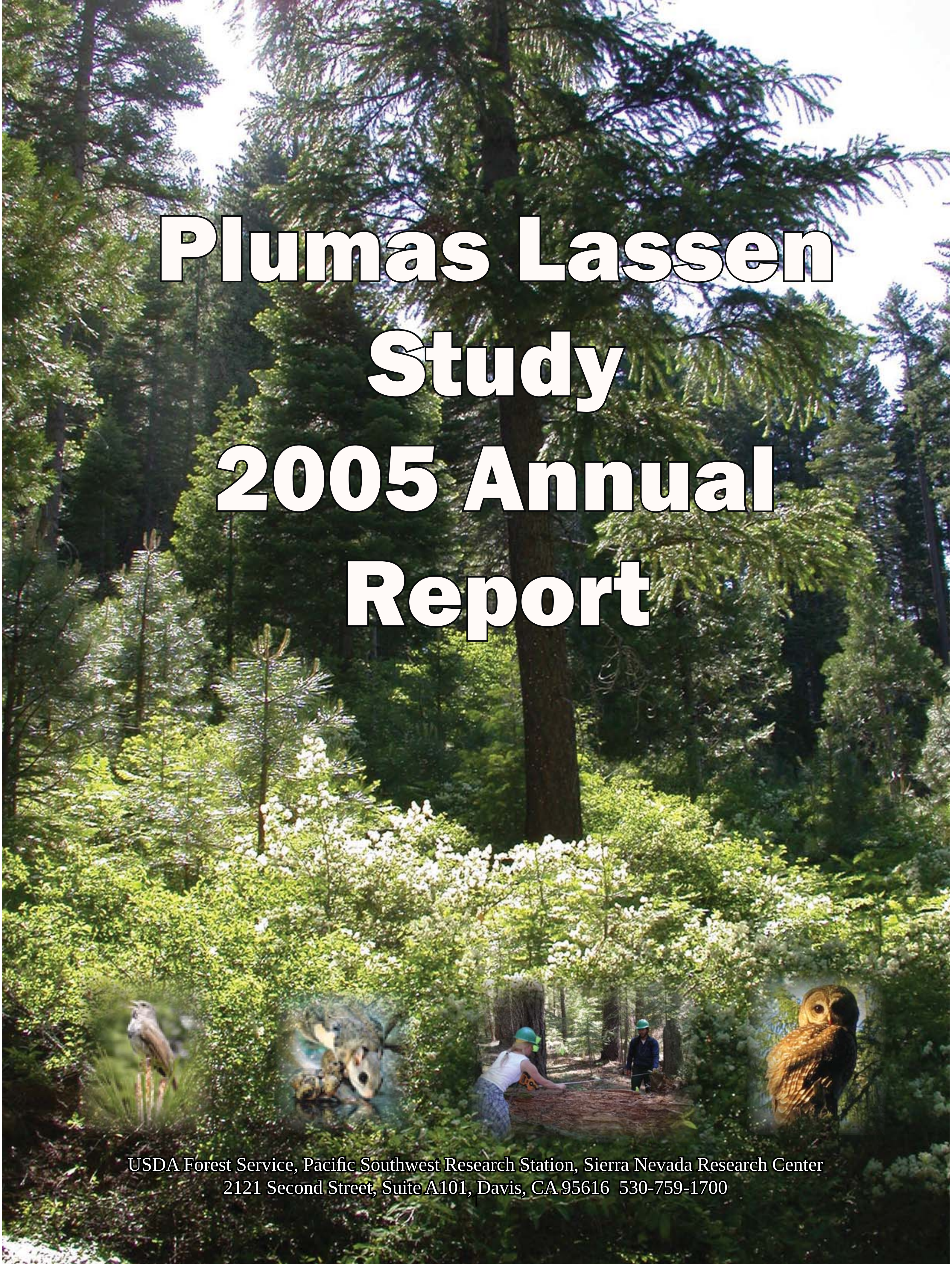

Plumas Lassen Study 2005 Annual Report

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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 upon request.

This is the fourth 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 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 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 just now being put in place 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.

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.

The proposed 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.

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 using FlamMap)?
4. Fire and habitat model integration

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 fourth 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:

Relevant Publications/Presentations
Completed, In preparation, and Poster/Oral Presentations
As of 17 February 2006

Finished Manuscripts/Theses:

Coppeto, S. A., D. A. Kelt, D. H. Van Vuren, J. A. Wilson, and S. Bigelow. "Habitat associations of small mammals at two spatial scales in the northern Sierra Nevada" (05-MAMM-A-086R), for publication in Journal of Mammalogy. I have
tentatively scheduled your paper for the February 2006 issue (volume 87, issue number 1).

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

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

Wilson, J. A., D. A. Kelt, D. H. VanVuren, and M. B, Johnson. Submitted. Population dynamicsof small mammals inhabiting four forest types in the northern Sierra Nevada. Western North American Naturalist.

Keane, J.J., M.L. Morrison, and D.M. Fry. Prey and weather factors associated with temporal variation in Northern Goshawk reproduction in the Sierra Nevada, California. Studies in Avian Biology.

Anderson, D.E., S. DeStefano, M.I. Goldstein, K.Titus, C. Crocker-Bedford, J.J. Keane, R.G. Anthony, and R.N. Rosenfield. The status of northern goshawks in the western United States. Journal of Raptor Research.

Menning, K. M. and S. L. Stephens. "Ladder Fuel Hazard Assessment: A Semi-Qualitative, Semi-Quantitative Approach." To be submitted to International Journal of Wildland Fire.

Manuscripts in Preparation (order of authors and number of authors in flux):

SMALL MAMMAL MODULE

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

Innes, R.J. In Prep. Factors affecting the abundance and distribution of dusky-footed woodrats in mixed-conifer forest of the Sierra Nevada, California. M.S. Thesis, Univ. California, Davis, Winter 2007.

Innes, R. J., D. H. Van Vuren, D. A. Kelt, M. B. Johnson, J.A. Wilson. In Prep. Habitat use of dusky-footed woodrats (*Neotoma fuscipes*) in mixed-conifer forest of the Sierra Nevada, California. To be submitted to the Journal of Mammalogy, Fall 2006.

Innes, R. J., D. H. Van Vuren, J. M. Eadie, D. A. Kelt, and M. B. Johnson, and J. A. Wilson. In Prep. Space use and social organization of dusky-footed woodrats (*Neotoma fuscipes*) in mixed-conifer forests of the northern Sierra Nevada. To be submitted to the Journal of Mammalogy, Winter 2007.

Innes, R.J., Burnett, R., D. A. Kelt, D.H. Van Vuren, M. B. Johnson, and others. In Prep. Local and landscape effects on small mammal assemblages in the northern Sierra Nevada, California. Fall 2008.

Innes, R.J., D. H. Van Vuren, D. A. Kelt, and M. B. Johnson. In Prep. Dispersal ecology of the dusky-footed woodrat (*Neotoma fuscipes*) in mixed-conifer forest of the Sierra Nevada, California. Fall 2008.

TERRISTRIAL 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

Society. June 2005. Gurnsey Creek, Lassen National Forest, California.

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 habit 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.

VEGETATION MODULE

I. Experimental thinning and group selection in mixed-conifer

Seth Bigelow, Malcolm North. Understory irradiance and ecosystem trajectory in western forest after fuels treatments.
Submit Fall 2007, one year after treatments.
Datasets: Light from hemispherical photos at mammal sampling spots. Light penetration through shrub layer from linear PAR sensor. Stand inventory and canopy structure data.
Analyses: before and after treatment comparisons. Are treatment effects enough to foster regeneration of shade intolerants? Use models developed for saplings to estimate effect on understory community.

Jason Moghaddas, Seth Bigelow, Malcolm North. Fuels treatments in western forests: relationship between canopy cover reduction and fire hazard reduction.
Submit Fall 2007, one year after thinning.
Data sets: Stand inventories from FIA measurements, fuels from Brown's lines,
Analysis: Before-after comparison. Use fire model (e.g., FMA,--Fuels Management Analyst) to estimate effects of treatments on rate of spread, crown scorch, mortality.

Jason Moghaddas, Seth Bigelow, Malcolm North. Surface Fuel Consumption and Conifer Mortality in a Mixed Conifer Forest.
. Submit 2008, one year after prescribed fire.
Data sets: Stand inventories & fuels measurements before and after prescribed burning.
Analysis: Compare tree mortality in heavily, lightly, and un-thinned stands.

Malcolm North, Seth Bigelow. Fuels Treatment Effects on Fire Climate.
Submit 2008, 2 years after thinning.
Data sets: air temperature and humidity, wind speed, and fuel moisture, duff moisture, for 3 yrs before thinning to 1 yr after.
Analysis: compare microclimate in thinned and un-thinned stands, before and after treatment.

Malcolm North, Seth Bigelow. Canopy openness effects on soil wetness and the understory plant community.
Submit 2009, 3 years after thinning.
Data sets: mineral soil wetness (2-4 weekly during growing season for 4 yrs), visual assessment of plant understory cover at small-mammal sampling points (annually, for 5 yrs). {Consider shrub height and volume measurements taken for Stephanie Copetto, with follow-up}.

II. Juvenile tree performance along east-west transect of plumas nf.

Seth Bigelow, Malcolm North, and Will Horwath. Performance of Western Conifers along Environmental Gradients: Unifying Community, Physiological, and Silvicultural Perspectives.
Submit Winter 2006.
Data set: sapling growth, light, carbon isotope ratio, soil mineralizable nitrogen, pH.
Analysis: create models of sapling growth with respect to light and soil moisture.

Seth Bigelow, Malcolm North, Carl Salk. Interaction of soil wetness and light on survival of western conifers.
Submit Fall 2007.
Data set: seedling growth and survival over three years. Light, soil wetness.
Analysis. fit models of survival with respect to light and soil moisture using maximum likelihood.

III. Papers on group selection silviculture in east-side pine

Seth Bigelow, Malcolm North. Group selection harvest impacts in an ecotonal environment.
Submit Fall 2006.
Datasets: soil wetness at three depths over 1-2 seasons, understory cover and species composition, soil bulk density, overstory canopy, survival of natural and planted seedlings.
Analyses: compare inside and outside group selection openings and natural openings.

Seth Bigelow, Sean Parks. Landscape analysis of group selection placement strategy in an ecotonal environment. Submit Spring 2006.
Datasets: Orthoquads of east-side.
Analyses: Placement of simulated group selection openings in neutral gradient landscape model and real landscape (binary), followed by edge analysis. Is there a critical density at which edge location shifts?

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.

Presentations and Posters:

Coppeto, S. A., D. A. Kelt, D. H. Van Vuren, J. A. Wilson, S. Bigelow, and M. B. Johnson. 2005. Spacial scale and habitat use of small mammals in the northern Sierra Nevada, California. Poster 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.

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, Humbolt, 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.

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:) Forest Structural Diversity: Spectral Entropy Canopy Diversity Analysis. Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf, Switzerland. December 5, 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. December 12, 2005.

Bigelow, S. W., M. P. North, and W. R. Horwath. 2006. Performance of Western Conifers along Environmental Gradients: Unifying Community, Physiological, and Silvicultural Perspectives. Presentation to U. C. Davis community ecology seminar.

Oral Presentations

Burnett, R.D. Integrating Avian Monitoring into Forest Management. Washington, Oregon, California Joint Partners in Flight Meeting. April 2005. Ashland, Oregon. and Plumas Audubon Society October 2005.

Howell, C.A. Local versus Landscape factors for coniferous forest birds. Washington, Oregon, California Joint Partners in Flight Meeting. April 2005. Ashland, Oregon.

Burnett, R.D. and C.A. Howell. Assessing Forest Management: Monitoring Songbird Populations in the Northern Sierra Nevada. Feather River College Plumas Lassen Administrative Study Symposium. March 2005. Quincy, California.

Howell, C.A. Conservation in Practice: Monitoring Birds to Guide Conservation in California. Bay Area Conservation Biology Forum at Stanford University. January 2005. Palo Alto, California.

Howell, C.A. Conservation in the Hot-spots. Presentation at PRBO staff meeting. May 2005. Stinson Beach, California.

Summary

This work represents some significant scientific study that has occurred over the last four years and is expected to continue for up to next five 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:

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Field Personnel in 2005

- Suzanne Lavoie
- Bridget Tracy

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)

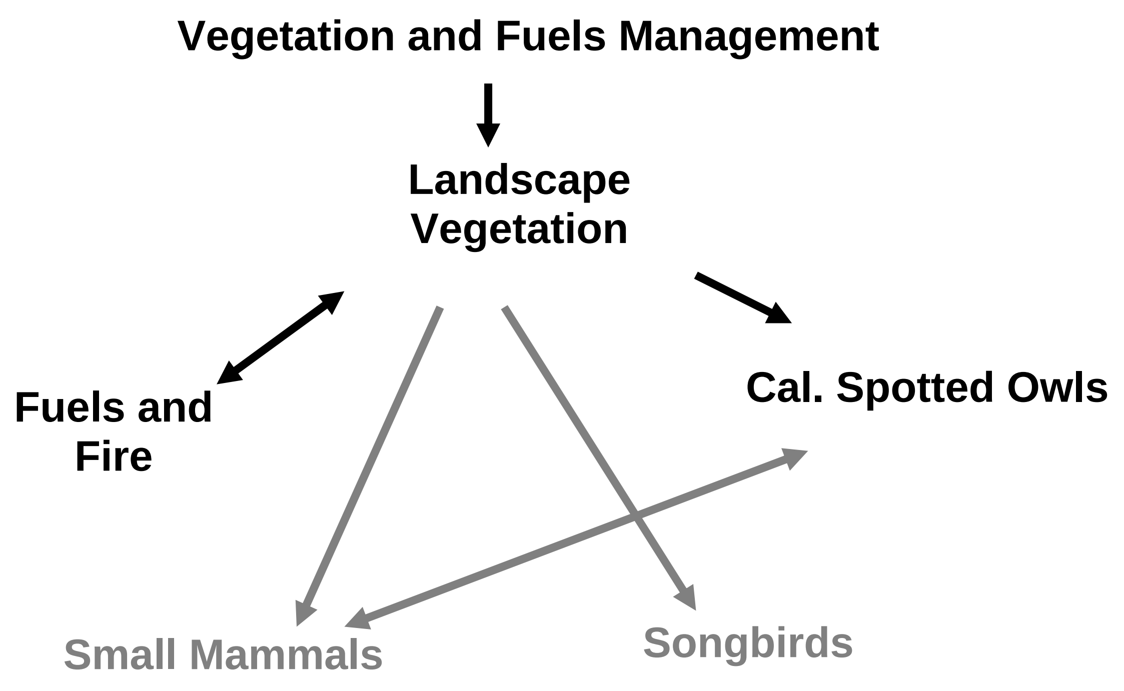


Table 1: Fuels and Fire Module: Summary of hierarchical arrangement of study topics

- 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 (LANDSAT 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 Remote sensing of annual fine fuels production using LANDSAT
    - 1.2.3 Ladder fuels: probability of fire ascending forest canopy (LaFHA)
    - 1.2.4 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)

- 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 Link current vegetation coverages to potential fire behavior & effects (as above)
  - 4.2 Provide link from vegetation coverage to Keane's owl habitat assessment
  - 4.3 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

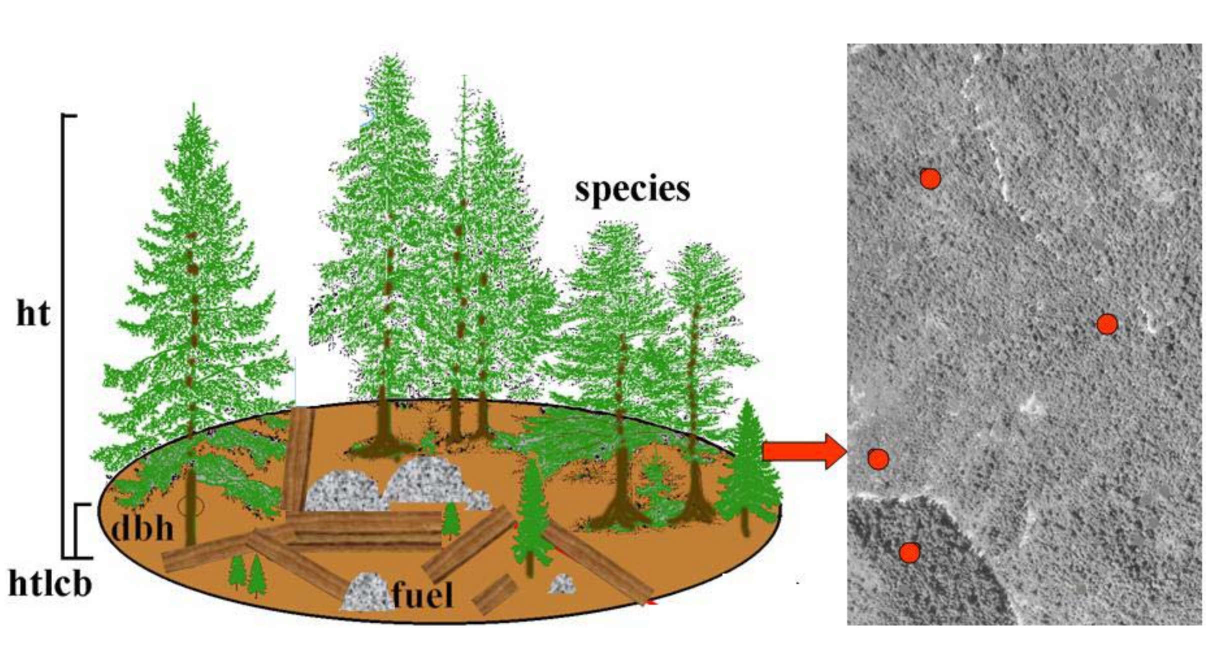
Plot Layout and Design

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

Two different remote sensing methods are being implemented. First, high spatial resolution IKONOS provides 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.

