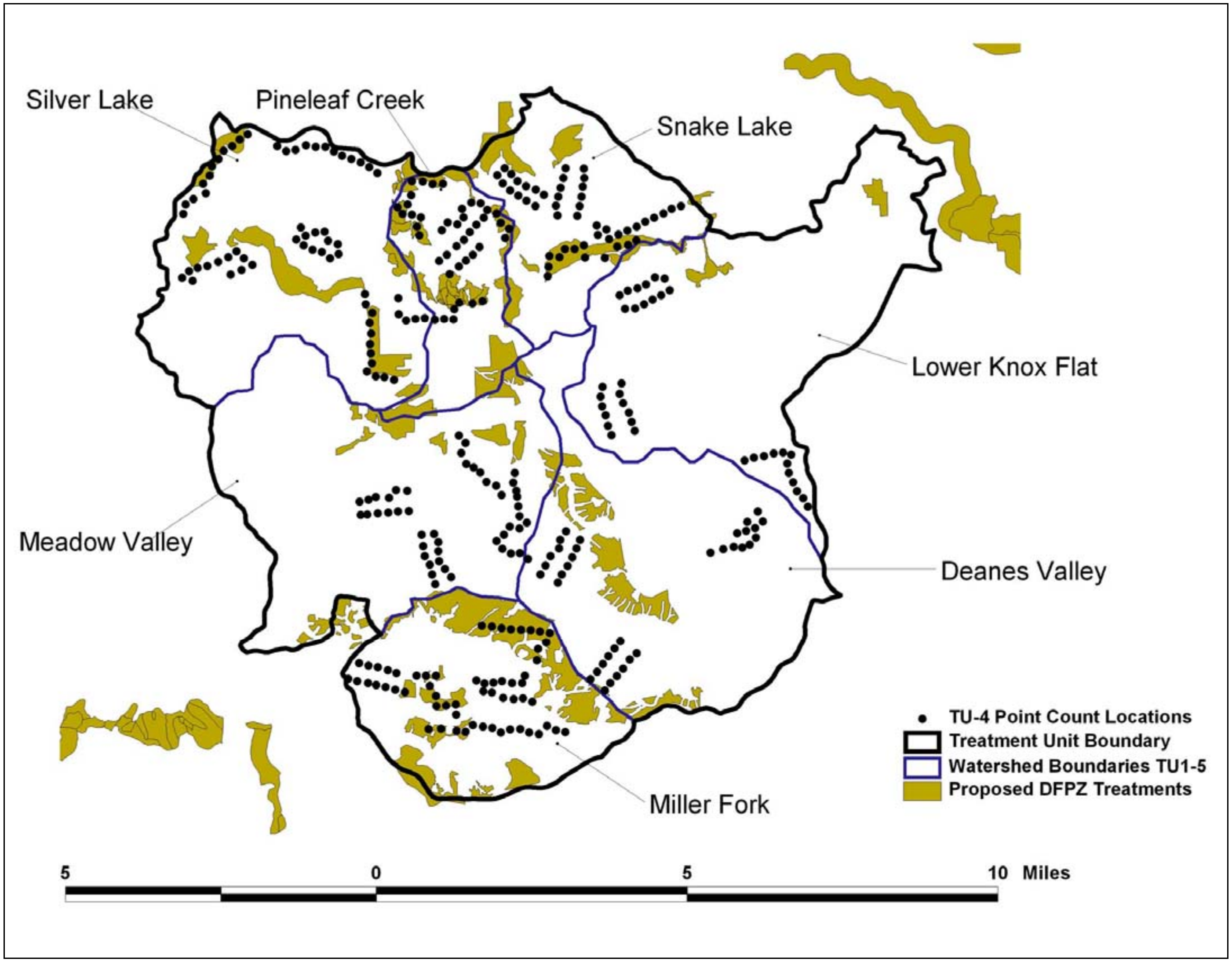
Appendix 4. Treatment Unit 2 map with watersheds, DFPZ outlines, and locations of point count transects surveyed in 2006 for the PRBO Plumas-Lassen Administrative Study.



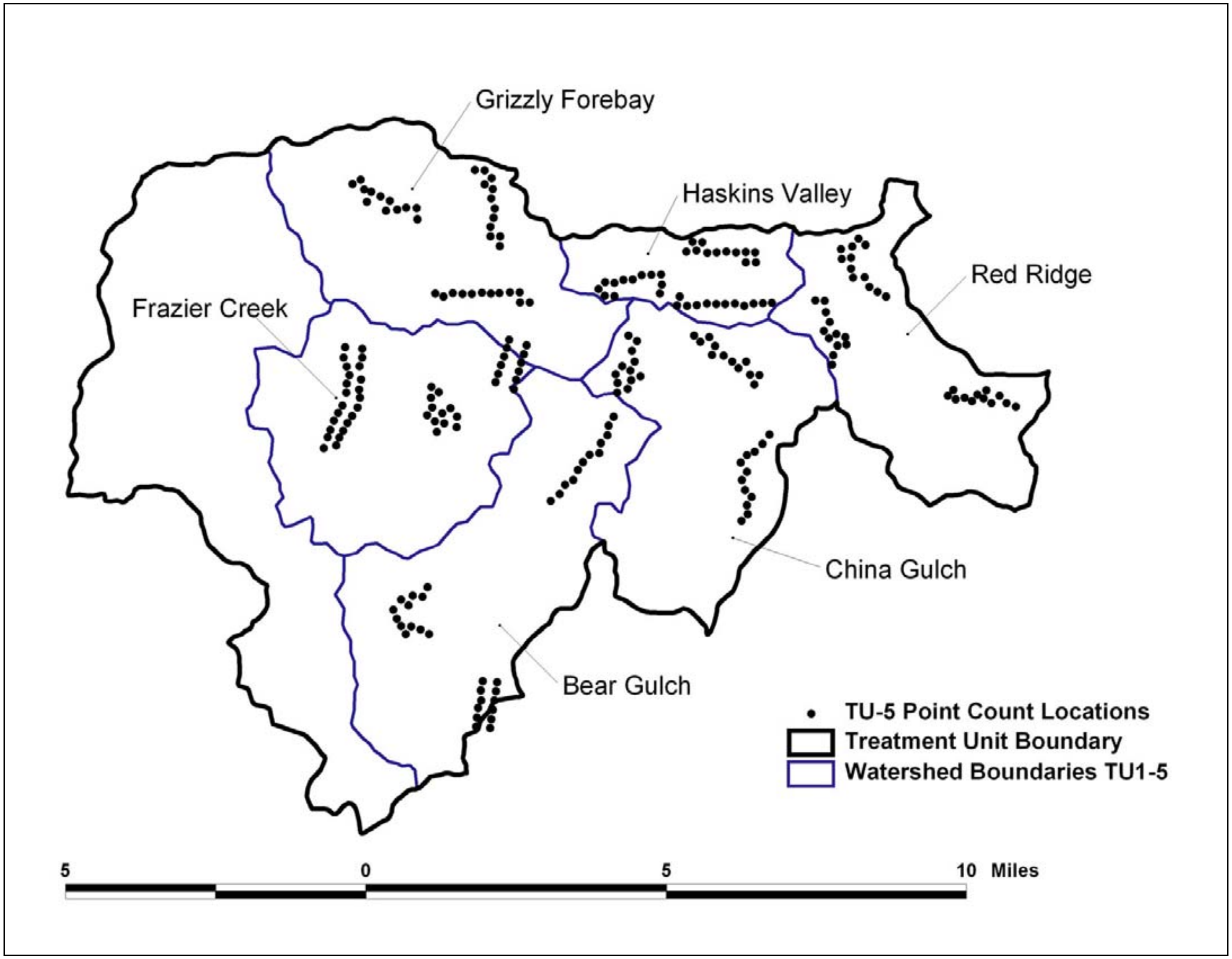
Appendix 5. Treatment Unit 3 map with delineating watersheds and locations of point count transects surveyed in 2006 for the PRBO Plumas-Lassen Administrative Study.