Second, an approach similar to that developed by van Wagtendonk and Root (2003) in Yosemite National Park is being used to provide information on vegetation and the annual cycle of fine fuel production. Two thematic mapper (TM) scenes are used to help differentiate the forest types. One TM scene is obtained in June and another over the same area from October. The two scenes are used to differentiate the vegetation types including forests, deciduous hardwoods, montane chaparral, wet meadows, and dry meadows. These are verified using data from the extensive network of field plots.

The spatial resolution of this second class of remotely sensed data is 30m by 30m. Bands 3 and 4 are being used from the TM data to calculate Normalized Difference Vegetation Index (NDVI). The result of this procedure will be a forest ecosystem map that will include rock, meadows (dry and wet), bare ground, montane chaparral, riparian areas over 30 m in width, and the three most common forest types (ponderosa pine, mixed conifer, white fir). Comparison of the pre- and post-summer growing season images will allow us to quantify the production of fine fuels in a variety of vegetation types. This will lead to more realistic inputs the fire modeling process.

Methods: Data Processing, Analysis and Model Integration

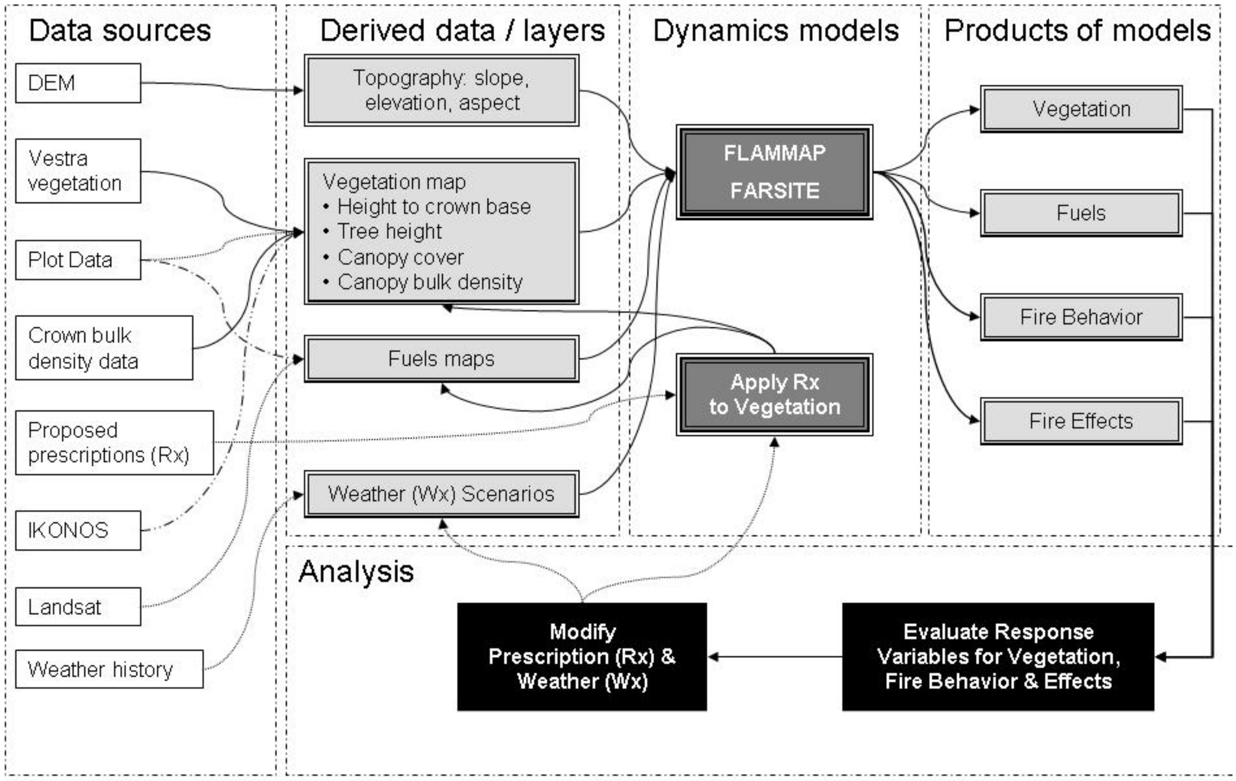
Fire behavior models such as FARSITE require maps of vegetation, topography, and fuels, as well as weather scenarios, in order to model the spatial behavior of fire (figure 3). These data are integrated from a variety of different sources. Development of the vegetation map has been described above, in 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).

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



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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 Landsat imagery analysis (van Wagtendonk and Root 2003). 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 50th (average) and 90th (extreme) percentile condition 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.

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).

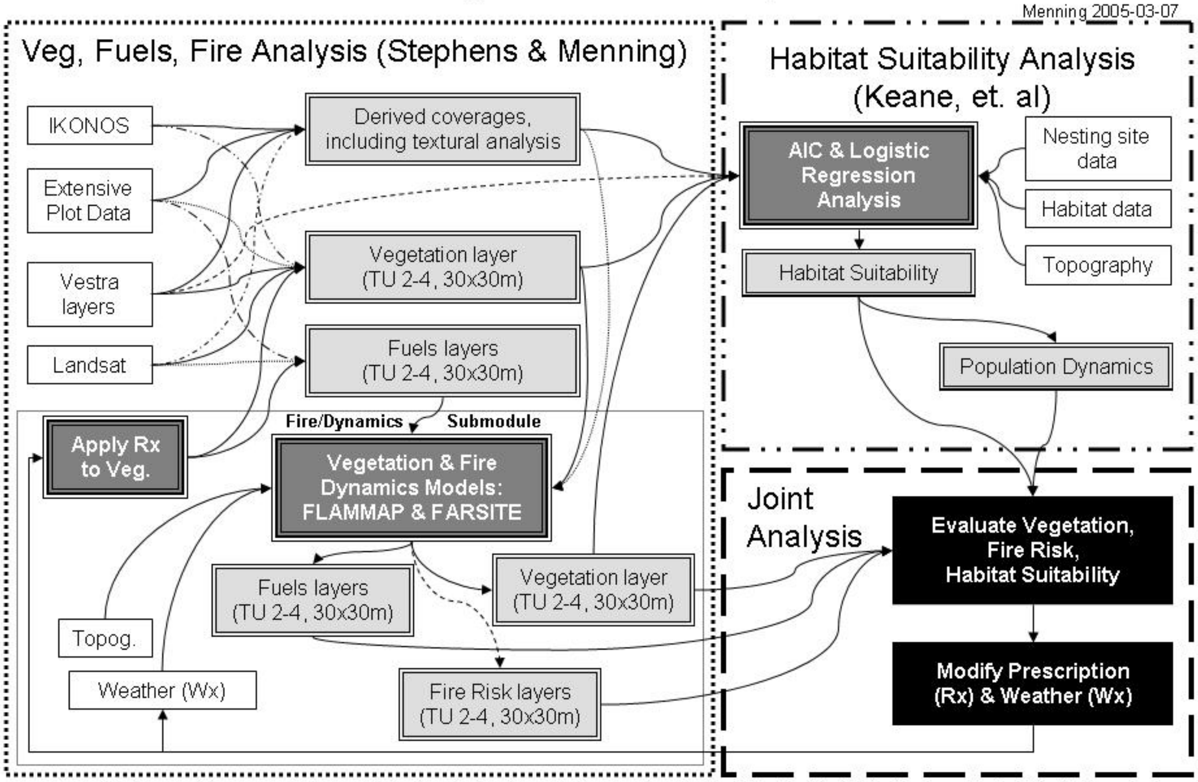
Fire and Habitat Model Integration

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 and LANDSAT 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).

Figure 4: PLAS Landscape Vegetation, Fire and Habitat Model Integration and Projection

Note: Vegetation, Fuels and Fire module diagram (left column) simplifed from Figure 4.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Key: white boxes = data sources; light grey = derived products or layers; dark grey = dynamics/analytical models; black = human evaluation & decision space

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 2005

Field

A field crew of two seasonal workers—Suzanne Lavoie and Bridget Tracy—were trained in field work by Kurt Menning. Suzanne and Bridget worked in the field for three months, from late May to late August. Suzanne did additional work in the office prior to and after the field season. Kurt spent 16 days in the field this summer with the field crew.

The field crew added 227 plots this summer, almost exclusively from TU2, the northernmost and steepest area in our study area. Lavoie and Tracy were quite capable and made a good team with minimal conflict.

In 2003, we inventoried 67 plots with the vegetation crew headed by Malcolm and Seth. In 2004, we added another 200 plots with our field crew. As a result of these three field seasons, we have a total of just under 500 plots for the three treatment units that comprise our study area (TUs 2-4). Of the 494 plots, most will have fully useable data. There are a few data holes that will prevent all plots from being used for all analysis. I would estimate that about 95% are fully useable, however.

In addition to these plots, the Songbird Module has been conducting rapid inventories of plots along their transects. These have been invaluable for adding data on ladder fuel hazards as well as total fuel loads across the landscape using the Fuel Photo Series. We are awaiting word of the current tally of these plots. They total several hundred from 2004 alone.

Remote Sensing

Remote sensing Imagery was acquired for TU 3&4 (2003) and TU 2&3 (2004). No new imagery was acquired in 2005 until current methods could be tested with the existing imagery. Processing and analysis of this imagery is currently underway and initial results will be presented in March 2006.

Modeling Fire and Integrating with Wildlife Habitat Analysis

Integrative modeling has been mapped out and presented in Quincy as part of the annual meeting in 2005. The actual modeling will proceed in spring 2006 when base inputs of field data in the project database, remote sensing products, and interpolated fuels maps have been prepared. Initial results will be presented in March, 2006.

Publications 2005

- Menning, K. M. and S. L. Stephens (submitted 2005). "Ladder Fuel Hazard Assessment: A Semi-Qualitative, Semi-Quantitative Approach." Forest Ecology & Management.

Presentations 2005

- 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 2006

Spring

Remote sensing processing and analysis and fire behavior and effects modeling are our primary goals in spring 2006. The field data database has been completed and interpolated fuels maps are being developed. Integrative modeling of fire and habitat scenarios with John Keane and the owl module has been mapped out and will proceed in late spring when remote sensing layers and interpolated fuels maps have been prepared.

Field Season

We plan to put a field crew of two (plus one part-time postdoctoral supervisor) back into the Plumas National Forest for three months. The team will have two functions: inventory new plots in TUs 2-4, and revisit a collection of previous plots to measure change in fuels and forest structure and cover. If initial results of the remote sensing analysis are successful (late winter), we plan to acquire new imagery (Landsat, IKONOS) using existing funds. No new request for funds is planned.

Autumn

Autumn goals include importing cleaned field data into the database, continuing remote sensing and modeling analyses and furthering the fire behavior and effects modeling. All these will be done with the goal of publications (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.

Publications Planned for 2006

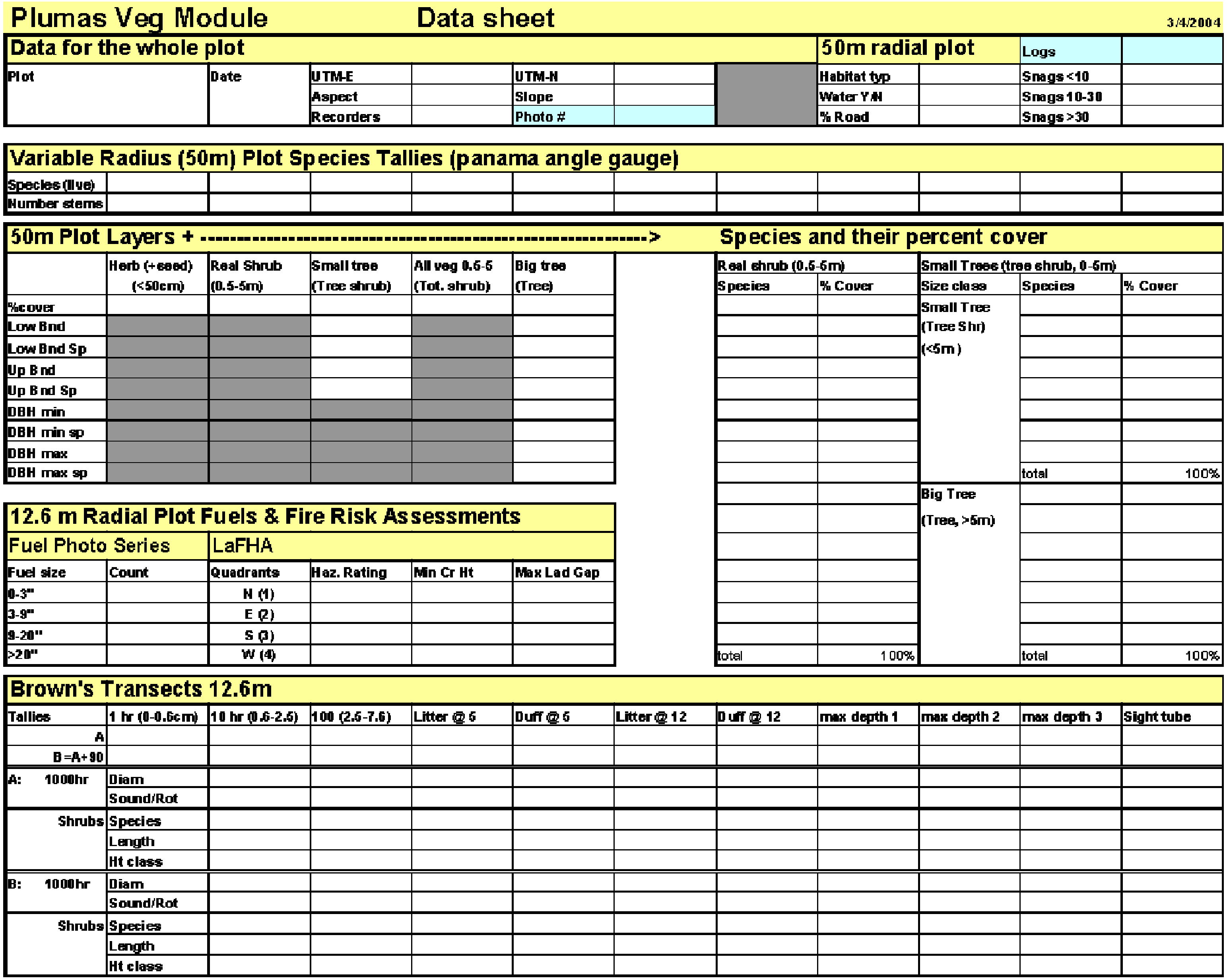
- Menning, K. M. and S. L. Stephens. "Spectral Entropy Canopy Diversity Analysis (SpECDA) used to Assess Variability in Forest Structure and Composition" To be submitted to Photogrammetric Engineering and Remote Sensing.
- Menning, K. M. and S. L. Stephens. "Fire Behavior and Effects as a Result of Defensible Fuel Profile Zones" To be submitted to International Journal of Wildland Fire.
- Menning, K. M., S. L. Stephens, J. Keane (invited) and others. "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. "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							50m radial plot		Logs	
Plot	Date	UTM-E		UTM-N			Habitat typ		Snags <10	
		Aspect		Slope			Water Y/N		Snags 10-30	
		Recorders		Photo #			% Road		Snags >30	

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

Species (live)											
Number stems											

50m Plot Layers + -->

	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					

Species and their percent cover

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										

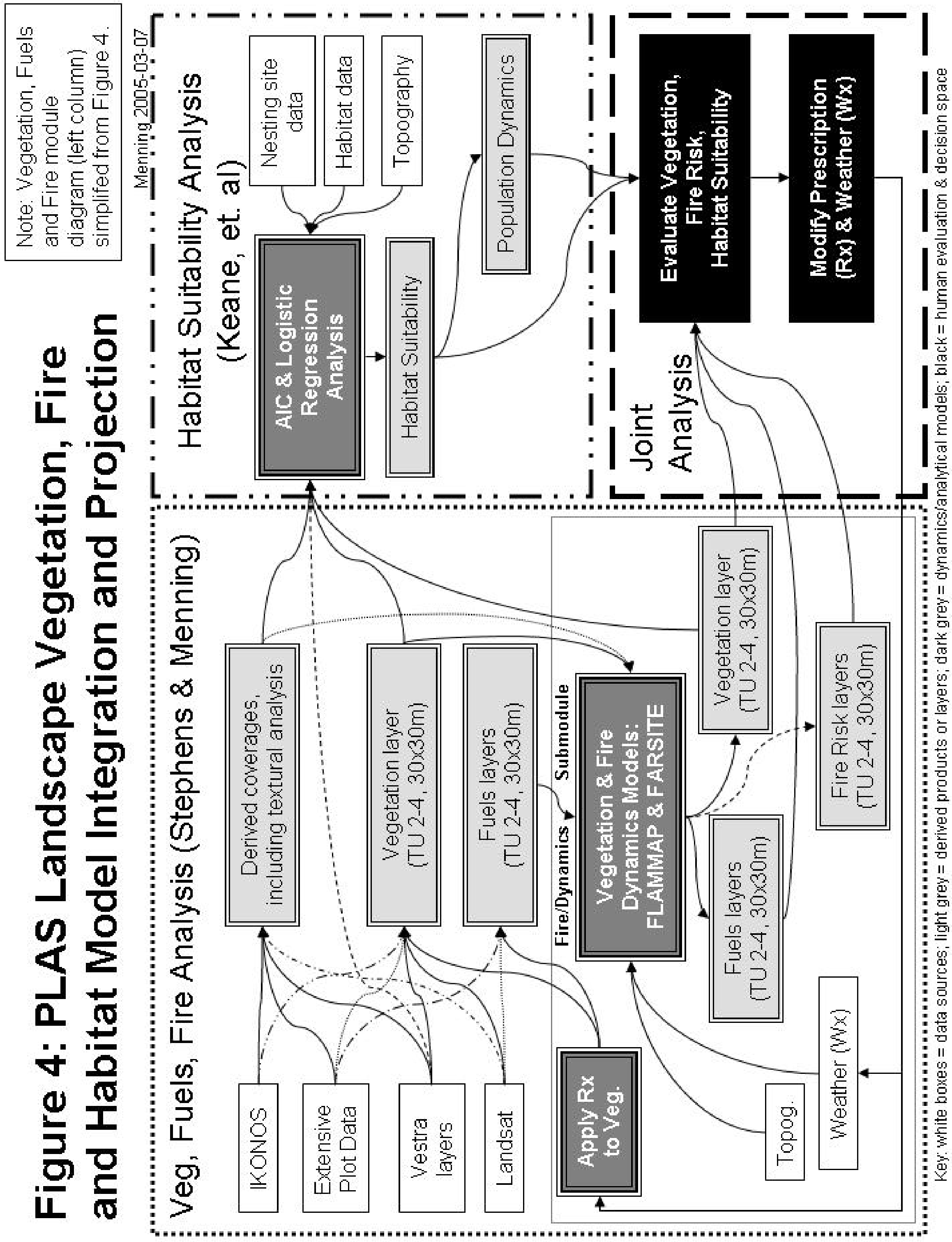
Appendix A (continued): Datasheet for field data collection, page 2 of 2

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.