Appendix 6. Treatment Unit 4 map delineating watersheds, DFPZ outlines, and locations of point count transects surveyed in 2006 for the PRBO Plumas-Lassen Administrative Study.



Appendix 7. Treatment Unit 5 map delineating watersheds and locations of point count transects surveyed in 2006 for the PRBO Plumas-Lassen Administrative Study.



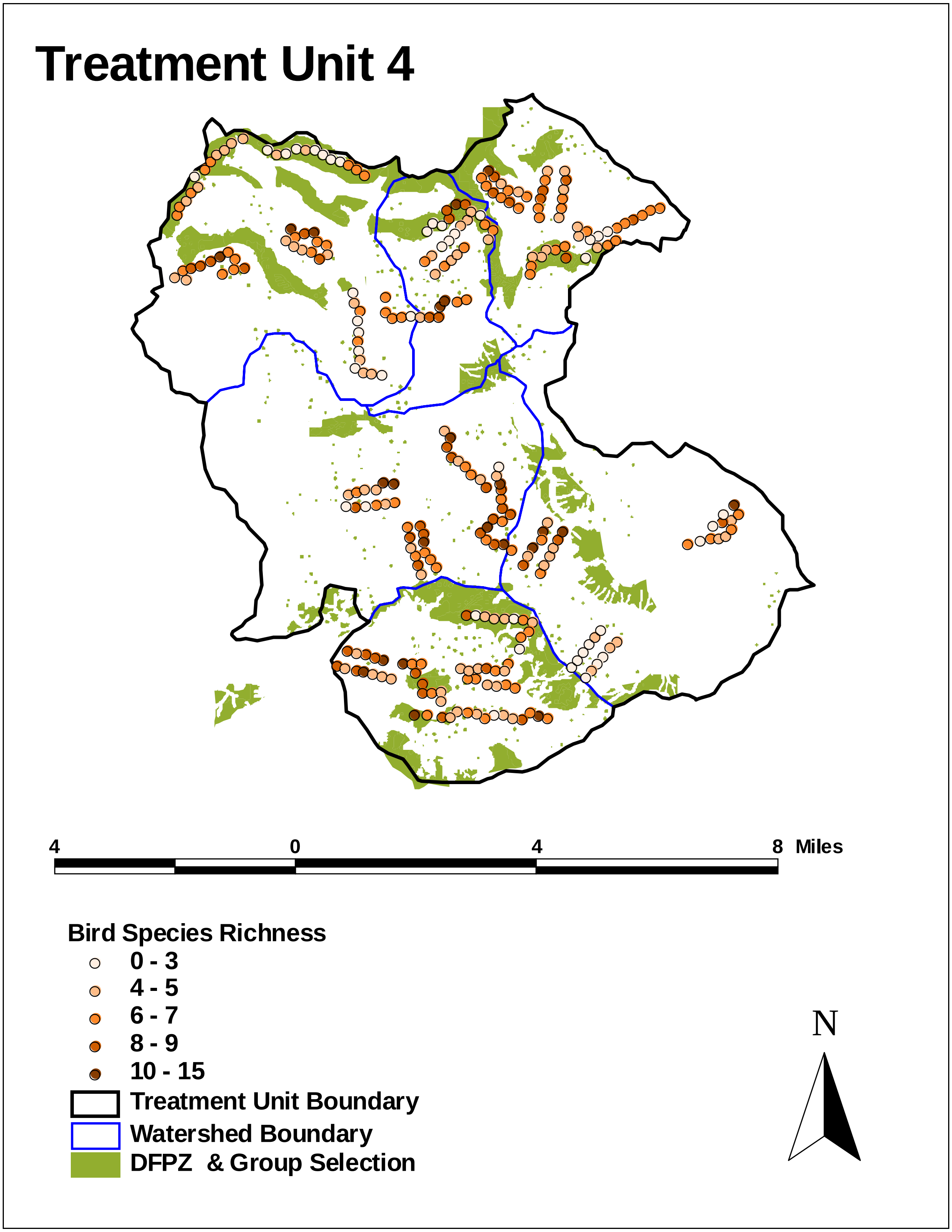
Appendix 8. List of all bird species detected by PRBO on point count surveys (common, AOU code, scientific name) in the PLAS in 2002-2006.

Common Name	AOU Code	Scientific Name
Acorn Woodpecker	ACWO	*Melanerpes formicivorus*
American Crow	AMCR	*Corvus brachyrhynchos*
American Dipper	AMDI	*Cinclus mexicanus*
American Kestrel	AMKE	*Falco sparverius*
American Robin	AMRO	*Turdus migratorius*
Anna's Hummingbird	ANHU	*Calypte anna*
Audubon’s Warbler	AUWA	*Dendroica coronata audubonii*
Bald Eagle	BAEA	*Haliaeetus leucocephalus*
Band-tailed Pigeon	BTPI	*Columba fasciata*
Belted Kingfisher	BEKI	*Ceryle alcyon*
Bewick’s Wren	BEWR	*Thryomanes bewickii*
Black Phoebe	BLPH	*Sayornis nigricans*
Black-backed Woodpecker	BBWO	*Picoides arcticus*
Black-headed Grosbeak	BHGR	*Pheucticus melanocephalus*
Black-throated Gray Warbler	BTYW	*Dendroica nigrescens*
Blue Grouse	BGSE	*Dendragapus obscurus*
Blue-gray Gnatcatcher	BGGN	*Polioptila caerulea*
Brewer’s Blackbird	BRBL	*Eupphagus cyanocephalus*
Brewer’s Sparrow	BRSP	*Spizella breweri*
Brown Creeper	BRCR	*Certhia Americana*
Brown-headed Cowbird	BHCO	*Molothrus ater*
Bushtit	BUSH	*Psaltriparus minimus*
California Quail	CAQU	*Callipepla californica*
Calliope Hummingbird	CAHU	*Stellula calliope*
Canada Goose	CAGO	*Branta Canadensis*
Cassin's Finch	CAFI	*Carpodacus cassinii*
Cassin's Vireo	CAVI	*Vireo casinii*
Cedar Waxwing	CEDW	*Bombycilla cedrorum*
Chestnut-backed Chickadee	CBCH	*Parus rufescens*
Chipping Sparrow	CHSP	*Spizella passerine*
Clark’s Nutcracker	CLNU	*Nucifraga Columbiana*
Common Nighthawk	CONI	*Chordeiles minor*
Common Raven	CORA	*Corvus corax*
Cooper’s Hawk	COHA	*Accipiter cooperii*
Downy Woodpecker	DOWO	*Picoides pubescens*
Dusky Flycatcher	DUFL	*Empidonax oberholseri*
European Starling	EUST	*Sturns vulgaris*
Evening Grosbeak	EVGR	*Coccothraustes vespertinus*
Fox Sparrow	FOSP	*Passerella iliaca*
Golden-crowned Kinglet	GCKI	*Regulus satrapa*
Gray Flycatcher	GRFL	*Empidonax wrightii*
Gray Jay	GRJA	*Perisoreus Canadensis*
Great Blue Heron	GTBH	*Ardea herodias*

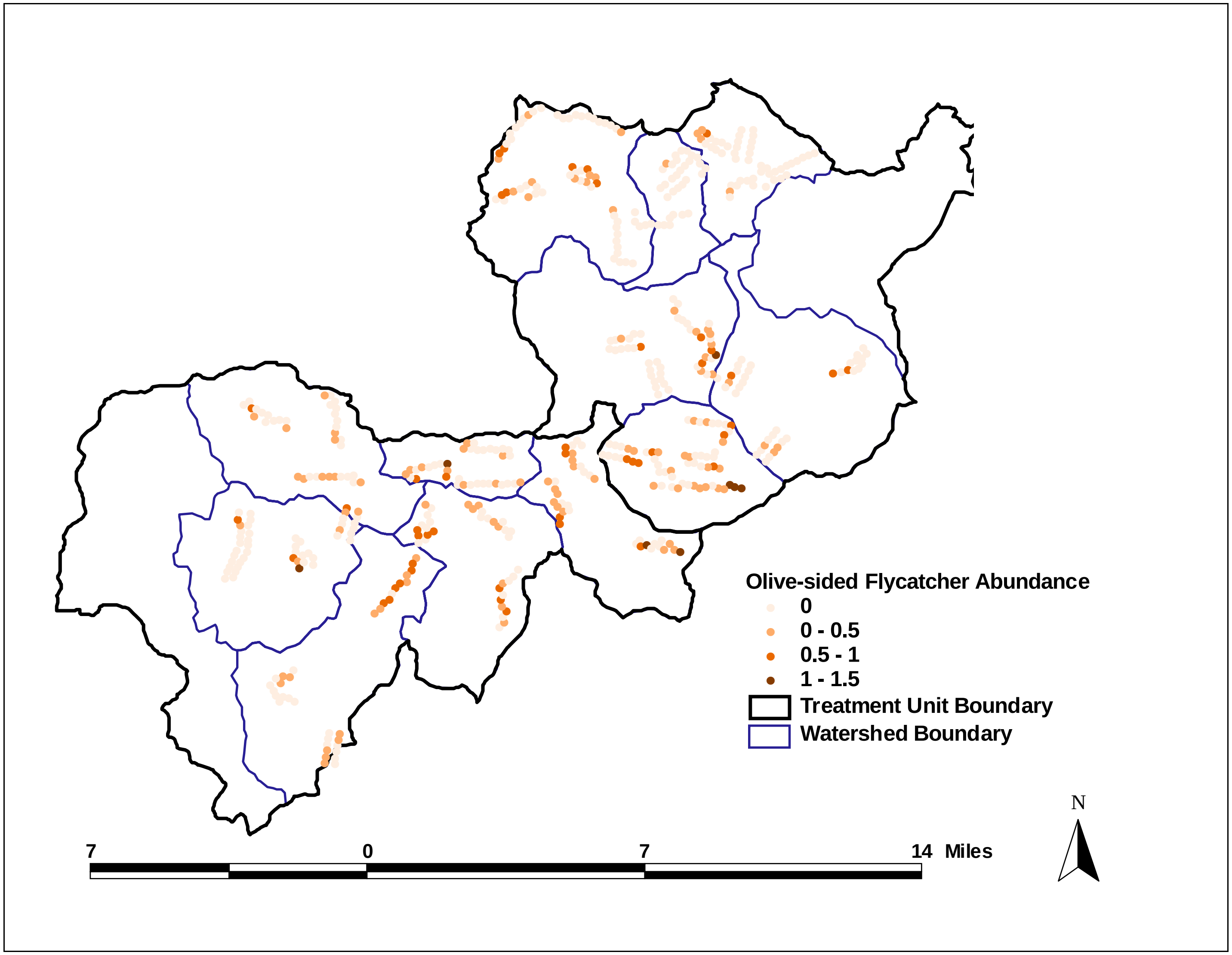
Common Name	AOU Code	Scientific Name
Green Heron	GRHE	*Butorides virescens*
Green-tailed Towhee	GTTO	*Pipilo chlorurus*
Hairy Woodpecker	HAWO	*Picoides villosus*
Hammond's Flycatcher	HAFL	*Empidonax hammondii*
Hermit Thrush	HETH	*Catharus guttatus*
Hermit Warbler	HEWA	*Dendroica occidentalis*
House Wren	HOWR	*Troglodytes aedon*
Hutton’s Vireo	HUVI	*Vireo huttoni*
Lazuli Bunting	LAZB	*Passerina amoena*
Lesser Goldfinch	LEGO	*Carduelis psaltria*
Lewis’s Woodpecker	LEWO	*Melanerpes lewis*
Lincoln’s Sparrow	LISP	*Melospiza lincolnii*
MacGillivray's Warbler	MGWA	*Oporornis tolmiei*
Mallard	MALL	*Anas platyrhynchos*
Mountain Bluebird	MOBL	*Sialia currucoides*
Mountain Chickadee	MOCH	*Poecile gambeli*
Mountain Quail	MOQU	*Oreotyx pictus*
Mourning Dove	MODO	*Zenaida macroura*
Nashville Warbler	NAWA	*Vermivora ruficapilla*
Northern Goshawk	NOGO	*Accipiter gentiles*
Northern Pygmy-Owl	NPOW	*Glaucidium gnoma*
Northern Saw-whet Owl	NOSO	*Aegolius acadicus*
Olive-sided Flycatcher	OSFL	*Contopus cooperi*
Orange-crowned Warbler	OCWA	*Vermivora celata*
Oregon Junco	ORJU	*Junco hyemalis*
Osprey	OSPR	*Pandion haliaetus*
Pacific-slope Flycatcher	PSFL	*Empidonax difficilis*
Pileated Woodpecker	PIWO	*Dryocopus pileatus*
Pine Siskin	PISI	*Carduelis pinus*
Purple Finch	PUFI	*Carpodacus purpureus*
Red Crossbill	RECR	*Loxia curvirostra*
Red-breasted Nuthatch	RBNU	*Sitta Canadensis*
Red-breasted Sapsucker	RBSA	*Sphyrapicus rubber*
Red-shafted Flicker	RSFL	*Colaptes auratus*
Red-tailed Hawk	RTHA	*Buteo jamaicensis*
Red-winged Blackbird	RWBL	*Agelaius phoeniceus*
Rock Wren	ROWR	*Salpinctes obloletus*
Rufous Hummingbird	RUHU	*Selasphorus rufus*
Sandhill Crane	SACR	*Grus Canadensis*
Sage Thrasher	SATH	*Oreoscoptes montanus*
Sharp-shinned Hawk	SSHA	*Accipiter striatus*
Song Sparrow	SOSP	*Melospiza melodia*
Spotted Owl	SPOW	*Strix occidentalis*
Spotted Towhee	SPTO	*Pipilo maculates*
Steller's Jay	STJA	*Cyanocitta stelleri*

Common Name	AOU Code	Scientific Name
Swainson’s Thrush	SWTH	*Catharus ustulatus*
Townsend's Solitaire	TOSO	*Myadestes townsendi*
Townsend’s Warbler	TOWA	*Dendroica towsendi*
Tree Swallow	TRES	*Tachycineta bicolor*
Turkey Vulture	TUVU	*Cathartes aura*
Vaux’s Swift	VASW	*Chaetura vauxi*
Violet-green Swallow	VGSW	*Tachycineta thalassina*
Warbling Vireo	WAVI	*Vireo gilvus*
Western Bluebird	WEBL	*Sialia mexicana*
Western Scrub-Jay	WESJ	*Aphelocoma californica*
Western Tanager	WETA	*Piranga ludoviciana*
Western Wood-Pewee	WEWP	*Contopus sordidulus*
White-breasted Nuthatch	WBNU	*Sitta carolinensis*
White-headed Woodpecker	WHWO	*Picoides albolarvatus*
Williamson’s Sapsucker	WISA	*Sphyrapicus thyroideus*
Wilson's Warbler	WIWA	*Wilsonia pusilla*
Winter Wren	WIWR	*Troglodytes troglodytes*
Wrentit	WREN	*Chamea fasciata*
Yellow Warbler	YWAR	*Dendroica petechia*

Appendix 9. Sample map from GIS CD supplement of bird species richness in treatment unit 4 of the PLAS study area in 2003.



Appendix 10. Sample Map from GIS CD Supplement of Olive-sided Flycatcher Abundance (all detections) in Treatment Units 4 and 5 in the PLAS study area in 2003.