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Objectives

The vegetation module of the Plumas-Lassen Administrative Study is focused on studying how changes in the forest canopy affect ecosystem functioning. Aspects of ecosystem function studied include understory microclimate, and growth and competition of shrubs and juvenile trees, and understory diversity. 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.

<u>Research activities 2005</u>

Group selection impacts in East-Side pine: stand scale. A project was initiated on the Beckwourth Ranger District to determine ecosystem effects of group selection harvesting in patchy East-Side pine types. The study took place in two areas where group-selection harvesting projects (the Red Clover and Stony Ridge projects) had taken place in 2002 and 2003. Measurements of microclimate, soil water, and plant community were taken along paired transects inside and outside of group selections and natural gaps. Our hypothesis was that the canopy openings associated with group selection silviculture would significantly affect the regeneration environment by drying out surface soils.

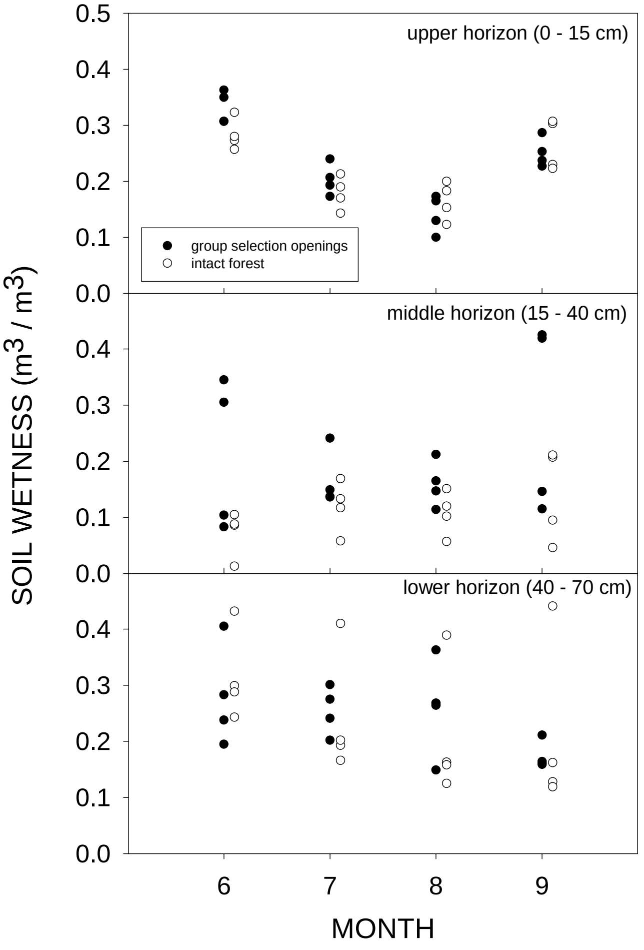


Figure 1. Volume soil wetness in group selection openings and nearby intact forest in the Red Clover project area. Each data point is a mean of readings at three locations along a transect. Readings were taken from June-September 2005.

These hypotheses have not been well supported by the data. Soil wetness appears to be slightly higher in group selection openings during the early season, at least in the 0-15 and 15-40 cm soil layers. Nevertheless, mortality of planted seedlings was high in the Stony Ridge project area, approaching 35% during the one season of this study.

Group selection impacts in East-Side pine: landscape scale (Seth Bigelow and Sean Parks). We are investigating whether group selection silviculture disrupts landscape connectivity and increases fragmentation of a patchy, ecotonal East-Side forest. Four areas in which group selection harvests took place in 2002 and 2003 were located on aerial photographs (DOQQ's). The DOQQs were classified into binary (tree cover / non-cover) at the 1 m^2 scale, and percolation was tested for in a pre-treatment state, and after a simulated harvest had been applied by converting pixels from cover to non-cover in the area where the group selection openings were made (Figure 2) In a landscape percolation occurs when a cover type extends from one side of an area to another without breaks.

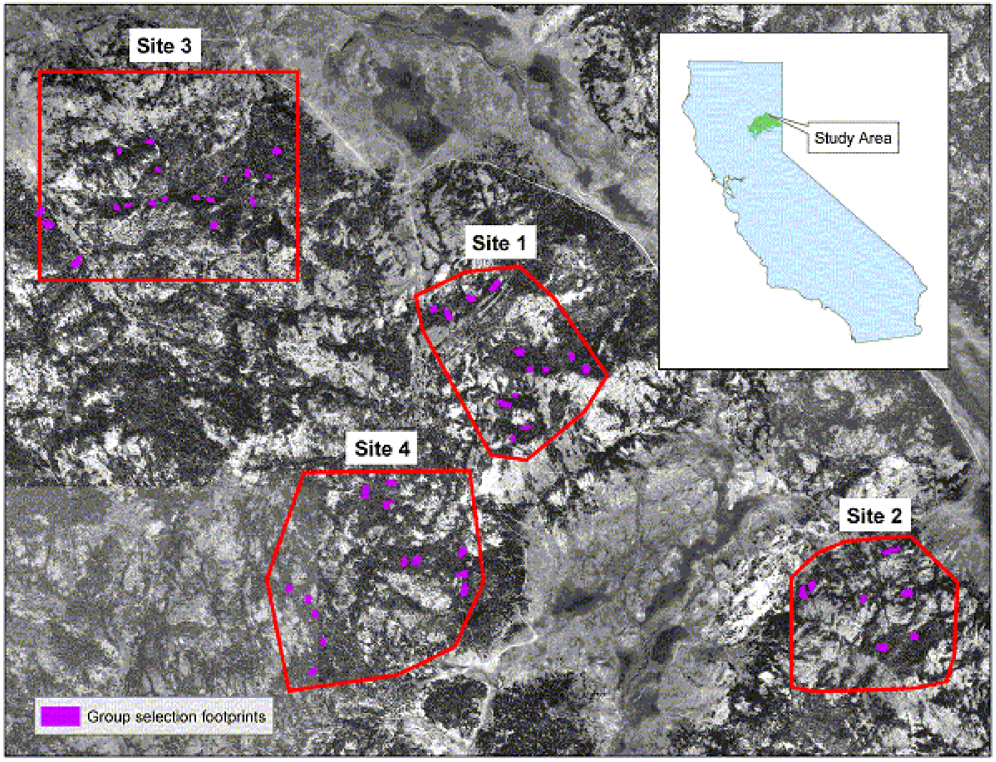


Figure 2. Aerial photograph of study landscape on Beckwourth Ranger District of Plumas National Forest. Photo was taken prior to group selection harvest: location of treatments is superimposed. Prior to treatment, sites 1, 2 and 4 percolated and site 3 did not. Application of group selection disrupted canopy cover connectivity in site 2, changing it from percolating to non-percolating.

Three of the four sites percolated prior to group selection harvest, and harvest changed one of these three sites from percolating to non-percolating. The significance of non-percolation has not been definitively established in the conservation literature, but may be associated with decreased ability of some animals to travel through landscapes. We are developing guidelines for simplified determination of when management actions may disrupt landscape connectivity.

Study on Effects of Experimental Thinning and Group Selection on Forest Structure, Fire Climate, and Plant Communities in West-Side Mixed-Conifer Forest. We continued to collect pre-treatment data in nine 22-acre plots and three 2-acre plots for this study. Data relevant to fire climate include 1) air temperature and humidity (at 0.2 and 2 m above ground), and windspeed (continuous monitoring), and 2) moisture in duff and 1000-, 100-, and 10-hr activity fuels at 2-4 week intervals. Data relevant to plant community development included 1) visual assessment of plant growth and species composition at 100 sampling points in each plot, 2) measurement of light penetration through the shrub layer at the same points, and 3) soil temperature (2 cm below mineral soil surface) and soil wetness in the 0-15 cm, 15-40 cm, and 40 – 70 cm horizons.

We worked with the staff of the Mt. Hough Ranger District and Annie Buma of the Act 2 Team to produce an Environmental Analysis (EA) for the treatments required for the canopy thinning and group selection. (The EA is required because one of the planned treatments brings canopy cover down to 30% and thus falls outside of the forest standards and guidelines on several parts of the experimental plots totaling less than 11 acres.) Trees to be thinned on the experimental plots were marked by a Mt. Hough RD team. A formula for determining spacing ratios to achieve canopy cover targets based on the assumption of triangular spacing was developed by Seth Bigelow (formula and derivation are given in the appendix). Once this formula is validated by peer reviewers we expect that it will be a useful tool for planning and implementation of thinning projects.

Study on mortality rate of mixed-conifer saplings with respect to soil conditions and canopy cover (*Seth Bigelow, Carl Salk, and Malcolm North*). The third census of the 500 saplings in this study took place this season; mortality rates are exceedingly low at well under 5% per year for all species. The study will be complete after the 2006 field season.

Study on stand structure at spotted owl nesting and activity sites. The vegetation module crew coordinated data collection on and participated in surveys of owl nesting and activity sites using Forest Inventory and Analysis protocols. Results are presented in the owl study section.

Outreach, Collaboration, Training, and Safety

Outreach

Vegetation module personnel gave three public research presentations at the 2005 Plumas-Lassen study symposium. A web page describing our research was prepared: www.fs.fed.us/psw/programs/snrc/forest_health/plumas_lassen_study_veg.shtml. Vegetation module personnel assisted in the 2005 Herger-Feinstein Quincy Library Group projects monitoring tour by presenting data on forest structure gathered in the as-yet-untreated plots that are part of the experimental canopy thinning and group selection study. Vegetation module personnel contributed to the Forestry Institute for Teachers II (FIT-II), presenting a research overview at an evening session and leading a day-long field research experience for FIT-II participants.

Collaboration

Module personnel continued to work with the staff of the Mt. Hough Ranger District to produce an Environmental Analysis (EA) for the treatments required for the canopy thinning and group selection study in accordance with the National Environmental Protection Act. The EA is required because the treatments exceed the standard and guidelines in some parts of the forest.

Training and Personnel Development

Seth Bigelow participated in a two-week course entitled likelihood methods in forest ecology at the Institute of Ecosystem Studies, Millbrook, New York. The four members of the 2005 vegetation crew did a two-day course on wilderness first aid, and one member of the crew did a 1-day course entitled Introduction to NEPA/CEQA for Botanists. Carl Salk, the GS-7 level crew leader, left the USFS after 2.5 years employment to attend the Graduate Program in Ecology at Duke University. Carl was awarded a National Science Foundation Pre-Doctoral Fellowship to support his planned research on tropical tree regeneration.

Publications

Work on a paper, entitled "Performance of western conifers along environmental gradients: unifying community, physiological, and silivicultural perspectives" is nearly complete and the manuscript will be submitted to Canadian Journal of Forest Research in February 2006.

Safety

No accidents occurred during the 2005 season.

Appendix A.

Derivation of general equation for predicting spacing ratios given a desired canopy cover

Seth Bigelow
November 10 2005.

A general formula for the factor by which tree diameter is multiplied to get intertree distance to achieve a desired canopy cover target assuming triangular tree spacing is

$$R = \sqrt{91 / C(\%)},$$

where R is the factor by which tree diameter is multiplied and C is canopy cover in percent. We'll assume even, triangular spacing, and we'll also assume that the radius of a tree's crown, in feet, is equal to half its DBH (in inches). So, a tree of 10" DBH would have a crown radius of 5 ft.

$$\text{Tree crown radius} = DBH / 2$$

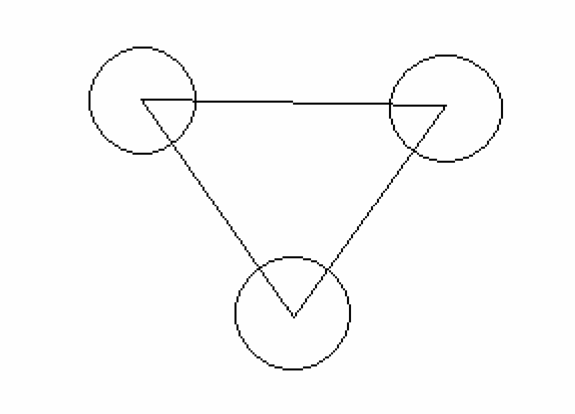
To solve the problem, let's define R as the ratio of intertree distance, D, to DBH, thus

$$R = D/DBH$$

We'll use this at the last step. And let's define canopy cover, C, as area of canopy cover (A_c) over area of ground (A_g), i.e.,

$$C = A_c/A_g$$

A triangular (equilateral) piece of ground with a tree at each apex would be covered by an area of tree canopy equivalent to half the crown of a single tree.



The area of a single tree crown is A_{ct}

$A_{ct} = \pi r^2$
$A_{ct} = \pi (1/2 * DBH)^2$
$A_{ct} = (\pi * DBH^2)/4$

So the area of the triangle covered by canopy (A_c) would be

$A_c = A_{ct} / 2$
$A_c = (\pi * DBH^2)/8$

Next we calculate the distance, D, between the trees at the apices of the triangle. The area of a triangle is ½ base times height, and in this case base (and hypotenuse) is equivalent to D. It's a equilateral triangle so we can solve for height: sin(θ) = opposite/hypotenuese, so

Opp = Hyp*sin(θ).

From the trigonometric concept of a unit circle, sin(θ) =sqrt(3)/2, so Opp=D*sqrt(3)/2, and

$A_g = 1/2\ D * (D * \mathrm{sqrt}(3)/2)$, or
$A_g = D^2 * \mathrm{sqrt}(3)/4$

Now, we can substitute these two findings into the canopy cover equation, $C = A_c/A_g$.

$C = ((\pi /8) * DBH^2) / (D^2 * (\mathrm{sqrt}(3)/4)))$

Rearrange algebraically, and get…

$D^2/DBH^2 = \pi / (C*2*\mathrm{sqrt}(3))$

Taking the square root of each side,

$D/DBH = \mathrm{sqrt}\ (\pi / (C*2*\mathrm{sqrt}(3))$

Recall that R = D/DBH. If we solve for π/(2*sqrt(3)), and change canopy cover (C) units to percent, we get

$$R = \sqrt{91 / C(\%)}$$

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

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INTRODUCTION

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

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

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

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

OBJECTIVES

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

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

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

Habitat associations of small mammal populations in the northern Sierra Nevada. This was investigated using multivariate techniques to identify key habitat characteristics used by individual species of small mammals. Nine additional grids were established in various representative habitats throughout the study site. Habitat grids were established in triplicate for each habitat, and did not necessarily need to be located near other grids in the same habitat type.

Dynamics of key spotted owl prey: dusky-footed woodrat and northern flying squirrel. Dusky-footed woodrats (*Neotoma fuscipes*) and northern flying squirrels (*Glaucomys sabrinus*) are of particular concern to forest managers, as they comprise a major portion of California spotted owl diets. We will capture and radio-collar dusky-footed woodrats and perform monthly radio-telemetry throughout the season. Through the use of radio-telemetry we will identify home ranges and nest locations for both sexes and various age classes. In addition, we will capture as many flying squirrels as we can and radio-collar them for use in home range analyses.

Fitness correlates to forest management. Some taxa may not exhibit numerical responses to forest treatments, but the quality of individuals as prey items may be altered, with important implications for spotted owls or northern goshawk. In particular, fat deposition is critical in ground squirrels that live off these stored reserves while hibernating. We will capture and follow 9 females of naturally varying fatness. All individuals will be captured and have their mass, body composition, and overall health measured. Offspring from these natural females will be captured, radio-collared, and followed to determine the effects of maternal body condition on offspring fitness, dispersal, and home range establishment.

Taxonomy and classification of Sierra Nevada chipmunks. Chipmunk species in the Plumas and Lassen National Forests display considerable overlap in habitat requirements, diet, and activity. Additionally, two species (long-eared chipmunk (*Tamias quadrimaculatus*) and Allen's chipmunk (*Tamias senex*)) overlap in appearance to such an extent that they are virtually impossible to identify without using skeletal features. We will collect tissue samples from all chipmunk species to use with molecular markers to determine species identification. In conjunction with molecular identification we will collect data on various aspects of each chipmunk's appearance. We will compare external characteristics with molecular identification to determine what characteristics, if any, are reliable for species identification. While this is not central to the present study, we have begun to establish collaborations with chipmunk taxonomists towards better understanding the nature and distribution of these species using outside funds.

METHODS – 2005 Field Season

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

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

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

Population demographics will be modeled by species using program MARK. Species that do not have enough individuals to generate detailed capture history will be modeled using the minimum number known alive (MNKA) parameter. Survival and population densities will be modeled for each species by habitat type using the Cormack-Jolly-Seber data type in program MARK.

Habitat associations of small mammal populations:

We continued to trap the habitat grids during June and October as was described above. However, no macro- or microhabitat characteristics were measured during the 2005 field season. Continued trapping on habitat grids will provide information on the variability found among the different habitats across years. Information from continued trapping will be used to build prey models for spotted owls in the Plumas/Lassen National Forests.