Appendix 11. Details on GIS CD Supplement Project for building species maps

I. Summary

With this GIS project and these tables, additional maps can be generated (e.g., abundance maps for individual species showing where they are most and least common; maps showing differences in diversity, richness or overall abundance; and maps showing presence/absence of species of interest that are not well surveyed with this method, but encountered during point counts) for 2003, 2004 and 2005 data. Included in the ArcView project (see below for details) are examples of such maps: abundances of Hammond's Flycatchers within 50 meters of every point in 2003 and 2004; abundances of Band-tailed Pigeons detected at each of the points in 2004; abundances of Black-backed Woodpeckers at each of the points in 2004; and species richness at each of the points in 2003. The directions and metadata below will allow the user to create such maps for any species or index in either of the two years.

II. PRIMARY ARCVIEW FILES

PRBO_PSWreportsupplement06.apr – ArcView project file. Double click this file to open the project.

PLASabsum06_allGIS.dbf – table which contains one line of data per point with all associated bird data from the 2006 point count season, including diversity, species richness, and abundance of all species combined, as well as abundance of individual species. Only includes data within 50m and for restricted species only (breeders in area and species well surveyed by the point count method; see *Methods*) This has been imported into an ArcView project file. It means "Point count abundance summary for birds less than 50 m from the observer in 2005".

PLASabsum06_l50GIS.dbf – table which contains one line of data per point with all associated bird data from the 2005 point count season, includes ALL data (birds within 50m, birds greater than 50m, and flyovers, combined) and is for all species, including non-breeders as well as species not well surveyed with the point count method. Has been imported into ArcView project file. It means "Point count abundance summary for birds of all detections in 2005."

PLASabsum05_l50GIS.dbf – same as above (less than 50 m) but for 2005 point count data.

PLASabsum05_allGIS.dbf – same as above (for all data) but for 2005 point count data

PLASabsum04_l50GIS.dbf – same as above (less than 50 m) but for 2004 point count data.

PLASabsum04_allGIS.dbf – same as above (for all data) but for 2004 point count data.

PLASabsum03l50.dbf – same as above (less than 50 m) but for 2003 point count data.

PLASabsum03all – same as above (for all data) but for 2003 point count data.

III. GIS DATABASE FIELDS EXPLAINED

Below are the definitions for each field within the pcabsuml50.dbf and pcabsumall.dbf (see above) tables.

YEAR = year that data was collected

STATION = abbreviated point count transect name (4-letters)

SITE = point count station number within a given transect

X_COORD = latitude in UTMs for the point

Y_COORD = longitude in UTMs for the point

VISITS (2003 database) = number of total point count visits done per point; all sites where this is not detailed were visited 2 times.

SW = bird diversity at that point (see *Methods: Statistical Analysis*)

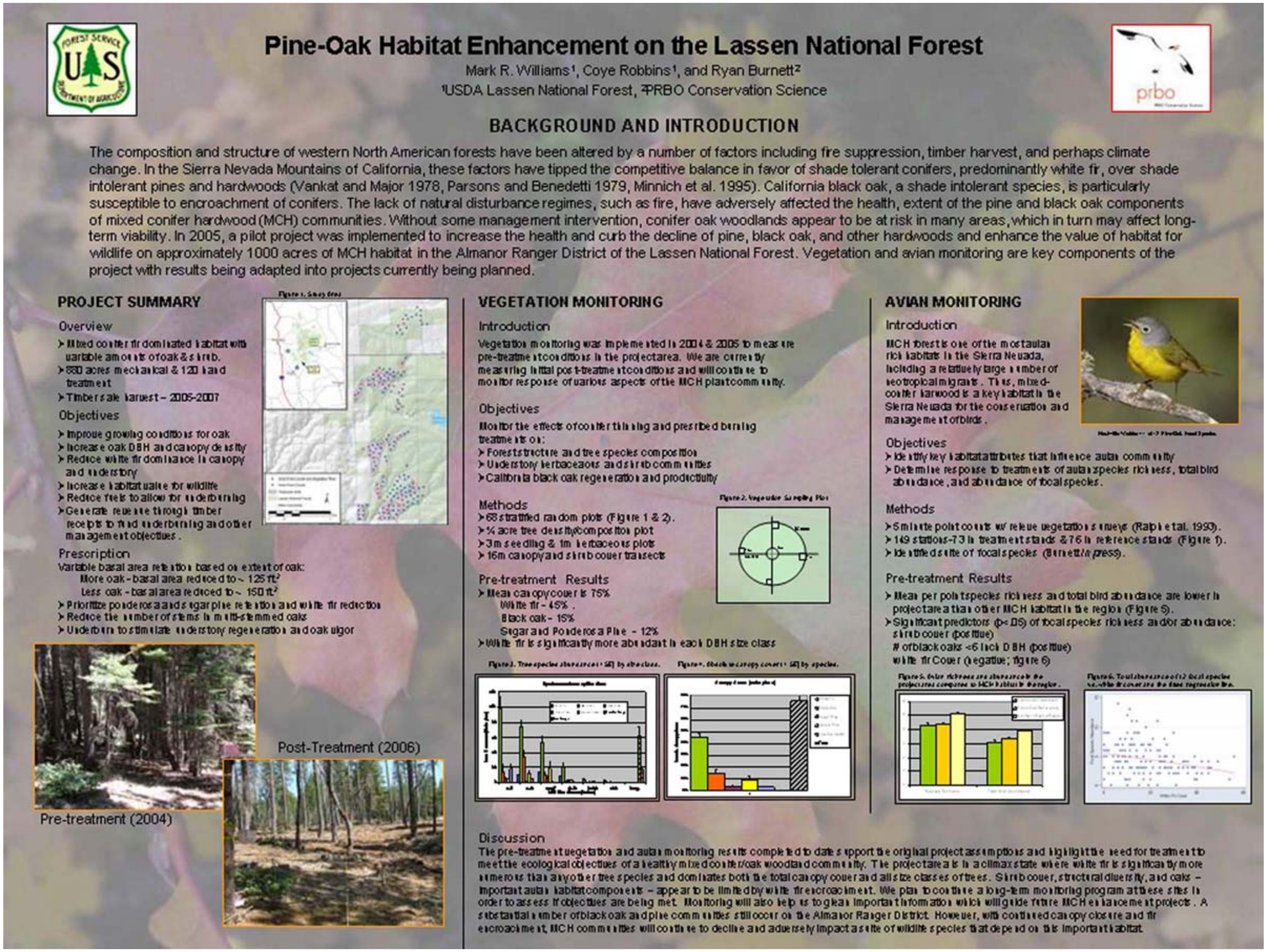
SPECRICH = bird species richness at that point (see *Methods: Statistical Analysis*)

ABUNDANCE = average number of individuals detected at that point per visit (total individuals/number of visits; see *Methods: Statistical Analysis*)
"SPEC"AB = multiple fields, detailing number of individuals of each species at each point (averaged across visits). Uses AOU 4-letter codes for each bird species, combined with "AB" for abundance (e.g., Audubon's Warbler abundance is delineated as *AUWAAB*). See Appendix 8 for explanation of all 4-letter bird species codes. This is done for 61 species within 50 meters (PLASabsum03L50.dbf) and 92 species when including all detections (PLASabsum03all.dbf).

IV. HOW TO GENERATE ABUNDANCE MAPS BY SPECIES

1. Save all files on the CD onto hard drive
2. Open **PRBO_PSWreportsupplement06.apr** in ArcView
3. Since it has been moved, you will have to direct ArcView to each file location (all wherever you have saved them) for the first time, and then save the project so you won't need to do so again.
4. Open view 1.
5. Once inside view 1 click on VIEW on the pull down menu and choose "add event theme"
6. Choose table you want to take data from (PLASabsum06L50.dbf, PLASabsum06all.dbf, or 2003/2004/2005 tables); click OK.
7. Double click on the newly created event theme in left margin
8. Under legend subfolder inside the project folder choose ***speciesabundance.avl*** if you are going to create a map for individual species abundance; or **choose richdivab_legend.avl** if you are going to create a map of community indices. This way all the legends for all species are identical, and done to the same scale.
9. Then under *load legend: field* pick the species abundance you wish to map (i.e., choose *wiwrab* if making a map of Winter Wren abundance based on point count stations) and click OK.
10. Hit APPLY (and close legend window).
11. While that event theme is still selected, under *theme*, click on *properties.* You can then modify the theme name here (e.g., *Winter Wren <50 m*)
12. You will likely choose to make each species map a *layout* if you wish to print them out with a legend (View → layout)

Appendix 12. Poster presented at 6th Oak Symposium in collaboration with the Lassen National Forest.