Dynamics of spotted owl prey taxa:

Dusky-footed Woodrat:

This study was conducted within the Sierra Nevada mixed-conifer forest type in Plumas National Forest, Plumas County, California between 1450-1750 m elevation near Meadow Valley, California. Study area boundaries and broad-scale habitat features were derived from

GIS data layers provided by the USDA, Forest Service. Four study areas (hereafter, Black Oak, Gulch, Oasis, and Shrub) where placed in early-seral forest, indicative of the Sierra Nevada mixed-conifer forest type (characterized by California black oak, *Quercus kelloggii*; white fir, *Abies concolor*; sugar pine, *Pinus lambertiana*; yellow pine: ponderosa pine, *P. ponderosa* and Jeffrey pine, *P. jeffreyi*; Douglas fir, *Pseudotsuga menziesii*; and incense cedar, *Calocedrus decurrens*), with a brushy understory component. This habitat type was selected since other studies have indicated that woodrats appear to be most abundant in mixed-conifer forest of this type (Forsman 1984, 1991; Carraway and Verts 1991; Carey et al. 1992; Sakai and Noon 1993, Raphael 1988; Sakai and Noon 1993, 1997).

Study areas differed in macrohabitat characteristics such as overstory and understory composition, canopy closure, and aspect. Oasis, Shrub, and Black Oak had overstories consisting of ponderosa pine and Douglas fir, whereas Gulch had ponderosa pine and white fir. Major undersotry components consisted of *Ceanothus integerrimus* (Oasis, Shrub, Gulch) and *Arctostaphylos* spp. (Black Oak). Crown diameter (% ground covered by tree canopy) ranged from 4-8 m for Oasis, Shrub, and Black Oak with Gulch having a crown diameter of 3-4 m. Cnaopy closure was 40-50% in Oasis and Shrub, 30-40% in Black Oak, and 50-60% in Gulch. Oasis and Shrub had moderately sloping topography with E and SW aspects respectively; Gulch and Black Oak had mixed terrain or undulating topography with NE and S aspects.

Historic logging activities (c. 30-40 years prior) and fire suppression practices have contributed to abundant dead wood as well as created dense, shrubby gaps and patches of closed canopy forest throughout each of the study areas. Recent (< 5 yr) management activities (i.e., prescribed burns, cutting) meant to restore pre-fire suppression conditions have created open understory and overstory conditions within intervening habitats allowing for ease of delineation of study area boundaries in the field and reduced house availability for potentially dispersing woodrats in the surrounding landscape (R. Innes, personal observation). No woodrats were observed moving between study areas.

Social Organization:

Animal movement data were collected at Black Oak, Gulch, and Oasis Jul-Oct 2003 and at all study areas May-Oct 2004 and 2005. Radiotelemetry was discontinued at Black Oak and Gulch in 2004. The study areas were systematically searched for woodrat houses in the spring and fall and opportunistically searched during regular monitoring of activities of radiocollared woodrats to ensure that all houses within a study area were discovered. Each house was marked with a flag as its location became known, and numbered sequentially. All woodrat houses were mapped within 1 m accuracy using a Trimble GPS unit. Since woodrat movements and house locations were not contained exclusively within study area boundaries, search efforts extended 100 m beyond study area boundaries to identify the presence of houses, and trap conspecifics that could potentially influence the social organization and habitat utilization of collared woodrats in the core of the study area. Sampling of vegetative characteristics were also not constrained by study area boundaries, but rather were reflective of houses available to resident woodrats. Therefore, within the 4 study areas, research efforts were concentrated within 4 broad-scale habitats, where woodrats and woodrat houses reached their greatest densities, but also included 6 peripheral broad-scale habitat types.

We conducted 2 trap sessions (May-Jun and July-Sep) of 4 consecutive trap nights each. Trapping sessions coincided with breeding and post-breeding activities. To obtain adequate information regarding the social organization of the species, we began collaring efforts within the center of the study area boundaries and radiated outward until all adults within the study area had been successfully radio-collared. We conducted additional trapping intermittently to document the presence of immigrating adults, and monitor juvenile activities to determine when to initiate post-breeding trapping efforts. Four Sherman live-traps (3 x 3.75 x 12″), baited with raw oats and sunflower seeds lightly covered with peanut butter, were placed within 1 m of the base of each house. Synthetic batting was provided as necessary to provide thermal insulation. Woodrats were highly trappable, as most individuals were captured multiple times. All houses within each study area, even those that appeared vacant, were trapped to ensure that all individuals were caught. Captured woodrats were transferred to a mesh weight bag then marked with numbered aluminum ear tags, weighted, sexed and released at there point of capture. Small snips of ear tissue were collected from all newly captured individuals and stored for future genetic analyses. A 4.0 g collar-type radio transmitter (Model PD-2C) made by Holohil Systems Ltd. was placed on the neck of all adult woodrats captured in the study area. Woodrats were lightly sedated with ketamine hydrochloride (100 mg/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. Radiotelemetry activities of newly collared individuals were initiated after a 24-hour acclimation period succeeding their release.

We documented nocturnal activities and diurnal locations of radio-collared woodrats using radiotelemetry. Diurnal locations were determined once per day, sporadically in 2003 and 3 days per week in 2004 and 2005 using homing techniques. Locations were accurately ($\leq$ 1 m) mapped using a Trimble GPS unit. Nocturnal telemetry sessions using triangulation techniques occurred during 5 nights per month in 2003 and 10 nights per month in 2004 and 2005. 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). Triangulation systems were tested regularly using dummy collars to ensure the accuracy of the triangulation method. Radiolocations were obtained for each woodrat 2-3 times per night, a minimum of 2.5 hours apart to avoid serial correlation. The timing of nightly telemetry was varied from dusk until dawn to ensure that radiolocations were sampled at different times of activity.

Macrohabitat-relations:

Dusky-footed woodrats are considered local dietary specialists (Cameron 1971). Studies of woodrats that examined feeding preferences predominantly showed a preference for oak foliage and acorns where available; although diets may include a variety of fruits, nuts, and foliage from woody plants, as well as fungi, associated with the plant community of study (Cameron 1971, Meserve 1974, Atsatt and Ingram 1983). This suggests that woodrat density may be positively associated with oak density or acorn production. To test the hypothesis that woodrat density was positively correlated with California black oak, we estimated California black oak density at each of the study areas using 10 x 100 m belt transects placed in a stratified random fashion, such that ≈10% of the total area was sampled for California black oak. California black oak trees greater than or equal to 5 cm DBH were recorded. We examined correlations between woodrat density and density of woodrat houses in two size categories of California black oaks to test the hypothesis that woodrat density would show a stronger relationship with the density of mature, larger diameter trees that provide acorns and other wildlife habitat attributes such as cavities, in addition to foliage for forage. California black oaks begin to produce acorns in moderate quantities at about 80 years of age (≈ 33 cm DBH); therefore, the density of California black oak ≥ 33 cm and < 33 cm were chosen (McDonald 1969).

To test the hypothesis that woodrat density was positively correlated with annual acorn crops, acorn production of California black oak was measured on 25 and 28 trees located at Oasis and Shrub, respectively. Black Oak and Gulch 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 1974). 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 visible acorns for the two 15 sec count periods were combined to yield a total count for a 30 sec 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).

Microhabitat-relations:

One of the trials of researchers studying dusky-footed woodrats is that the species may be found in many plant communities that satisfy its food requirements and still be limited in its density by the structural factors and composition of the environment (Willy 1985). Horton and Wright (1944) suggest that higher concentrations of houses are due to greater protection from thick vegetation than from an increased food supply. To look at these potentially limiting factors to the distribution and abundance of woodrats, differences between the structural characteristics and the abundance and composition of plant species adjacent to woodrat houses and the surrounding habitat were measured.

We sampled vegetative and structural characteristics within 4 m radius plots (50.3 m^2) centered at 185 randomly selected woodrat houses. Plot size was based upon ocular estimates of patch size at woodrat houses (e.g., the microhabitat changed beyond a 4m radius). Houses less than 0.2 m in height were not included in vegetative surveys since these houses were considered too small to accommodate a woodrat (Willy 1985). Houses that appeared used based upon green clippings, newly accumulated debris, and fresh feces, and houses that appeared unused or in advanced stages of decay were included in analyses to examine which habitat variables best predicted house site selection and use.

To determine whether habitat variables predicted house placement, we visually estimated percent cover of 4 ground cover variables; in addition, density and frequency of shrubs, trees, snags, stumps, and logs were recorded (Table 1). Only woody plant species were measured in the vegetation sampling, as dusky-footed woodrat diet consists of the leaves, fruits and nuts of woody plants. Woodrats use downed or standing dead woody material and live vegetation to build their houses (English 1923, Vestal 1938, Linsdale and Tevis 1951, Willy 1985). Therefore, a minimum size criterion for downed woody material (e.g., logs) was chosen to quantify debris that a woodrat could not pick up and carry. The volume of each log (m^3 ha^{-1}) was estimated as a frustrum paraboloid (Husch et al. 1993) using logs length and diameters of both ends. For stumps, snags and trees, the distance from the variable to plot center was recorded. Slope and aspect were measured using a compass and clinometer, respectively, by sighting from the top-most part edge of the plot, viewing downward through the plot center to the bottom-most edge of the plot. The percent of canopy closure was quantified by using a Moosehorn with an 8.5 x 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.

To determine whether habitat variables or house characteristics best predicted house occupancy by a woodrat we measured house-specific characteristics. Woodrat houses are constructed of sticks, bark, and plant cuttings, as well as various other materials. Houses may be conspicuously placed in the crotch of tree limbs, in tree cavities, or on the ground. We measured house-specific characteristics such as house volume, location (i.e. ground, tree), type (i.e. cavity dwelling, stick mound), and supporting structure (e.g., stump, log, tree). Thirteen house volume categories were devised as 0.1 m^3 increments between 0.0 and 2.0 m^3. We regressed ocular estimates of house volume using these categories against a random subset (n = 24) of house volume estimates obtained by measuring height, length, and width of each house and found that volume category determined by ocular estimates was strongly correlated with house volume ($P < 0.001$, $R^2 = 0.71$).

We also sampled, with replacement, the same vegetative and structural characteristics at paired points located a random distance between 10 and 50 m and a random direction between 1 and 360° from the center of each house, resulting in 185 paired random points. Random points were further constrained to lie within the same broad-scale habitat type as the paired house; in addition, woodrat houses could not be built within roadways or drainages, thus random points falling within roadways and drainages were excluded. Adult residents are thought to be the primary creators of new stick houses, and thus these individuals are assumed to be making decisions regarding the placement of houses within their home range area. Current knowledge indicates that the home range in which an adult woodrat satisfies its life history requirements is limited to the vicinity of its house, with the house often lying within the center of the home range (Cranford 1977). In the literature, home range estimates for adult woodrats range from 1942 m^2 to 4459 m^2 (Cranford 1977; Lynch et al. 1994); therefore, the maximum distance to a random point was set to constrain random plots within the bounds of a surrogate home range area and represent the full range of habitat choices that a resident woodrat could make with regards to house site selection.

We hypothesized that woodrats will place houses with regards to increased structural complexity, vegetative composition and density. Specifically, we hypothesized that woodrats would place houses, 1) with respect to the location of house supporting structures, in the form of increased snag, log, and stump volume, 2) to maximize foraging opportunity in the form of increased density of preferred forage species, such as young and mature oaks trees, and deer brush, 3) to improve access to and mobility within the tree canopy (i.e., increased tree density), 4) to minimize seasonal temperature fluctuations in internal house space through means of increased canopy closure, tree density, and high (> 1m) shrubs, and 5) to enhance protection from predators through an increased density of shrubs (> 1m), greater abundance of logs as travel routes to and from houses, and a decrease in the average distance of trees and snags to house center.

Statistical Analyses:

Program *Locate II* was used to calculate woodrat locations from bearing data obtained during triangulation. Woodrat locations were then entered into an ArcView GIS 3.2 database and plotted. We used the Animal Movements Extension for ArcView GIS to calculate 95% minimum convex polygon (MCP) home range estimates and 50% MCP core area estimates for home range and area overlap analyses. Future analyses will also include fixed kernel (FK) home range and core range estimates. Overlap (shared area) of home ranges and core areas between individuals was calculated. For two animals, A and B, we calculated mean overlap as the geometric mean of the product of the ratios of overlap size to home range size.

$\text{Overlap} = (\text{Overlap}/\text{Home Range A} \times \text{Overlap}/\text{Home Range B})^{0.5}$

Overlap values ranged from 0 - 1, with a mean overlap of 1 equivalent to 100% overlap between two individuals. We compared home range size among sexes using nonparametric tests (e.g., Mann Whitney U).

We used Conditional logistic regression (CLR) to predict the odds for the event of finding a house at a certain location given the explanatory variables. CLR using a 1:1 matched case-control study takes the stratification of the data set into account by basing the maximum likelihood estimation of the model parameters on a conditional likelihood for paired observations. CLR is suitable for studies with few subjects per group as it can fit a model based on conditional probabilities that “condition away” or adjust out the grouped effect. Here, we considered each house-random pair to be a separate stratum or group, conditioned out subject-to-subject (in this case house-to-house) variability and concentrated on within-subject (in this case house-to-random) information. CLR conditions out house-to-house variability due to site or broad-scale habitat differences and concentrates on house-to-random variability due to microhabitat preference. This is conceptually similar to using differences between cases and controls as predictors (Stokes et al 2001). The primary advantage of conditional logistic regression is that it allows one to statistically control for effects that characterize clustered data, such as woodrat houses (Hosmer and Lemeshow 2000). Quantitative comparisons of habitats 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).

To meet the assumptions of CLR, we used the general guideline that each possible outcome should have a minimum of 5 observations per explanatory variable in the model for valid estimation to proceed (Stokes et al. 2001). We checked all pairs of nominal variables and merged or divided categories as necessary to obtain cells that have expected frequencies greater than 1 and less than 20% of cells with observed frequencies less than 5. Prior to CLR analyses, we examined Spearman's rank correlations between variables and tolerance values for each variable to identify potential collinearity problems. Variables that were highly correlated ($r \geq 0.7$, tolerance < 0.1) and that explained similar biological phenomenon were not included together in multivariate models (Hosmer and Lemeshow 1989). To determine which habitat variables best discriminated between house and random location, we performed CLR using the proportional hazards regression (PHREG) procedure in SAS, initially using univariate analyses to screen for candidate variables. We identified main effects and biologically important interactions and then built multivariate models using forward stepwise selection ($P = 0.05$ to enter and $P = 0.10$ to remove). We examined model residual chi-square and residual diagnostics to further assess model goodness-of-fit (Hosmer and Lemeshow 2002, Stokes et al. 2000).

Logistic regression was used to examine differences between used and unused houses and for differences among age groups (e.g., subadult, adult). Statistical assumptions were validated using the methods described for CLR and simple linear regression was applied using JMP 5.1 (SAS Institute, 2001). Statistical significance was set at $P < 0.05$.

Northern flying squirrel:

We captured northern flying squirrels in the Plumas National Forest, northern California. Animals were collected from red fir and mixed conifer forests at an elevation of approximately 2,100 and 1,500 m, respectively. Red fir forests were dominated by red fir (*Abies magnifica*), interspersed with western white pine (*Pinus monticola*), lodgepole pine (*Pinus contorta*), and sugar pine (*Pinus lambertiana*). Prostrate manzantia (*Arctostaphylos prostrata*) and snowplant (*Ceanothus* spp.) composed much of the understory. Mixed conifer consisted of Douglas fir (*Pseudotsuga menziesii*), ponderosa pine (*P. ponderosa*), white fir (*A. concolor*), and sugar pine with a complex understory of manzanita (*A.* spp), *Ceanothus*, and other shrubs.

We trapped for northern flying squirrels using a combination of Sherman (Model XLK; Tallahasee, FL) and Tomahawk (Model 201 Tomahawk, WI) live traps placed on the ground or strapped to trees at a height of approximately 1.5 m. Traps were baited in late afternoon with a mixture of rolled oats, peanut butter, molasses, and raisins (modified from Carey et al. 1991), and checked for captures in the morning. Polyfill fluff and a cardboard box were provided for warmth during cold nights. All work was performed under the auspices of an approved animal care and use protocol (ACUC 10394) and followed guidelines established by the American Society of Mammalogists.

All captured individuals were weighed using spring scales, and both sex and reproductive condition were noted. For males, testes were recorded as either scrotal or non-scrotal; for females, the vagina may be perforate (thereby receptive) or imperforate (not receptive), the vulva was either swollen or not, and nipples may be enlarged and/or reddened (reflecting nursing offspring), or not. All animals were individually marked with numbered ear tags and fitted with a radiocollar (Model PD-2C; Holohill, Carp, Canada). Following radiocollar attachment, individuals were released at the site of capture and monitored until they entered a nest or cavity. The animal was allowed to rest for 24 - 48 hrs before radiotelemetry began.

We radiotracked individuals during the day to locate nest trees. We marked each nest tree and determined the location with hand-held GPS units, in UTM coordinates. We recorded diameter at breast height (DBH), species, condition (live, dead snag), and nest type (cavity or external nest) of each nest tree.

Squirrels were located with hand-held radiotelemetry receivers (Communications Specialist R-1000, Tustin, CA) 5-8 times per month from May to October, 2004 and August to October, 2005. Within each session we located animals at least 3 times, with each "fix" separated by at least 1 hour following Swihart and Slade (1988) and Taulman and Smith (2004). The latter authors found that this interval was sufficient to achieve independence of locations and that the occasional lack of independence was due to nonrandom use of home ranges. Animal locations were determined in UTM coordinates from triangulation using program LOCATE II, and entered into an ArcView GIS database. The animal movement extension in ArcView was used to generate monthly home range estimates using the 95% minimum convex polygon for interspecific comparison with published data. Additionally, we evaluated 50% and 95% adaptive kernel home ranges to identify core usage for individuals (50%) and because this method is not subject to some of the constraints of MCP.

Technician accuracy was quantified at each study site. We placed a radiocollar in a hidden location to determine location error using these "dummy collars." Technicians did not know where collars were located and collars were moved periodically. To assess bearing error rates technicians recorded bearings to dummy collars as if they were performing telemetry on individual squirrels. Bearings to dummy collars were recorded in conjunction with normal telemetry sessions; giving a potential dummy location for each night of telemetry. Dummy collar locations were determined and compared to their actual location. The dummy collar was located an average of 253.3 ± 47.2 m from any given station. Results of this procedure indicated that we had a mean angular error of 15.9 ± 1.4 degrees, resulting in a mean error of location of 34.9 ± 4.0 m for our flying squirrels.

To provide an index of activity throughout the night we measured the distance between each location and the nearest known nest tree. We tracked squirrels periodically during daylight hours to find nest trees. Although we did not find evidence of additional, unknown nest trees it is possible that we missed some. These distances were used to generate a time series of distances each individual was found from its nearest nest 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).

We performed a T-test to determine if non-adult male home ranges differed from adult males. Analysis of adult home range size and nocturnal activity was performed using a 2 x 2 factorial design, with habitat (red fir, mixed conifer) and time of night (4 3-hr 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 2006). 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 $\alpha = 0.05$.

Fitness correlates to forest management:

Nine female golden-mantled ground squirrels were captured for use as experimental subjects in June of 2005 and fitted with radio-collars. Individuals represented a range of naturally occurring body conditions. All females were anesthetized (using ketamine hydrochloride, 100 mg/ml), had total mass measured to the nearest 0.1g using a portable electronic balance, had head+body length recorded, and had total body electrical conductivity (ToBEC) was measured using an EM-SCAN body composition analyzer. Following body composition analysis the radio-collar was reattached.

Once offspring become available aboveground (mid July 2005) the remaining mothers were located early in the morning before they became active and traps were placed around the burrow. Traps were checked around 11:00 for the presence of the female squirrel and her offspring. Typically the female was captured along with a number of offspring within 2 hours of trap placement. A total of 14 offspring from 6 females were captured and used for the remainder of the study. Offspring were fitted with radio-collars and subjected to the same measurements: overall mass, body condition, head+body length, and home range. Each offspring was marked as described above and tissue samples will be collected for possible maternity analyses. All subjects (i.e., offspring and mothers) were followed throughout the remainder of the 2005 field season (July-October) to determine home ranges and dispersal locations. Dispersal distance was calculated as the linear distance between the point of initial capture (mother's burrow) and the final location for a particular individual (hibernation burrow).

Taxonomy and classification of Sierra Nevada chipmunks:

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

In addition, external features were characterized for every chipmunk captured. Features included the length of the face stripe (if it extended to the base of the ear or not), the color of the face stripe (black or brown), rump color (grey or red), size (large or small) and brightness (white or dull) of the earpatch, shape of the ears (narrow and pointed or rounded), and hind foot and ear notch measurements (mm). Features were characterized every time a chipmunk was captured, regardless as to whether a particular individual had been previously captured. This will enable us to identify differences in the variation within and among technicians on how well these external characteristics can be used to identify sympatric chipmunk species. External characteristics will be matched to molecular identification to determine which characteristics, if any, is a reliable indicator for separating the two species of chipmunk inhabiting our study site.

2005 FIELD SEASON PROGRESS AND RESULTS

The 2005 season began in April with the hiring of 8 technicians. Work began at the study site on 23 May and continued through 31 October. Due to heavy snow, we were limited in the amount of area we could access at the beginning of the season. As a result, we began the field season by training the technicians on trapping and telemetry methods. We continued pretreatment trapping of the nine experimental grids and continued a third season of trapping for the nine habitat grids. However, rather than trap the grids every month we switched to only trapping them in June and October. This allowed us to have more time to focus on finding and marking flying squirrels. The nine experimental grids (Grids 1-9) were located in white fir dominated forests in the Snake Lake, Dean's Valley, and Waters districts. During each trap session, we trapped 5 consecutive days (4 nights), opening traps for an AM2 check on the first day and closing the traps after the AM1 check on the last day of trapping. Each night's effort comprised 100 Sherman trap-nights and 72 Tomahawk trap-nights (n = 172 trap-nights total), and each grid experienced 688 trapnights during each month of trapping. Similarly, the habitat grids were trapped on the same schedule.

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

During the 2005 field season we captured and marked a total of 566 individuals across all species of small mammal and all sites (Table 2). A total of 10,368 trapnights were evenly distributed across all sites during June and October 2005. Predominant species in the study area include dusky-footed woodrat (*Neotoma fuscipes*), deer mice (*Peromyscus maniculatus*), long-eared and Allen's chipmunks (*Tamias quadrimaculatus* and *T. senex*), California and golden-mantled ground squirrels (*Spermophilus beecheyi* and *S. lateralis*), montane vole (*Microtus montanus*), Douglas squirrel (*Tamiasciurus douglasii*), and the northern flying squirrel (*Glaucomys sabrinus*). Incidental species captured during our trapping included shrews (*Sorex* spp.), brush mice (*Peromyscus boylii*), snowshoe hare (*Lepus americanus*), striped skunk (*Mephitis mephitis*), and pocket gopher (*Thomomys bottae*).

To allow for more research time with flying squirrels we have reduced grid trapping to June and October. This will give us an index of the relative abundance of small mammals, particularly *Peromyscus*, across years. Results from the previous three years of trapping indicate high interannual variance within *Peromsycus* (Figure 1). *Peromyscus* levels were very low in 2003, increased dramatically in 2004, and were intermediate in 2005 across all habitats. The similarity in pattern between all forest types suggests that *Peromyscus* populations are being driven by a large-scale environmental factor. Fewer *Peromyscus* were captured in Fall compared to Summer (Figure 1). October abundances were at least half that of June across all forest types. Changes in *Peromyscus* populations represent an important factor in determining whether spotted owls have a good reproductive year.

Dynamics of spotted owl prey taxa:

Dusky-footed woodrats:

Adult woodrat densities were variable between sites and among years, with adult woodrat densities consistently lower at all sites in 2005 as compared with 2004 (Table 3). In 2005 we radio-collared 18 adult woodrats (6 Oasis, 12 Shrub). In 2004 we fitted 31 adult woodrats (14 Oasis, 17 Shrub) with radio-collars. In 2003 we radio-collared 20 adult and juvenile woodrats (12 Oasis, 4 Black Oak, 2 Gulch, 1 Between, and 1 Nogo,). We captured 17 woodrats in 2005 that were also captured in 2004 (10 Shrub, 5 Oasis, 1 Black Oak and 1 Gulch). In 2004 we captured 9 woodrats that were also trapped in 2003 (6 Oasis, 3 Gulch). Notably, 1 adult male woodrat was trapped at Gulch in 2003, 2004 and 2005.

Home range estimates have been calculated for 2003 and 2004 and core range estimates have been calculated for 2004. Core area calculations are from the Shrub study site only. Male woodrats consistently had larger home range and core area estimates compared to that of females. In 2003 mean home range size for males (1.9 ha) and females (0.9 ha) were larger than in 2004 (1.1 males, 0.7 females). Core areas calculated from 2004 data were 0.4 and 0.1 ha for males and females respectively.

Overlap indices, ranging from 0.0 (no overlap) to 1.0 (total overlap), for female-female, male-male and female-male dyads at Shrub in 2004 indicated overlap among individual's home ranges. Male-male overlap was greatest (0.42) followed by female-male (0.36), and female-female (0.22). Core area overlap also showed overlap among female-male (0.29) and female-female (0.59). Occurrences of home range overlap among male-female and female-female dyads were higher than that between males. An individual female overlapped with an average of 3.4 other females and 1.9 males. A given male overlapped with an average of 1.2 other males and 4.6 females. Male-male dyads overlapped more than female-female and male-female dyads; however this relationship was not significant, perhaps due to the high amount of variation evident in overlap among male-male dyads (range: 0.03 - 0.75) and the small number of adult males present in the study area. Core range overlap analyses revealed greater segregation between same sex pairs than was evident in home range overlap analyses (Figure 2). Female core ranges overlapped with 0-1 male core ranges, whereas male core ranges overlapped with 1-3 female core ranges.

Home ranges were larger in comparison to other studied populations. A high degree of home range overlap and a low degree of core area overlap between same sex pairs suggest that woodrats are semi-territorial and share foraging areas, but defend the area around houses, a result supported by studies elsewhere. Male home ranges were larger than females, and male core ranges typically overlapped with several females while females overlapped with only one male, suggesting a polygynous mating system. Conversely, some males overlapped with only one female; these pairs exhibited a high degree of core area overlap and readily shared the use of houses, suggesting that some woodrats may be monogamous. In addition, the incidence of female-female overlap was low, but did occur on one occasion. This, combined with evidence elsewhere that suggests that female woodrats may be philopatric to natal home range area, suggests that relatedness between individuals may influence territorial behavior and ultimately population density. Our preliminary results suggest that the sex-ratio and age structure of a population appear to play an important role in the social organization and movement patterns of the species. In addition, mating system and genetic relatedness may play a role in population density.

House Use:

Most woodrat houses were located on the ground, but many were also located in tree and snag cavities or on the limbs of live trees. The proportion of available ground/tree woodrat houses was 75/25% in Oasis and 66/34% in Shrub. Use of these houses reflected their availability in the habitat with occupancy at Oasis being 70/30% and 63/37% in Shrub.

There was no apparent difference between sexes with regards to type of house used (ground: $P = 0.28$, tree: $P = 0.53$); therefore all house types were combined. Woodrats had more houses available within their home range than were used. Males used ($P = 0.18$) more houses (7.4 houses/home range) and had more houses available (22.2 houses available; $P = 0.19$) than females (5.3 houses used/home range; 16.3 houses available).

Woodrats used multiple houses within their home range; however, not all houses available within a home range were used, suggesting that woodrats may be selecting some houses preferentially. Stick houses in trees and those located on the ground were used in accordance with availability, a somewhat surprising result since houses on the ground were more vulnerable to destruction by black bears (see below). Males had more houses available within their home range than females, a pattern consistent with the larger home range areas of males; males also used more houses than females, likely as a result of the polygynous mating system.

Macrohabitat features:

California black oak densities varied among sites and between small (< 33 cm DBH) and large (> 33 cm DBH) oaks. Shrub, Oasis, Gulch, and Black Oak had oak densities of 1.0, 0.7, 0.3, and 0.6 ba/ha for small DBH oaks, and 5.1, 3.1, 1.9, and 0.0 ba/ha for large DBH oaks. There was no statistical correlation between woodrat house density and density of California black oak < 33 cm DBH ($P = 0.19$) or density of California black oak < 33 cm DBH and adult woodrat density in 2004 ($P = 0.25$) or 2005 ($P = 0.19$). In addition, there was no statistical correlation between woodrat house density and density of California black oak ≥ 33 cm DBH ($P = 0.11$). The lack of a statistical correlation between woodrat house density and California black oak density was not surprising given the lack of correlation between woodrat house density and adult woodrat density in 2004 ($P = 0.10$) and 2005 ($P = 0.11$). However, there was a strong statistical correlation between density of California black oak ≥33 cm DBH and adult woodrat density in 2004 ($P = 0.0001$, $R^2 = 0.99$; Figure 3) and 2005 ($P = 0.0215$, $R^2 = 0.96$; Figure 3).

Although our sample only included 4 sites, our results suggest that woodrat density consistently responds in a linear fashion to the density of mature, California black oak trees. These data should be accepted with caution until further study to determine whether this pattern is consistent across the landscape. California black oaks begin to produce acorns in moderate quantities at about 80 years of age (33 cm DBH), therefore, the density of California black oak ≥ 33 cm DBH represents the potential of the site to produce acorns (McDonald 1969). We quantified acorn production at Oasis and Shrub in 2005. Average acorn production indices in 2005 were greater at Shrub (mean: 13.1; range: 0 - 65) compared with Oasis (mean: 9.4; range: 0 - 29). We will continue to monitor acorn production in the coming field season to look for long term trends and further examine the relationship between woodrat density and acorn production.

Microhabitat features:

Our data suggest that the abundance and distribution of woodrats is affected by habitat composition and structure at the microhabitat scale, which plays an important role in predicting the presence and use of woodrat houses. Results of these analyses will be completed shortly.

Destruction of houses by black bear:

In addition to dusky-footed woodrats, many mammals, including the black-tailed deer, black bear, and several bird species rely upon acorn production. Black bears heavily use mixed-conifer forest in California during the fall during acorn production and in the winter-spring when other food resources are minimal. Dusky-footed woodrats cache large quantities of acorns in their houses. In future reports we intend to examine patterns of destruction of woodrat houses by black bears at Shrub in 2004 and 2005 and to examine the relationship between black bears and ducky-footed woodrats.

Northern flying squirrels:

We captured 20 (6 in 2004, 14 in 2005) northern flying squirrels over both years, consisting of 14 males and 6 females (Table 4). Sixteen individuals were adult, based on size and coloration (Villa et al. 1999), with M2, F2, and M10 being subadults and M9 a juvenile. In 2004 only 3 individuals (M1, M3, and F3) survived long enough to calculate home ranges. The remains of 2 squirrels were found within a week of release (M2) or within 24 hr of release (F2). Radiotracking of M1 stopped after 7 July 2004 because the collar never moved from the top of a tree indicating the squirrel had lost its collar or had been predated. The final two squirrels (M3 and F3) were tracked until October when snowfall precluded access to our study site.

In 2005, we applied radiocollars to 11 individuals. Three of these (M4, M5, F4) were captured in mixed conifer forest; the remainder (M6 – M13, F5 – F7) were captured in the same red fir forest as the individuals from 2004. Three individuals (M6, M7, M12) died either during handling or shortly after release. One squirrel (F6) was successfully collared and released, but the radiosignal disappeared after a week. The fate of F6 is unknown and no home range was generated for her. We were able to calculate home ranges for all 3 individuals in the mixed conifer forest and for 10 of the 17 individuals from the red fir forest.

Adaptive kernel home ranges were calculated for all individuals with >20 locations (Figure 4). Considerable overlap existed in the distribution of home ranges and showed both inter- and intra-sexual overlap. Home range size (95% adaptive kernel) was significantly smaller for non-adult males (6.3 ± 1.6 ha) compared to adult males (25.5 ± 4.0 ha; $T_7 = 2.45$, $P = 0.04$). As a result, juveniles and subadults were not included in further analyses. Within adults, we did not find a significant difference between male and female (35.8 ± 10.4 ha) home range size ($F_{1,7} = 0.96$, $P = 0.4$; Figure 5). We also did not find a difference in the home range size between adults inhabiting mixed conifer, and those from red fir forests ($F_{1,7} = 0.08$, $P = 0.8$). The use of minimum convex polygon home ranges produced similar results as the adaptive kernel method; however, MCP home ranges are susceptible to outlier locations (White and Garrot 1990) and in one individual (M3) produced a wildly exaggerated home range size (Table 4).

Nest trees were located for 13 individuals. Only 2 external nests were used by flying squirrels in this study area, with the remainder of nests consisting of cavities drilled by woodpeckers, or natural cervices. Both external nests were found in live trees: one in a red fir (*Abies magnifica*) and one in a sugar pine (*Pinus lambertiana*). Of the cavity nests, most were in live trees of various species, four in solid, well formed snags, and one in a decayed snag. All snags, but one consisted of the trunk of a dead red fir with a diameter at breast height (DBH) of 44.0 - 121.3 cm. The decayed snag was a small red fir 4.9 m in height with a DBH of 22.3 cm and was in an advanced stage of decay.

In both males and females the mean distance to the nearest nest tree was similar throughout the night; however, females moved significantly greater distances compared to males ($F_{1,607} = 22.53$, $P < 0.0001$; Figure 6). Movement patterns did not show a time effect ($F_{3,607} = 1.60$, $P = 0.2$) and were similar through the four time periods: evening (18:00 – 21:00), night (21:00-24:00), late-night (24:00 – 03:00), and morning (03:00 – 06:00).

Fitness correlates to forest management:

Nine females representing a continuum of naturally occurring body conditions were captured and fit with radio-collars during 2005. These females were followed throughout 2005, as described above, until their offspring emerged from the natal burrow. Their offspring (n = 14) were captured and fitted with radio-collars as described above. Offspring were then followed through the remainder of the year to determine their dispersal locations and exploratory behavior.

Offspring from both experimental females (2003 mothers) and natural females (2005 mothers) were used to determine the relationship between maternal body condition and offspring dispersal (Figure 7). Male offspring dispersed ~120m farther than female offspring at any given maternal body condition (Figure 7). Both male (slope = 7.76) and female (slope = 8.35) offspring increased dispersal distance with increasing maternal body condition ($F_{1,19} = 0.1$, $P = 0.7$). Although dispersal distance in relation to maternal body condition did not differ by offspring sex, exploratory behavior showed a sex bias (Figure 8). Mean (slope = 7.6) and maximum (slope = 11.1) male exploratory distances increased with increasing maternal body condition (Figure 8). Female exploratory distance, however, did not vary with maternal body condition (slopes = 0.1 mean; 1.9 maximum; Figure 8). Dispersal distance in male and female offspring was directly proportional to the mean exploratory distance (slope = 0.97, $r^2 = 0.80$; Figure 9).

Taxonomy and classification of Sierra Nevada chipmunks:

All tissue samples collected during the 2005 field season will be stored in refrigeration until funds are appropriated to run molecular analyses. Data pertaining to the external characteristics of individual chipmunks handled during 2005 will also be stored until molecular analyses have taken place.

COLLABORATION WITH OTHER MODULES

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

CONCLUISONS

The 2005 calendar year marked the third full year of data collection. We continued to trap all 18 grids that were trapped in 2003 and 2004. We have now completed three years of pretreatment data on the nine experimental grids. We have also added a third year of trapping on the nine habitat grids. We anticipate that the thinning treatments will occur sometime in 2006 and allow us to trap for 2-5 years (2007-2011) of post treatment seasons.

With the budget forecast for 2006, we plan to continue trapping on the nine experimental grids to obtain a third year of pretreatment data for June and October, or if the thinning treatments occur then we will begin post treatment data collection. Thinning on the treatment grids will begin as early as spring 2006. In an effort to increase our flying squirrel sample size we will change our methodology to include stratified habitat sampling for northern flying squirrels throughout the Plumas and Lassen NF. We will also try to bring in a new Master’s student to take control of the flying squirrel habitat associations study. We will continue to trap and follow flying squirrels in various habitats throughout the Plumas National Forest.