Chapter 5:
Spotted Owl Module

Principal Investigator:

John J. Keane
Sierra Nevada Research Center
Pacific Southwest Research Station
U.S. Forest Service
2121 2nd Street, Suite A-101
Davis, CA 95616
530-759-1704; jkeane@fs.fed.us

Research Team:

Claire V. Gallagher, Sean A. Parks, Paula, A. Shaklee, Dan W.H. Shaw.
Sierra Nevada Research Center
Pacific Southwest Research Station
U.S. Forest Service
2121 2nd Street, Suite A-101
Davis, CA 95616
530-759-1700

Introduction

Knowledge regarding the effects of fuels and vegetation management on California spotted owls (***Strix occidentalis occidentalis;*** CSOs) and their habitat is a primary information need for addressing conservation and management objectives in Sierra Nevada forests. The specific research objectives of the California spotted owl module as identified and described in the Plumas-Lassen Study (PLS) Plan are:

1) What are the associations among landscape fuels treatments and CSO density, distribution, population trends and habitat suitability at the landscape-scale?

2) What are the associations among landscape fuels treatments and CSO reproduction, survival, and habitat fitness potential at the core area/home range scales?

3) What are the associations among landscape fuels treatments and CSO habitat use and home range configuration at the core area/home range scale?

4) What is the population trend of CSO in the northern Sierra Nevada and which factors account for variation in population trend?

5) Are barred owls increasing in the northern Sierra Nevada, what factors are associated with their distribution and abundance, and are they associated with reduced CSO territory occupancy?

6) Does West Nile Virus affect the survival, distribution and abundance of California spotted owls in the study area?

Current information on the distribution and density of CSOs across the HFQLG study area is required to provide the data necessary to build predictive habitat models and provide baseline population information against which we will assess post-treatment changes in CSO populations and habitat. Continued monitoring on the Lassen Demographic Study Area is critical for estimating CSO population trends and status. Our focus in 2006 was to conduct landscape inventories of CSO distribution and abundance, and continue banding to provide the required data and baseline information to meet the objectives of Research Questions 1-4 identified above. Complete landscape inventory surveys were conducted across 9 of 11 survey areas in 2006 (Figure 1). Surveys were not conducted in 2 survey areas in 2006 (SA-5, SA-7, Figure 2). Surveys were not conducted in these 2 study areas in 2006 because sufficient data for determining the number and distribution of CSO sites for initial habitat modeling efforts was collected in 2004-2005. Details on survey methods are described in the study plan. Efforts were made to monitor the pair and reproductive status of each owl, and to capture, uniquely color-mark, and collect blood samples from each individual owl across the study area. Capture and color-marking is necessary to estimate survival and population trend, and to assess exposure to West Nile Virus (WNV)(Research Question #5). We also recorded all barred and hybrid barred-spotted owls encountered in the study area and synthesized all existing barred owl records for the northern Sierra Nevada to address Research Question #6.

Results

<u>CSO Numbers, Reproductive Success, Density and Population Trends</u>:

A total of 66 territorial CSO sites were documented in 2006 across the study area (Figure 2). This total consisted of 56 confirmed pairs, 2 unconfirmed pairs (i.e., one member of pair confirmed as territorial single plus single detection of opposite sex bird), and 8 territorial single CSOs (single owl detected multiple times with no pair-mate detected). Eight pairs successfully reproduced in 2006 (14% of confirmed/unconfirmed pairs). A total of 12 fledged young were documented in 2006 (1.50 young per successful nest). CSO reproduction in 2006 was similar to 2005, with reproduction in both years lower than 2004 (Table 1). CSO reproduction is known to vary with Spring weather and other factors. The Spring of 2004 was relatively dry while those of 2005 and 2006 had higher levels of precipitation from March-May (Figure 3).

Table 1. California spotted owl reproduction on the Plumas and Lassen National Forests 2004-2006.

Year	Percent of confirmed/unconfirmed pairs	Young fledged per

	with successful nests	successful nest
2004	49.4%	1.61
2005	18.3%	1.53
2006	13.8%	1.50

The Lassen Demographic Study Area (SA 1A, SA-11, SA12, SA-13, SA-14, SA-15) and Plumas NF Survey Areas (SA-2, SA-3, SA-4, SA-5, SA-7) were fully integrated in 2005 to define the overall Plumas-Lassen Study project area and provide consistent CSO survey effort across the project area. (Figure 2). We estimated the crude density of CSOs based on the number of territorial owls detected across 9 survey areas during 2006 surveys at the Survey Area spatial scales (Table 2). The estimated crude density across the overall study area in 2006 was 0.061 territorial owls/km^2. Overall study area crude densities are not directly comparable across years because different total areas were surveyed in each year. However, crude density estimates within individual study areas indicate similar densities between 2004 and 2005 with lower CSO densities in 2006 (Table 2). The crude density estimates for 2005 provided in this report differ slightly from those reported in the 2005 Annual Report for the same year because of updates and corrections to the GIS base survey maps and CSO survey results databases that were conducted in winter 2005-2006 to correct the original survey area boundaries and survey results to make them congruent with the actual watershed boundaries of each survey area. The lower crude density observed in 2006 may suggest a decline in CSO numbers or could reflect lower detection rates for individual CSOs during a second consecutive year of low reproduction and high Spring precipitation. In general, overall survey detection rates are lower and individual owl identification is more difficult in low reproduction years because individual owls are not strongly defending active nests and wander more widely within the landscape.

Table 2. Crude density of territorial California spotted owls across survey areas on the Plumas and Lassen National Forests in 2005 and 2006. Locations of survey areas are identified in Figure 1.

		Crude Density of Territorial Owls (#/km^2)		
Survey Area	Size (km^2)	2004*	2005*	2006*
SA-2	182.5	0.126	0.126	0.115
SA-3	218.5	0.093	0.093	0.093
SA-4	238.3	0.067	0.067	0.046
SA-5	260.3	0.077	0.077	not surveyed****
SA-7	210.4	0.071	0.071	not surveyed
SA-1A	190.5	not included***	0.047	0.042
SA-1B**	130.4	not included	0.023	not surveyed
SA-11	180.0	not included	0.056	0.033
SA-12	192.4	not included	0.088	0.068
SA-13	193.4	not included	0.067	0.067
SA-14	331.2	not included	0.054	0.042
SA-15	317.4	not included	0.041	0.022
Total Study	2,645.3	0.084	0.075	0.061

Area				

*Total Area surveyed each year: 2004 = 1,106 km^2; 2005 = 2,645 km^2;in 2006 = 2,039 km^2.
**Project level area surveyed only in 2005. Included for comparative purposes.
***Lassen Demographic Study Area – incorporated into the overall study in 2005.
****Survey areas not surveyed in 2006.

In January 2006, a meta-analysis was conducted to estimate CSO population trends and to assess population status in response to a petition submitted to the United States Fish and Wildlife Service to list the CSO under the Endangered Species Act (Blakesley et al. 2006). Data collected between 1990-2005 from four CSO demographic studies across the Sierra Nevada and southern Cascades, including the Lassen Demographic Study Area, were analyzed as part of the meta-analysis workshop. The Lassen Demographic Study Area is contained within the overall PLS study area and consists of survey areas SA-1A, SA-11, SA-12, SA-13, SA-14 and SA-15 in Figure 2. Full details on meta-analysis methods and results are provided in Blakesley et al. (2006). In synopsis, across the four study areas results indicated that the Lassen Study CSO population exhibited the strongest evidence for a population decline between 1990-2005. Mean lambda for the Lassen Demographic Study was 0.973, with 95% confidence limits ranging from 0.946-1.001 (Table 3).