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

Forest managers will benefit from these data in being able to more accurately predict the responses of small mammals to forest treatments, and to relate these to the population dynamics of important predator species such as northern goshawk, California spotted owl, and American marten. We have begun to publish the data obtained and expect to continue publishing through the next year. Articles have been submitted for publication to the following journals: Western North American Naturalist, Journal of Mammalogy, and Ecology (see below).

PUBLICATIONS

Wilson, J. A., and Mabry, K. E. Submitted. Trapping rodents in a dangerous world: effects of disinfectants on trap success. Journal of Mammalogy

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

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

Copetto, S., D. A. Kelt, D. H. VanVuren, J. A. Wilson, and S. Bigelow. In Press. Habitat associations of small mammals at two spatial scales in the northern Sierra Nevada. Journal of Mammalogy.

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

PRESENTATIONS

Data from the 2003 – 2005 field seasons will be used in the development of 2-3 presentations to the 2006 annual meeting of the American Society of Mammalogists in Amherst, Massachusetts or the Ecological Society of America meetings in Memphis, TN. We anticipate giving presentations on 1. Northern flying squirrel home ranges, and 2. Woodrat home range structure and nest use. To date, the following presentations have been given.

Wilson, J. A., D. A. Kelt, and D. H. Van Vuren. 2005. The effects of maternal body condition on offspring fitness. Presentation to the 2005 American Society of Mammalogis, Springfield, MO.

Mabry, K. E., and J. A. Wilson. 2005. Trap disinfection to reduce hantavirus risk: does it also reduce small mammal trapability?
Presentation to the 2005 American Society of Mammalogists, Springfield, MO.

Wilson, J. A., D. A. Kelt, and D. H. Van Vuren. 2005. Effects of maternal body condition on offspring dispersal in golden-mantled ground squirrels (*Spermophilus lateralis*). Presentation to the Ninth International Mammalogical Society, Sapporo, Japan.

PERSONNEL

Fieldwork was coordinated by James A. Wilson, postdoctoral fellow at the University of California, Davis. Principal investigators for the small mammal module are Doug Kelt and Dirk VanVuren, Dept. of Wildlife, Fish, & Conservation Biology, University of California, Davis, and Mike Johnson, John Muir Institute of the Environment, University of California, Davis. Fieldwork in 2005 was conducted by James A. Wilson, Robin Jenkins, Sean Connelly, Holly Robertson, Dan Haggerty, Valerie Godfrey, Stephanie Bergh, Laura Cheney, Kelly Weintraub, Rachael Carson, Deborah Hill, Meghan Edgar, and Amber Gates.

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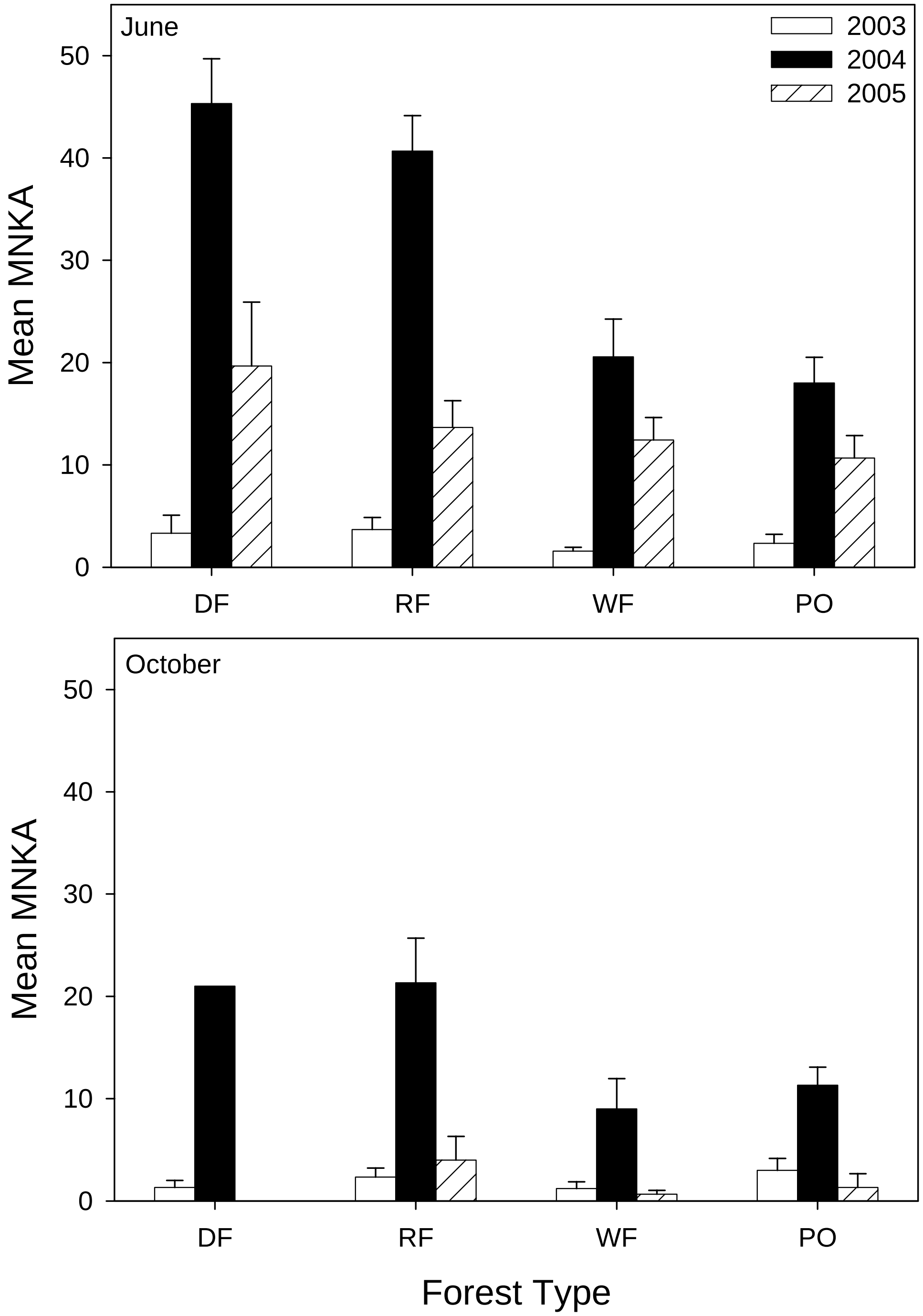

Figure 1. Mean minimum number known alive (MNKA) of Peromyscus manicualtus in June and October. Forest type is Douglas fir (DF), red fir (RF), white fir (WF), and ponderosa pine (PO).

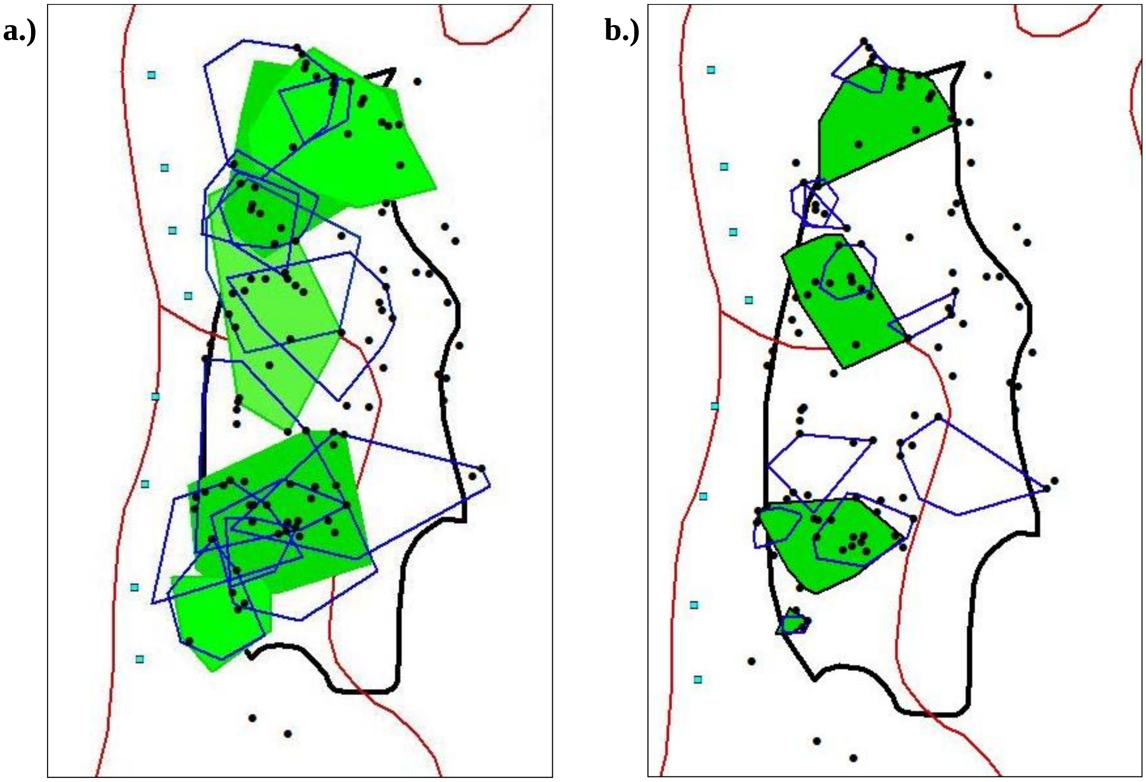

Figure 2. Examples of a) home range overlap of 12 female and 5 male woodrats and b) core area overlap of 10 female and 4 male woodrats at Shrub in 2005.

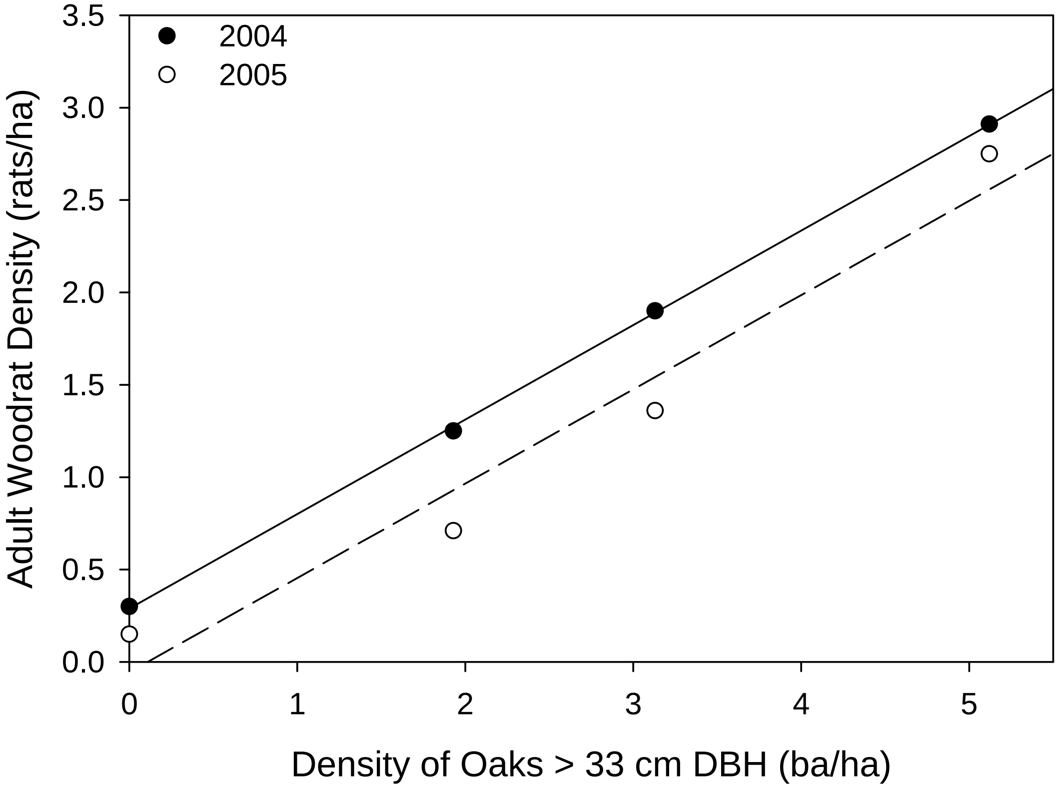

Figure 3. Abundance of adult woodrats in relation to Black Oak (Quercus kellogii) basal area. Only oaks > 33 cm diameter at breast height (DBH) were counted.

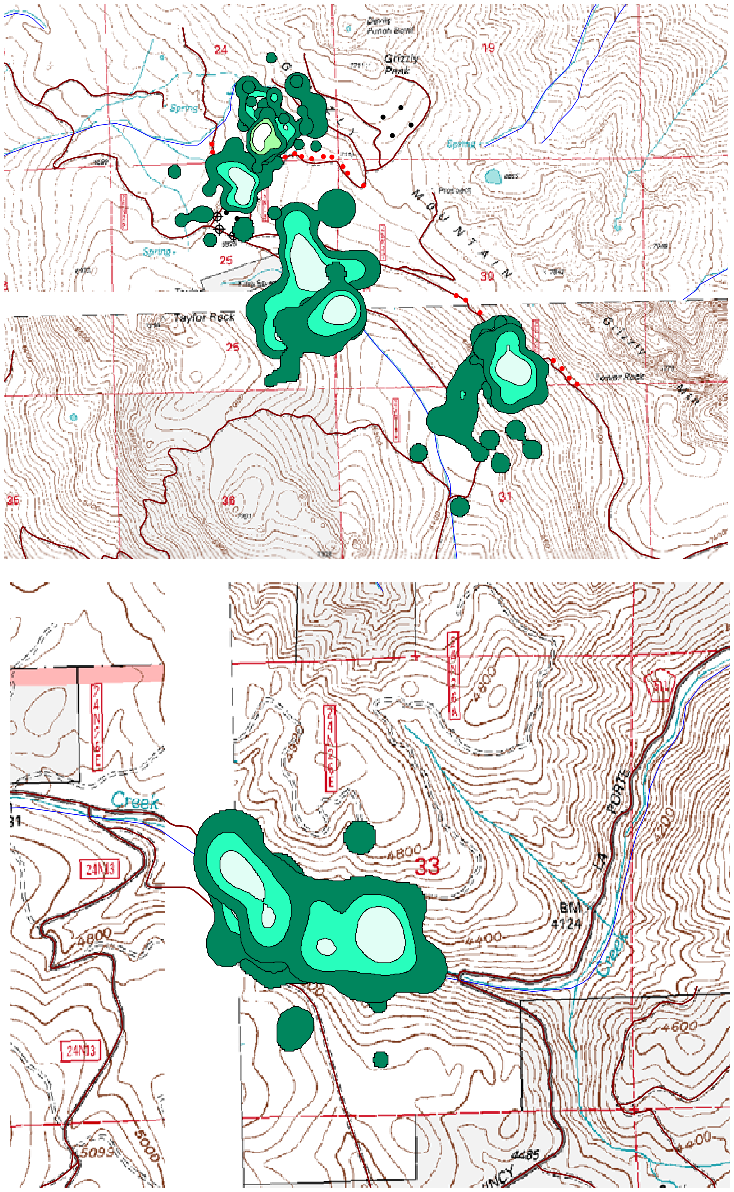

Figure 4. Location and distribution of 14 flying squirrel home ranges inhabiting red fir (top) and mixed conifer (bottom) forests. Home ranges represent 95% (dark green), 75% (med green), and 50% (light green) kernel core use. Considerable overlap exists among the home ranges.

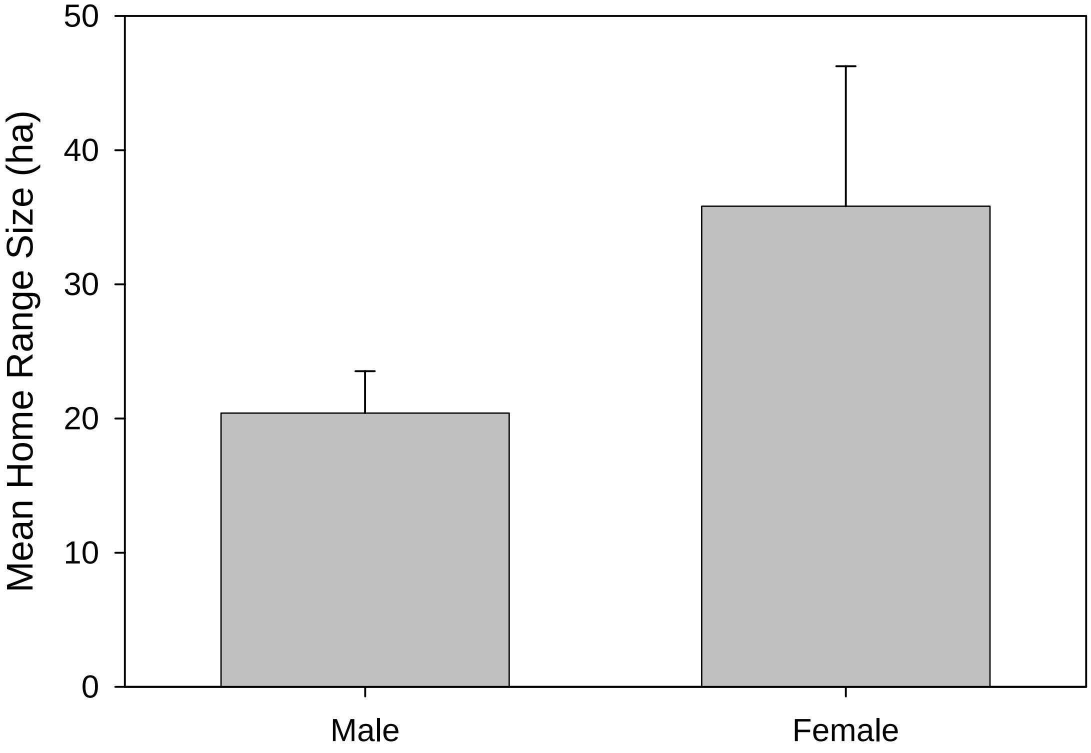

Figure 5. Mean home range size (ha) of male and female northern flying squirrels in the northern Sierra Nevada. Mean home range size represents the 95% adaptive kernel estimates.