Table 3. Mean estimated population lambda (population change) for California spotted owls on four study areas in the southern cascades and Sierra Nevada, 1990-2005 (Blakesley et al. 2006)

Study Area	Lambda	Standard Error	95% Confidence Interval
Lassen National Forest	0.973	0.014	0.946-1.001
Sierra National Forest	0.992	0.013	0.966-1.018
Sequoia-King Canyon National Park	1.006	0.031	0.947-1.068
Eldorado National Forest	1.007	0.029	0.952-1.066

<u>Vegetation Sampling – Nest Plots</u>

Vegetation plot sampling was conducted at a total of 102 CSO territories across 2005 and 2006. Vegetation plots were centered on CSO nest trees were measured using the national Forest and Inventory Assessment (FIA) protocol. The FIA protocol is used nationally by the USDA Forest Service for inventorying and monitoring vegetation. Use of the FIA sampling protocol will facilitate monitoring of vegetation and development of CSO habitat models that can be used as adaptive management planning tools. Habitat models are currently being evaluated that can be used to assess projected changes in CSO nesting habitat suitability under varying fuels and vegetation treatment scenarios.

Banding, Blood Sampling, West Nile Virus Monitoring

Thirty-one owls were captured and banded in 2006. Blood samples were collected from 16 individuals and screened at the University of California, Davis for West Nile Virus antibodies. None of the 76 individuals tested positive for WNV antibodies in 2005. The 2006 samples have not been analyzed to date.

Barred and Sparred (spotted/barred hybrid) Distributional Records:

We detected the presence of 5 barred owl and 3 sparred owls during 2006 surveys within the study area. Our synthesis and update of barred-sparred owl records through 2006 based on Forest Service and California Department of Fish and Game databases indicates that there are a minimum of 36 individual site records across the northern Sierra Nevada (Figure 4). This includes 17 records that have been documented within our intensively surveyed study area. The first barred owl in the region was reported in 1989. Twenty-one of the 36 site-records were recorded and known occupied between 2002-2006. The pattern of records suggests that barred/sparred owls have been increasing in the northern Sierra Nevada between 1989-2006.

California Spotted Owl Diet:

A single survey plot was established at a CSO nest or roost location at each CSO territory on the Plumas National Forest in 2003-2005. Systematic searches for pellets and prey remains were conducted in each plot during each year. A total of 2256 pellets have been collected over the three years (2003 = 606; 2004 = 812; 2005 = 838). To date 1418 pellets have been sorted and all prey items identified to species or taxonomic group when species identification could not be ascertained. Mammals comprised the dominant taxonomic group identified in the diet. The three most frequently detected species were the dusky-footed woodrat (detected in 43% of pellets), northern flying squirrel (detected in 39% of pellets), and *Peromyscus* species (detected in 27% of pellets)(Table 4). The 838 pellets collected in 2005 have been sorted and identification of all prey species is near completion.

Summary 2004-2006

Our efforts to date have focused on collecting the initial data to address our primary research objectives and provide the baseline data for monitoring HFQLG implementation. In conjunction with the now fully integrated Lassen Demographic Study we have collected landscape-scale information on the distribution and abundance of CSOs across approximately 650,000 acres of land. Determining the accurate number and distribution of CSO sites requires multiple years of survey and marking of individual CSOs to delineate separate territories and identify individual birds that move among multiple sites within and across years. These baseline data are fundamental for developing empirically based habitat models for understanding CSO habitat associations and developing adaptive management tools and models. Dedicated monitoring of CSOs on the Lassen Demographic study continues to provide critically valuable demographic and population trend information for determining the status of CSOs. The declining population trend estimated through the meta-analysis of the Lassen Demographic Study data and the overall lower densities observed in 2006 warrant close continued monitoring of the status of CSOs within the study area and continued management focus on providing high-quality CSO habitat. Our focused diet analyses have broadened and deepened our understanding of CSO diets and sources of variation in CSO diets among pairs and across environmental gradients. Monitoring of WNV exposure coupled with demographic monitoring has provided an opportunity for assess if WNV may ultimately be a factor influencing CSO viability. Finally, through our research into historical and current occurrence records, in conjunction with our field surveys, we have been able to document the colonization of the northern Sierra Nevada by barred owls, which may become a potential serious threat to CSO viability.

Current Research: 2007

In 2007 we will continue monitoring owl distribution, abundance, demography, and population trend across the Study Area. Beginning in March 2007 we will initiate a radio-telemetry component to the overall study to address how owls are using habitat within their home ranges. We will attempt to radio-tag 6 pairs of CSOs in 2007. In addition to continuing field surveys in 2007 designed to address our six research questions, we have broadened our emphasis on the development of predictive habitat relationship models as described in the module study plan. We have been working closely with biologists on the Plumas and Lassen National Forests, and the R5 Regional Office, to identify and define the types of analyses and tools that would best address management needs. Baseline information collected through 2006 forms the foundation for this phase of the research. These models should be completed in 2007. The combination of broad-scale landscape CSO distribution data, in conjunction with detailed demographic information available from the Lassen Demographic Study, will facilitate exploration and development of predictive habitat models for use in an adaptive management framework and to directly monitor implementation of the HFQLG project.

Literature Cited

Blakesley, J.A., M.E. Seamans, M.M. Connor, A.B. Franklin, G.C. White, R.J. Gutierrez, J.E. Hines, J.D. Nichols, T.E. Munton, D.W.H. Shaw, J.J. Keane, G.N. Steger, B.R. Noon, T.L. McDonald, S. Britting. 2006. Demography of the California Spotted Owl in the Sierra Nevada: Report to the US Fish and Wildlife Service on the January 2006 Meta-Analysis. February 2006.