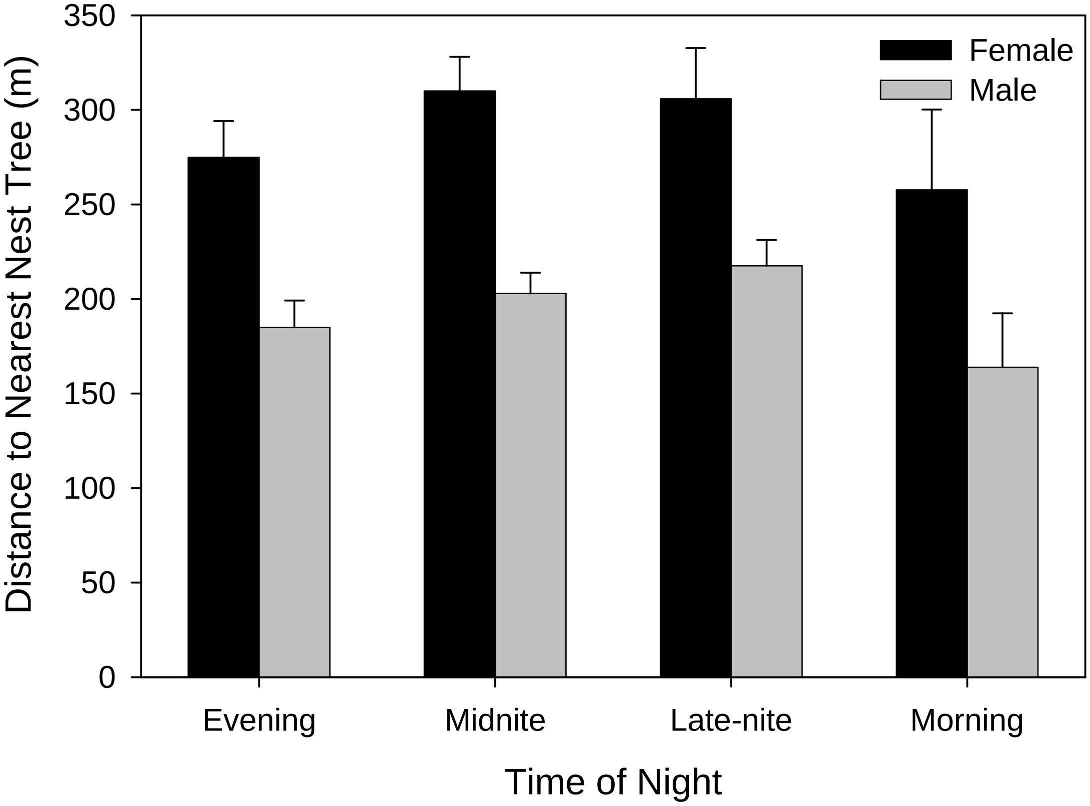

Figure 6. Nocturnal movement patterns of northern flying squirrels represented as distance to the nearest known nest tree. Only locations between 18:00 and 06:00 were used.

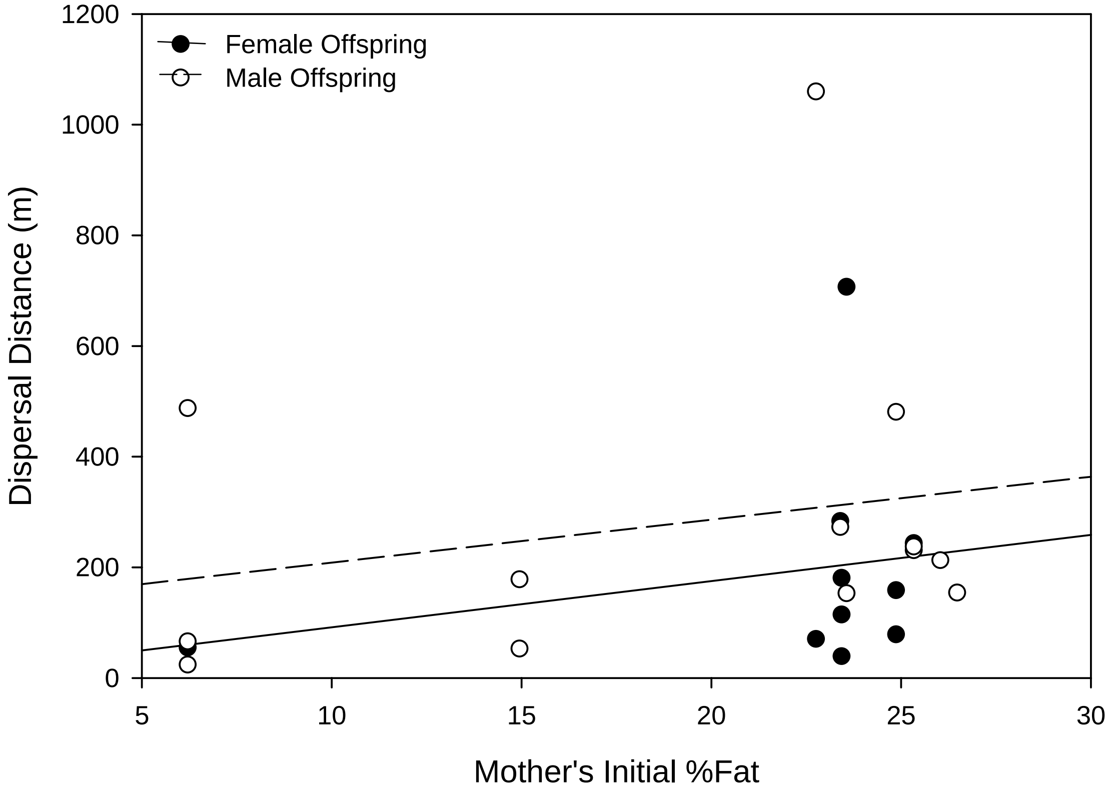

Figure 7. Dispersal distance (m) in relation to standardized maternal body condition as measured by total body electrical conductivity (ToBEC). Mother's initial % fat was standardized to % fat on June 11, the earliest capture date.

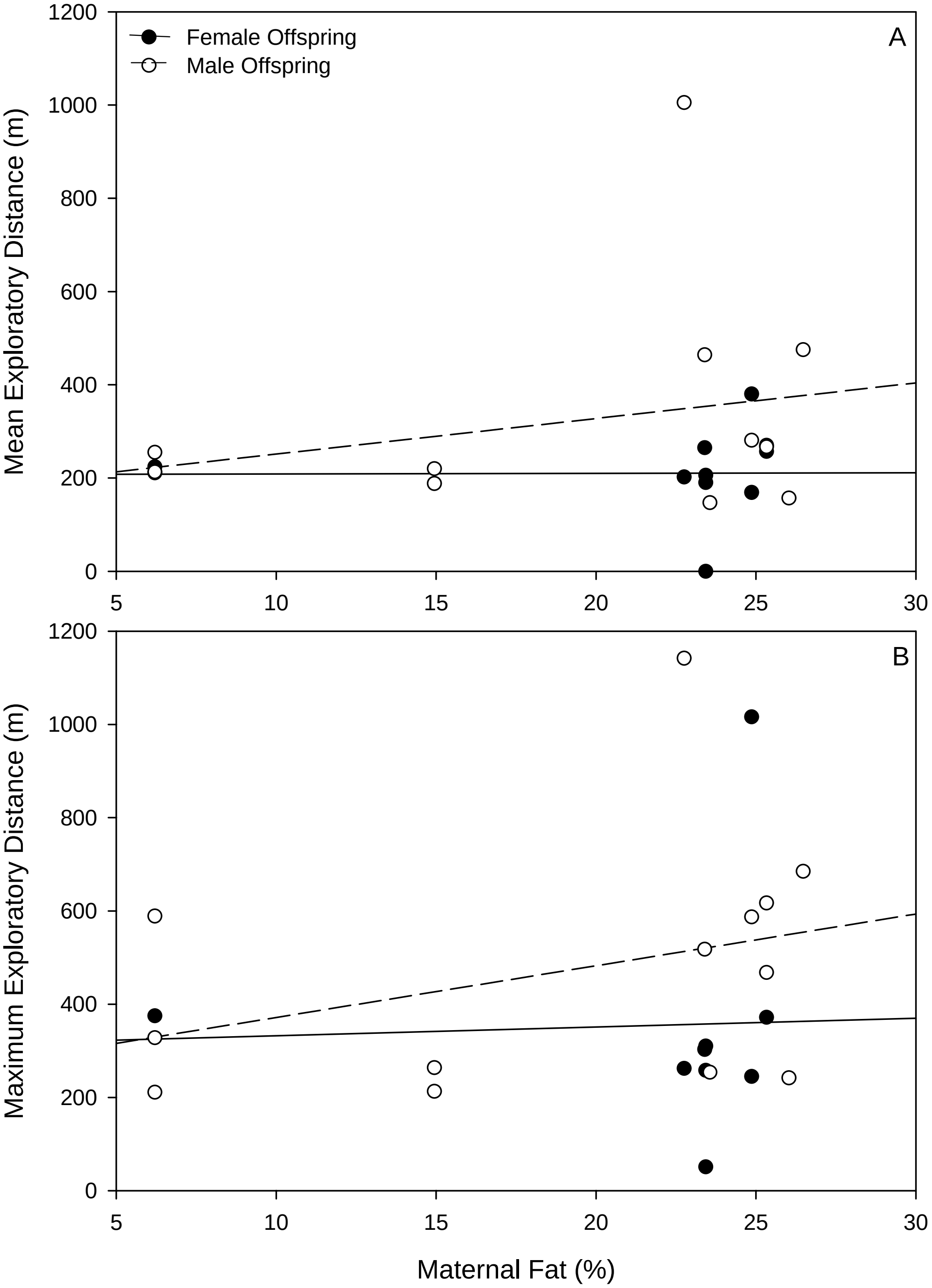

Figure 8. Mean (A) and Maximum (B) exploratory distances for male (open circle, dashed line) and female (solid circle and line) offspring in relation to standardized maternal body condition. Offspring locations more than 1 maternal home range radius were considered as exploratory.

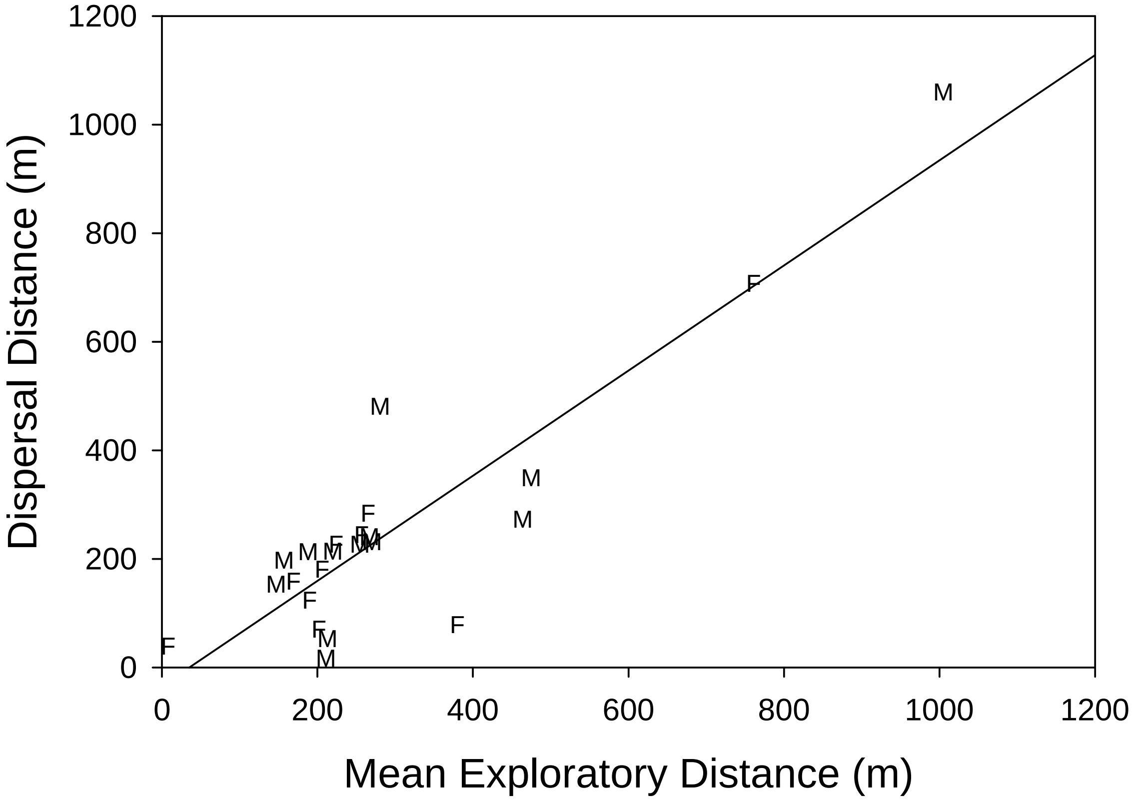

Figure 9. Relationship between mean exploratory distance and post-natal dispersal in male (M) and female (F) golden-mantled ground squirrel offspring.

Table 1. Description of habitat variables measured in 4 m radius plots at all woodrat house and random points. Values for variable categories are in the form of counts (stem density and dead woody material), percent (ground cover and canopy closure), and degrees (slope).

Variable	Description
Stem Density	
High Shrub	Woody stems > 1 m tall and ≤ 5 cm DBH
Low Shrub	Woody stems < 1 m tall, excluding mat vegetation
Tree	Woody stems > 5 cm DBH
Dead Woody Material	
Log	Downed dead wood > 1 m long and > 5 cm diameter
Snag	Standing dead wood > 5 cm DBH and 1.3 m tall
Stump	Standing dead wood ? 10 cm diameter and 0.1 - 1.3 m tall
Ground Cover	
Mat Shrub	Trailing, near ground surface (< 0.3 m tall), woody stem cover
Rock	Exposed rocks and stones
Bare Ground	Exposed soil
Litter	Dead leaves, pine needles, and wood chips
Canopy Closure	Percent closed at eye-level (1.7 m)
Slope	Degree of surface decline/incline

Table 2. Number of individuals captured on each site during the 2005 field season. Sites 1-9 were established for use in the thinning experiment. Habitat types are white fir (WF), red fir (RF), Douglas fir (DF), and ponderosa pine (PO). Incidental species were captured on a single occasion and not recaptured. All sites were only trapped in June and October during 2005.

			Peromyscus		*Neotoma*	*Tamias*		*Microtus*	*Spermophilus*		*Tamiasciuris*	*Glaucomys*	
Code	Site	Habitat	*boylii*	*maniculatus*	*fuscipes*	*quadrimaculatus*	*senex*	*longicaudus*	*beecheyi*	*lateralis*	*douglasii*	*sabrinus*	Incidental
1	Triangle	WF		18			11						b
2	Cabin	WF		11			12						a, b
3	Ripper	WF		9			2						b
4	Gimp	WF		6					1			1	b
5	No Name	WF	2	26	1		1				1	1	b, d
6	TeePee	WF		4		2	3	1			2		b
7	Black Oak	WF	2	12		3							
8	Nogo	WF	2	12		2	1					1	
9	View	WF	3	18	1	1	3						
10	Greenbottom	RF	1	24		15	26	1		43			
11	Gulch	PO		15	3				2				b
12	Dogwood	DF		31		1	12		1				b
13	Boa	DF		12			9		2				
14	Mono	RF	3	13		14	27			22		1	
15	Swarm	PO	1	9									
16	Steep	DF	4	15	3	4	10		2	3			a, b, c
17	Ralph	RF	3	12		13	43			12			b
18	Oasis	PO		12									
	Total		21	259		55	160	2	8	80	3	4	

Incidental captures: Snowshoe hare (a), Shrew (b), Striped Skunk (c), gopher (d)

Table 3. Density of adult woodrats (rats/ha) at each of the study sites in 2004 and 2005. House density did not change between years.

Site	House Density	Woodrat Density 2004	Woodrat Density 2005
Shrub	15.8	2.9	2.8
Oasis	14.6	1.9	1.4
Gulch	2.3	1.3	0.7
Black Oak	1.2	0.3	0.1

Table 4. 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 kernal (kernal) analyses. Unknown values are indicated by NA.

					Home Range Size (ha)	
Squirrel	Sex	Age	Mass	Nests	95% MCP	95% Kernal
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	A	103	NA	NA	NA
F3	F	A	117	1	35.5	63.4
M4	M	A	75	3	18.8	17.2
M4	M	A	75	3	19.5	24.8
M6	M	A	91	NA	NA	NA
F4	F	A	93	2	26.7	35.5
M7	M	A	96	NA	NA	NA
M8	M	A	104	2	24.8	39.4
M9	M	J	78	3	4.5	4.7
M10	M	A	96	2	6.9	7.8
F5	F	A	99	1	25.1	31.4
M11	M	A	100	3	15.2	22.8
M12	M	A	73	NA	NA	NA
F6	F	A	141	NA	NA	NA
F7	F	A	NA	1	8	13.0
M13	M	A	139	1	12.7	11.7

Chapter 4:
Landbird Abndance, Distribution, and Habitat Relationships

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EXECUTIVE SUMMARY

In this document we report on the avian module of the Plumas Lassen Area Study (PLAS). 2005 was the third full year of avian monitoring in the PLAS study area. As of the end of the 2005 bird breeding season, none of the proposed treatments had been implemented, thus everything we report on herein reflects pre-treatment conditions.

Analysis and discussion in this report are intended to provide background information on the pre-treatment status of the avian community, provide information to help guide ongoing planning of treatments, and provide a preliminary analysis and discussion of concepts that are being further developed for publication.

Species richness and total bird abundance in 2005 was higher than in either of the two previous years in each treatment unit. We recorded an increase in these metrics at over 80% of transects surveyed. General patterns of abundance and richness were consistent across years and treatment units. Units 1, 4 and 5 had the highest total bird abundance and species richness while units 2 and 3 had significantly lower species richness in both 2004 and 2005. Proposed Defensible Fuel Profile Zones (DFPZ's) in Treatment Unit 1 and 4 have slightly higher species richness than the surrounding landscape. The two most abundant shrub nesting species, Fox Sparrow and Dusky Flycatcher, were significantly more abundant in proposed DFPZ treatments than areas not scheduled for treatment, while three late seral associated species – Hermit Warbler, Brown Creeper, and Hammond's Flycatcher – were all significantly more abundant in areas not slated for DFPZ treatment.