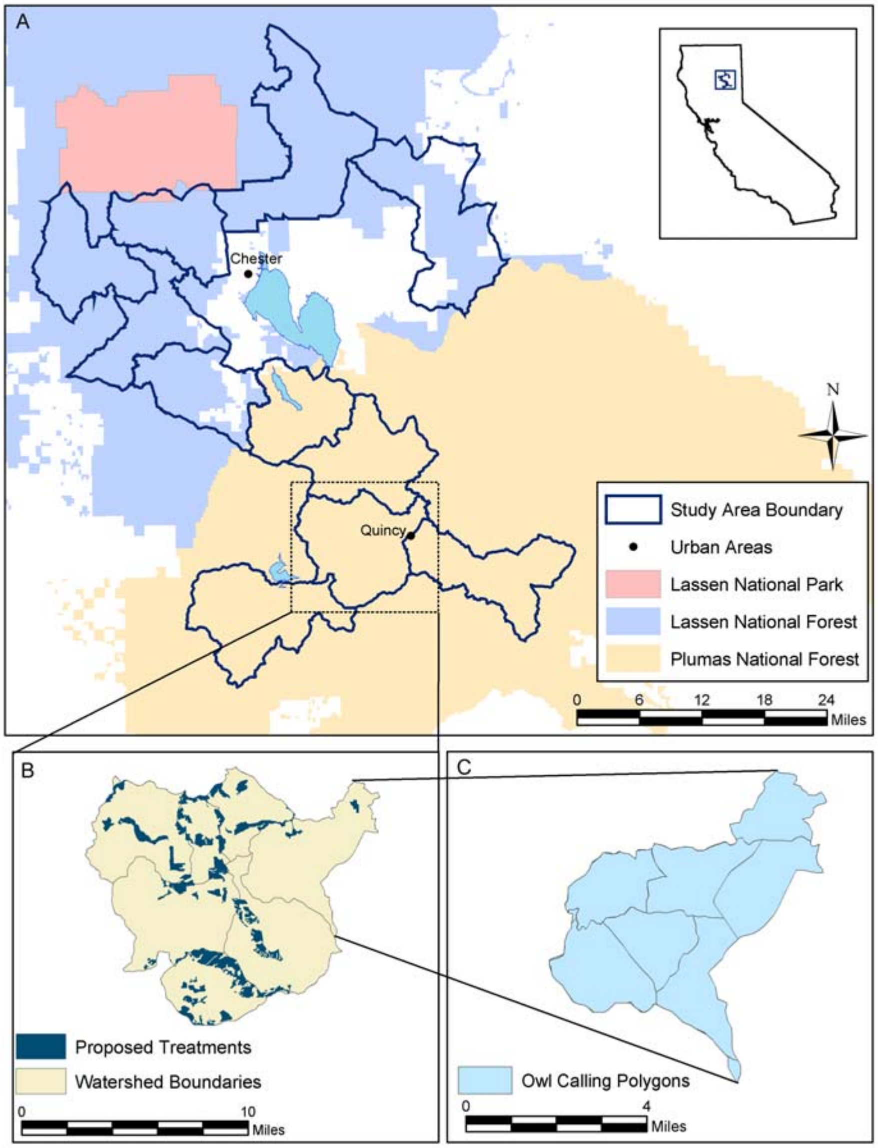


Figure 1. (A) Location of CSO Survey Areas surveyed in 2004-2006. (B) Example of original survey plot consisting of multiple Cal-Planning watersheds. (C) Example of Primary Sampling Units for surveying for CSOs. See text and study plan for further details .

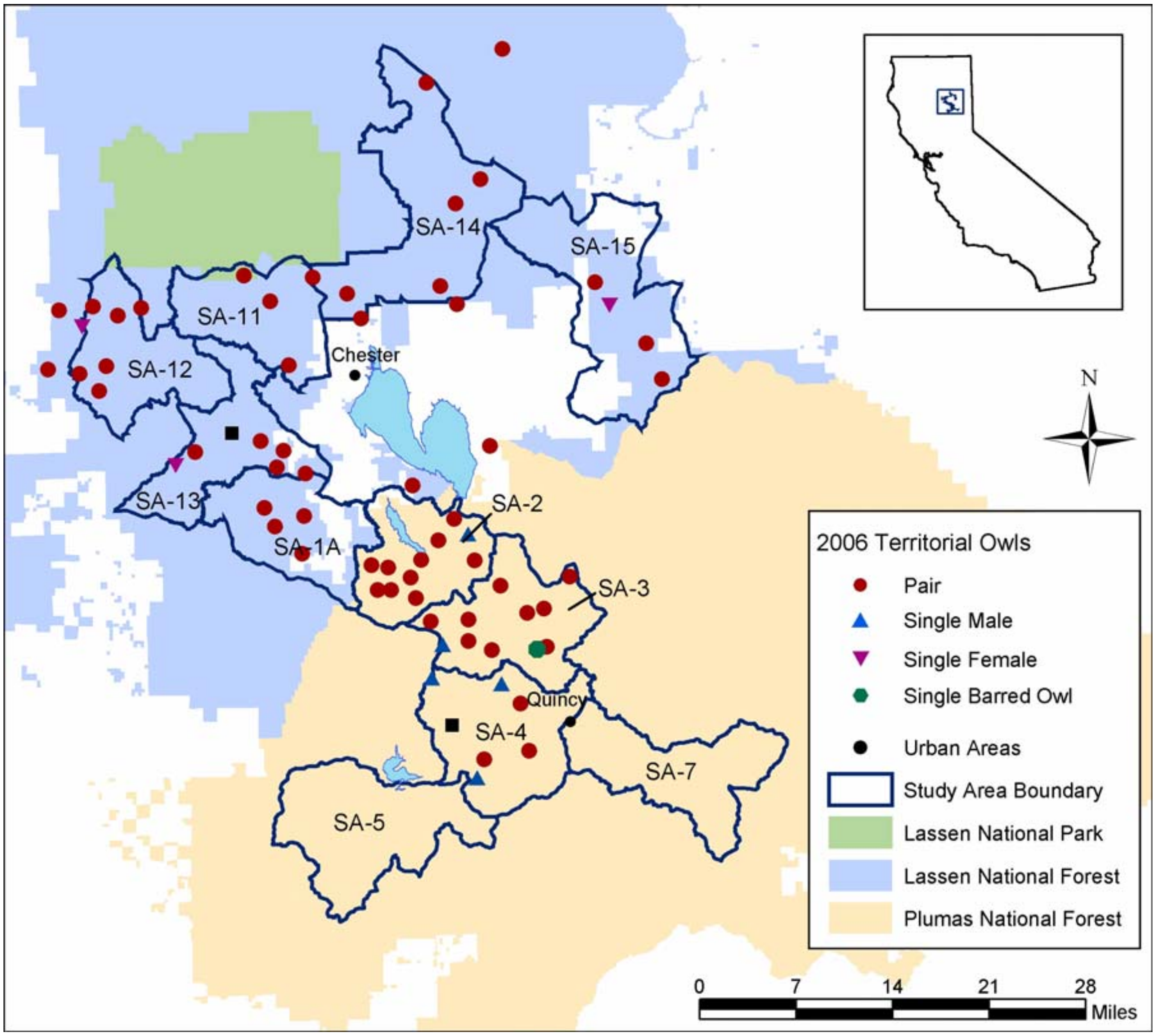


Figure 2. Distribution of California spotted owl territories within CSO survey plots across the Plumas and Lassen National Forests, 2006.

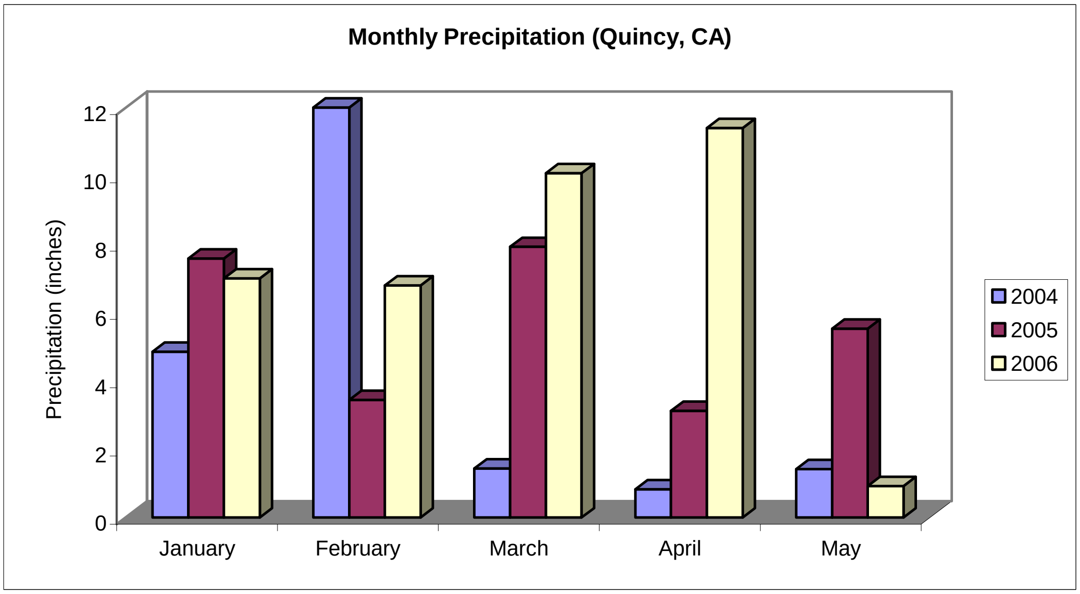


Figure 3. Monthly precipitation totals for Quincy, California, during January-May, 2004-2006 (data from Western regional Climate Center).

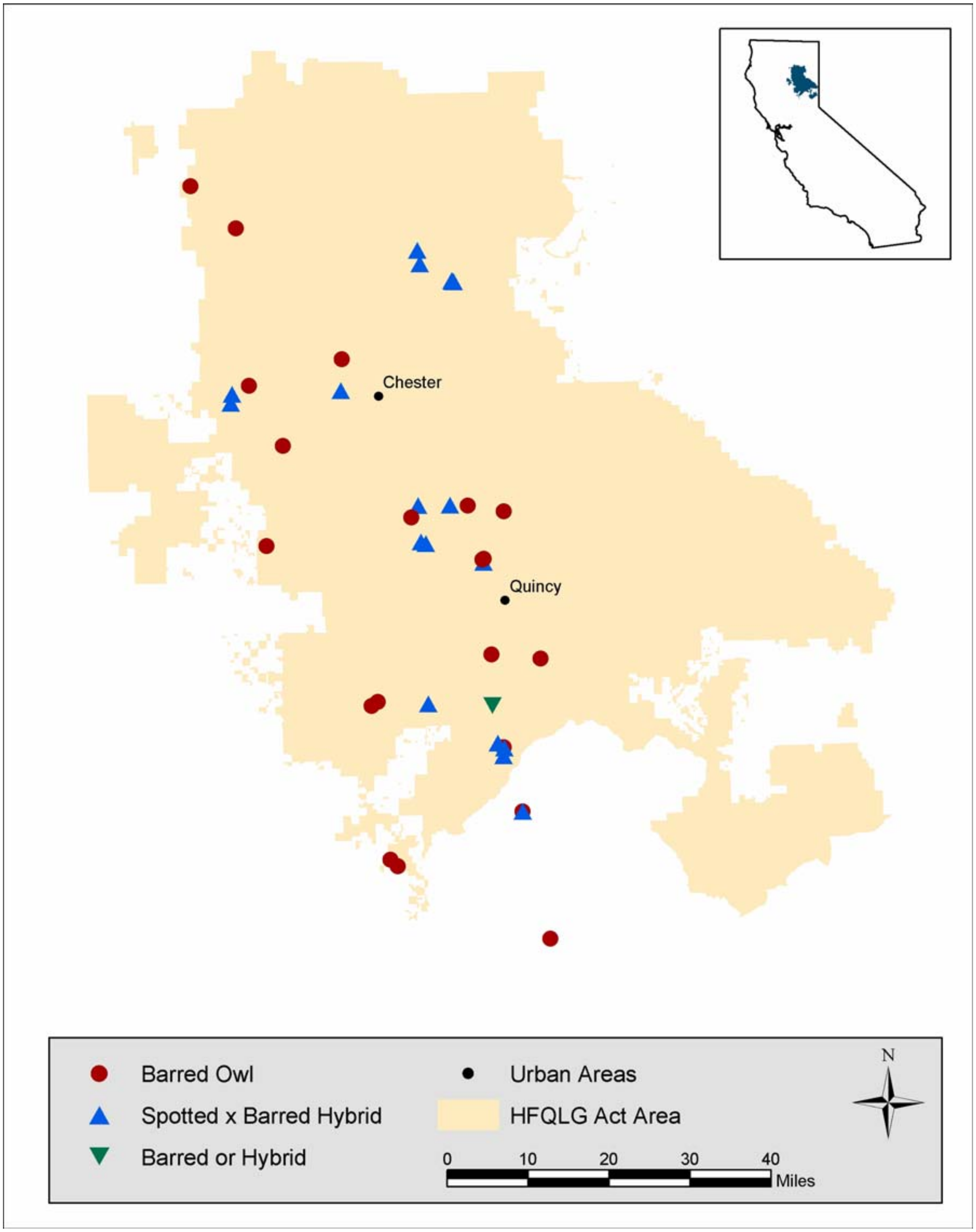


Figure 4. Distribution of Barred and Sparred (Spotted-Barred hybrids) Owls between 1989-2006 within the HFQLG Project area.

Table 4. Prey species occurrences in California spotted owl pellets collected on the Plumas National Forest 2003-2004.

Prey Species	Number of 2003 Pellets Containing Taxon (n=606)	Percentage of 2003 Pellets Containing Taxon	Number of 2004 Pellets Containing Taxon (n=812)	Percentage of 2004 Pellets Containing Taxon	Total Number of Pellets Containing Taxon (n=1418)	Total Percentage of Pellets Containing Taxon
Mammals	**581**	**95.87**	**797**	**98.15**	**1378**	**97.18**
Dusky-footed woodrat (*Neotoma fuscipes*)	287	47.36	318	39.16	605	42.67
Northern flying squirrel (*Glaucomys sabrinus*)	254	41.91	298	36.70	552	38.93
Deer mouse (*Peromyscus* spp.)	145	23.93	237	29.19	382	26.94
Unidentified mouse (*Peromyscus* spp. or *Mus musculus*)	16	2.64	32	3.94	48	3.39
California red-backed vole (*Clethrionomys californicus*)	11	1.82	11	1.35	22	1.55
Meadow voles (*Microtus* spp.)	12	1.98	32	3.94	44	3.10
Unidentified vole	6	0.99	6	0.74	12	0.85
Pocket gopher (*Thomomys bottae*)	26	4.29	73	8.99	99	6.98
Chipmunk (*Tamias* spp.)	6	0.99	32	3.94	38	2.68
Western harvest mouse (*Reithrodontomys magalotis*)	0	0.00	1	0.12	1	0.07
Shrew (*Sorex* spp.)	22	3.63	40	4.93	62	4.37
Broad-footed mole (*Scapanus latimanus*)	23	3.80	89	10.96	112	7.90
Large bat (e.g., *Eptesicus* spp.)	8	1.32	13	1.60	21	1.48
Small bat (e.g., *Myotis* spp.)	10	1.65	8	0.99	18	1.27

Table 4. (Continued)

Prey Species	Number of 2003 Pellets Containing Taxon (n=606)	Percentage of 2003 Pellets Containing Taxon	Number of 2004 Pellets Containing Taxon (n=812)	Percentage of 2004 Pellets Containing Taxon	Total Number of Pellets Containing Taxon (n=1418)	Total Percentage of Pellets Containing Taxon
Unidentified rabbit or hare (family *Leporidae*)	1	0.17	11	1.35	12	0.85
Unidentified large rodent (comparable to a woodrat)	15	2.48	28	3.45	43	3.03
Unidentified small rodent (comparable to a mouse)	30	4.95	56	6.90	86	6.06
Unidentified mammal	3	0.50	2	0.25	5	0.35
Unidentified vertebrate (may include non-mammals)	8	1.32	15	1.85	23	1.62
Birds	**59**	**9.74**	**104**	**12.81**	**163**	**11.50**
Unidentified bird (unknown size)	4	0.66	4	0.49	8	0.56
Unidentified large bird (e.g., American robin)	23	3.80	38	4.68	61	4.30
Unidentified medium bird (e.g., western tanager)	15	2.48	31	3.82	46	3.24
Unidentified small bird (e.g., pine siskin)	12	1.98	20	2.46	32	2.26
Steller's jay (*Cyanocitta stelleri*)	2	0.33	5	0.62	7	0.49
Northern flicker (*Colaptes auratus*)	3	0.50	6	0.74	9	0.63
Insects	**82**	**13.53**	**145**	**17.86**	**231**	**16.29**
Long-horned beetle (*Ergates* spp.)	46	7.59	61	7.51	107	7.55
Giant lacewing (*Polystoechotes lineata*)	11	1.82	25	3.08	36	2.54
Jerusalem cricket (*Stenopelmatus* spp.)	25	4.13	45	5.54	70	4.94
Carpenter ant (*Camponotus* spp.)	1	0.17	11	1.35	12	0.85
Cicada	2	0.33	25	3.08	27	1.90

Unidentified insect	3	0.50	14	1.72	17	1.20