Preliminary analysis indicates that species richness is lower – though not significantly – adjacent to Spotted Owl nest and roost sites than areas outside of owl protected activity centers. Shrub and ground nesting species were significantly less abundant at owl sites while tree nesting species were significantly greater at owl sites. Cavity nesting species abundance showed no difference between owl and non-owl sites.

We have updated our interactive GIS tool to include the 2005 data. This tool can provide forest planners with information on avian species richness, total bird abundance, and the abundance of each species detected at each of the 1176 point count stations surveyed across the five treatment units for each year 2003 – 2005.

INTRODUCTION

Coniferous forest is one of the most important habitat types for birds in California (Siegel and DeSante 1999, CalPIF 2002). In the Sierra Nevada, a century of intensive resource extraction and forest management practices 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; declines and extirpations 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). 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 Spotted Owl respond to these conditions?

Specifically, 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 (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 stability 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, this module will address 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) Determine population trends for landbirds to identify 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 (again over the short term).

In addition to this study PRBO has been monitoring songbird populations in the Northern Sierra since 1997. Since 2001, these efforts have aimed to complement the avian research of the Administrative Study by focusing on monitoring the non-coniferous habitats within the HFQLG area (see Burnett et al. 2005a and Burnett et al. 2006). 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. Working closely with the project planners from Forest Service ranger district staff, these studies are being implemented as adaptive management experiments. These efforts 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.

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) 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 begin around local sunrise, are completed within four hours, and do not occur in inclement weather. Each transect is visited twice during the peak of the breeding season from mid May through the end of June.

Treatment Unit and Transect Nomenclature

In this report we use the former treatment units (TUs) – those defined in the original Admin 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” that is consistent across them and are simply used here as a tool to describe geographically linked portions of the study area. Additionally, it is important to note that while we refer to DFPZ’s as treated sites and our extensive sampling points as untreated sites, to date all of our data is pre-treatment.

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 class and size class of the randomly generated starting point respectively (e.g. 222 is in TU-2, cover class 2, and size class 2). In 2003 and 2004, under the existing study plan, transects are named after the CalWater Planning Watershed (CalWater 1999). For example, SNK1 is in the Snake Lake watershed and is the first transect established while CHG3 is in the China Gulch watershed and was the third transect established. The numeric ending is simply for designating between the different transects in the same watershed and does not have any additional significance.

Owl Point Count Site Selection

In 2005 we added an additional 72 point count locations adjacent to known Spotted Owl nest or roost sites that were inside of previously designated Protected Activity Centers (PAC’s). Our initial goal was to place 3 to 4 point count stations surrounding five different nests in each of the five treatment units. All points were at least 200 meters apart and no new points established were within 100 meters of a designated nest. We first attempted to choose known nest sites when for logistical reasons we could not establish points at 5 nests in each unit we settled for probable nests, followed by known roosts of pairs. Where it was feasible we attempted to tie new points into existing transects to minimize additional survey effort. In multiple cases only 1 to 3 points were added, as points from existing transects were already located in close proximity to owl nests by chance thus meeting our 4 point criteria. Each owl point was surveyed using the same protocol as all other points described above.

2005 Survey Effort

In 2005 we surveyed 93 transects of 12 points each as well as the 72 additional owl territory points for a total of 1188 points (Table 1). Each site was surveyed twice for a total of 2376 point visits. Of these 1188 points, 1043 are located in areas not-currently slated for DFPZ treatment (extensive and owl sampling), with the remaining 145 located within DFPZ's scheduled for treatment. All of these DFPZ transects are located in TUs 1 and 4 (Table 1). As the location of additional DFPZ networks is solidified in (former) TUs 2, 3, and 5, and potentially elsewhere, we will add additional transects to those sites, as described in the study plan (Stine et al. 2004).

Field Crew Training

Point count crew members all have had previous experience conducting avian fieldwork and undergo extensive training onsite for three 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 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 a survey. Distance and bird identification calibration continues throughout the field season.

Vegetation Sampling Methods

Vegetation is assessed using the relevé method, following procedures outlined in Ralph et al. (1993). In summary this method uses a 50-meter radius plot centered on each census station where habitat characteristics of the site are recorded (e.g. # of snags, basal area) and the cover, abundance, and height of each vegetation stratum (tree, shrub, herb, and ground) are determined through ocular estimation. Within each vegetation stratum, the species composition is determined and each species' relative cover recorded, as a percentage of total cover for that stratum (see Ralph et al. 1993 for complete description). In addition we collect fuel loads and conduct ladder fuel hazard assessments at each station following methods outlined in the fire and fuels module study plan (Menning and Stephens 2004). In 2005 we only collected vegetation data from sites that had not been surveyed in the past two years or have been treated since they were surveyed (e.g., points in the Kingsbury-Rush project area).

Statistical Analysis

We analyzed point count data in order to create by-point community indices for each transect. Community indices were created using 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 surveyed using the point count method (e.g. raptors, waterfowl, grouse, nightjars, swallows, crows, ravens).

We present the mean by point (average per point per visit, per year, by transect) for the following three indices. This method allows for using the point as the individual sampling unit and

Table 1. Extensive and DFPZ point count transects surveyed in the Plumas – Lassen Study in 2005.

Treatment Unit	Watershed	Code	Extensive Survey Points	DFPZ Survey Points	New Owl Territory 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	57	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	62	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**		**201**	**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		**971**	**145**	**72**

therefore makes possible the stratification of points for analysis based on attributes other than the transect and comparison of uneven sample sizes.

Species Richness

Species richness is defined 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

Species diversity is defined as the mean number of species detected within 50 m (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-Wiener 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.

Spotted Owl Nest Avian Community Analysis

We are in the process of analyzing differences in the avian community inside and outside of different Spotted Owl habitats, considering differences at multiple scales ranging from the area immediately surrounding nests and roost sites, to the larger protected activity centers (PACs) and the even larger core areas. The preliminary analysis presented here only compares the avian community in close proximity to owl nests and roost sites (<500 meters) to areas outside of Spotted Owl PACs. In this analysis we removed points that were within PACs but not within 500 meters of nests or roosts.

RESULTS

Overview

A total of 93 species were detected during point count surveys in 2005, the same as in 2004 and one more than was detected in 2003. A total of 102 species have been detected across all 4 years of the study (Appendix 9). We determined breeding bird species richness and abundance at all sites surveyed in 2005 (Table 2), and included indices for these same transects from all previous years they were surveyed (i.e. 2002 -2004). For the location of each transect we refer you to the supplemental GIS project available on compact disc. In 2005, abundance (the average number of individuals detected within 50 meters of each point per visit) ranged from a 1.38 on the SOD3 transect to 7.33 on HAL3. Species richness ranged from 2.13 on the SOD3 transect to 8.13 on the HAL3 transect. The mean index of abundance was higher in 2005 than 2004 for 79 of the 93 transects, and richness was higher in 2005 for 80 of the 93 transects. The mean abundance for all non-DFPZ transects in 2005 was 4.83 compared to 3.50 in 2004 and 4.25 in 2003, and species richness was 6.17 in 2005 compared to 4.77 in 2004 and 5.73 in 2003.

Of all the DFPZ transects surveyed, the highest mean per point abundance in 2005 was recorded at both D401 and D407; the lowest was 3.38 at D409. The highest per point mean species richness was 7.25 recorded at D407 while the lowest was at 4.42 at D409. The mean total bird abundance and species richness from all DFPZ transects combined were higher for TU-1 DFPZ transects combined than for TU-4 transects – as in 2004 – though the differences were not statistically significant (Table 2).

Table 2. Mean abundance, ecological diversity, and species richness for all point count transects surveyed by PRBO in the Plumas/Lassen area study in 2005 (including all data from all years they were surveyed). Locations of all transects can be obtained in the CD supplement.

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

		Abundance				Richness			
Transect	**Unit**	**2005**	**2004**	**2003**	**2002**	**2005**	**2004**	**2003**	**2002**
324	3	5.21	4.63	3.83	4.54	6.00	5.25	5.17	6.83
BLH1	3	3.92	2.09	2.42	NS	5.08	3.36	3.25	NS
BLH2	3	2.71	3.55	NS	NS	4.00	4.73	NS	NS
HAL1	3	4.08	2.50	3.46	NS	5.83	3.92	5.58	NS
HAL2	3	4.50	3.00	3.92	NS	5.08	3.58	5.17	NS
HAL3	3	7.33	3.25	6.96	NS	8.17	4.67	7.67	NS
IND1	3	4.96	2.83	4.13	NS	6.83	4.50	5.50	NS
RUS1	3	5.04	5.79	5.83	NS	6.42	6.92	7.75	NS
SOD1	3	3.67	3.92	NS	NS	4.83	5.75	NS	NS
SOD2	3	4.04	2.75	NS	NS	6.58	4.17	NS	NS
SOD3	3	1.38	0.63	NS	NS	2.16	1.17	NS	NS
SPC1	3	3.79	3.13	3.29	NS	5.08	4.33	4.75	NS
SPC2	3	5.04	2.21	4.25	NS	6.00	3.50	5.75	NS
Subtotal	**3**	**4.47**	**3.43**			**5.88**	**4.74**		
413	4	5.29	4.83	2.83	5.83	6.83	6.33	2.58	7.83
414	4	4.42	4.75	4.38	6.79	6.25	6.08	6.50	8.58
422	4	5.36	3.71	4.54	4.29	6.42	4.58	5.42	5.92
423	4	5.04	3.58	3.29	4.58	5.92	4.92	4.50	6.75
424	4	4.25	3.54	5.46	5.75	5.75	5.33	7.42	8.00
MIF1	4	5.79	3.29	4.00	NS	6.75	4.25	5.50	NS
MIF2	4	5.50	3.00	5.67	NS	7.50	4.25	7.42	NS
MIF3	4	7.21	3.54	5.21	NS	7.25	4.50	6.17	NS
D404	4	5.00	3.35	6.50	4.96	6.25	5.00	8.33	7.08
D405	4	4.67	3.35	4.79	4.46	6.50	4.90	7.00	6.50
LKF1	4	5.04	2.96	NS	NS	6.58	3.42	NS	NS
LKF2	4	3.42	3.83	NS	NS	4.50	4.92	NS	NS
LKF3	4	4.21	5.13	NS	NS	5.58	6.75	NS	NS
MVY1	4	6.08	3.29	4.75	NS	7.42	4.33	6.92	NS
MVY2	4	5.92	3.79	5.58	NS	6.83	5.17	7.08	NS
PLC1	4	5.46	3.71	NS	NS	7.25	5.67	NS	NS
SIL1	4	6.96	3.08	5.17	NS	8.00	4.42	6.67	NS
SIL2	4	6.04	6.83	5.13	NS	7.17	7.08	7.17	NS
SIL3	4	3.25	2.46	2.29	NS	4.25	3.17	3.75	NS
SNK1	4	5.04	2.38	4.25	NS	6.58	3.75	5.50	NS
SNK2	4	4.08	2.33	4.54	NS	5.17	3.33	6.33	NS
SNK3	4	5.25	1.71	NS	NS	6.17	2.67	NS	NS
Subtotal	**4**	**5.15**	**3.57**			**6.41**	**4.77**		
513	5	4.79	6.79	3.00	5.38	6.58	7.67	4.33	6.92
514	5	4.38	4.08	5.75	2.46	6.58	5.58	5.17	4.25
522	5	5.25	3.17	5.63	5.50	6.00	4.42	7.25	7.67
523	5	5.50	2.42	3.33	3.54	7.00	4.00	5.75	5.25
524	5	5.17	3.04	2.79	4.42	6.33	4.92	4.08	6.42
BEG1	5	4.21	1.96	3.42	NS	5.75	3.25	4.42	NS
CHG1	5	3.58	2.46	3.46	NS	4.92	3.58	5.08	NS
CHG2	5	4.88	3.17	6.67	NS	6.08	4.33	8.25	NS
CHG3	5	4.38	5.79	3.54	NS	6.00	7.25	5.17	NS
FRC1	5	4.88	2.96	5.25	NS	6.50	4.67	7.08	NS
GRZ1	5	3.29	2.58	3.92	NS	4.25	3.50	4.92	NS

		Abundance				Richness			
Transect	**Unit**	**2005**	**2004**	**2003**	**2002**	**2005**	**2004**	**2003**	**2002**
GRZ2	5	4.25	3.96	3.58	NS	5.75	5.75	5.67	NS
GRZ3	5	6.96	3.38	4.71	NS	6.00	5.08	7.08	NS
RED1	5	4.96	4.42	4.75	NS	6.83	5.67	5.92	NS
RED2	5	5.58	3.38	3.00	NS	7.50	4.92	5.08	NS
RED3	5	4.71	3.92	4.13	NS	7.00	5.83	6.25	NS
D501	5	5.50	2.35	4.21	NS	6.67	3.40	5.75	NS
HAV1	5	5.17	3.42	5.75	NS	7.00	4.92	7.67	NS
HAV2	5	4.33	3.42	4.92	NS	6.92	5.08	7.25	NS
Subtotal	**5**	**4.83**	**3.51**	**4.31**		**6.30**	**4.94**	**5.90**	
Extensive Total	**1-5**	**4.83**	**3.50**	**4.25**		**6.17**	**4.77**	**5.73**	
DFPZ									
D102	1	5.08	2.42	3.54	5.29	6.42	2.75	5.00	5.92
D107	1	5.83	3.63	3.50	4.25	6.92	5.50	5.25	6.17
D108	1	5.25	6.09	NS	5.89	6.83	7.25	NS	4.67
D110	1	4.63	2.79	NS	NS	6.25	4.08	NS	NS
D111	1	4.88	3.42	NS	NS	6.58	5.33	NS	NS
D112	1	4.58	5.46	NS	NS	5.67	7.08	NS	NS
Subtotal	**1**	**5.04**	**4.27**	**4.58**	**5.17**	**6.46**	**5.61**	**6.29**	**6.90**
D401	4	6.04	2.30	4.21	6.79	7.67	3.33	5.00	8.75
D402	4	4.26	3.05	4.13	4.71	5.83	4.50	5.58	6.75
D403	4	4.21	1.85	3.79	3.71	5.75	2.45	5.58	5.42
D407	4	6.04	3.00	3.46	4.42	7.75	4.83	5.33	6.33
D408	4	4.67	3.70	5.88	4.50	6.08	5.08	7.58	6.75
D409	4	3.38	2.00	1.92	NS	4.42	2.73	3.00	NS
Subtotal	**4**	**4.77**	**2.65**	**3.90**	**4.83**	**6.25**	**3.82**	**5.35**	**6.80**

Species Richness by Treatment Unit

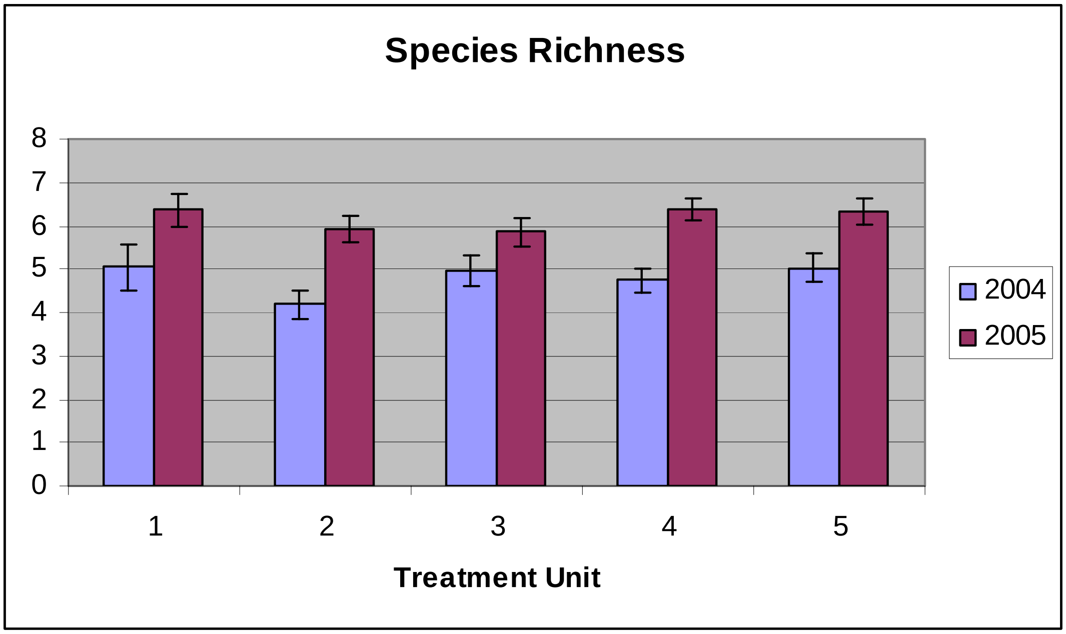
We compared per point mean species richness between treatment units and years (Figure 1). Treatment unit one was the most species rich in both years followed closely by unit five; the two highest elevation units. Richness in units 1, 4, and 5 did not differ significantly (p>.10) from each other though all three were significantly higher than units 2 and 3. Annual variation was significant for all units between 2004 and 2005 (p<0.01). The greatest difference in richness between years was in unit 2 which increased from 4.17 to 5.95 from 2004 to 2005.

		Abundance				Richness			
Transect	**Unit**	**2005**	**2004**	**2003**	**2002**	**2005**	**2004**	**2003**	**2002**
RED1	5	4.96	4.42	4.75	NS	6.83	5.67	5.92	NS
RED2	5	5.58	3.38	3.00	NS	7.50	4.92	5.08	NS
RED3	5	4.71	3.92	4.13	NS	7.00	5.83	6.25	NS
D501	5	5.50	2.35	4.21	NS	6.67	3.40	5.75	NS
HAV1	5	5.17	3.42	5.75	NS	7.00	4.92	7.67	NS
HAV2	5	4.33	3.42	4.92	NS	6.92	5.08	7.25	NS
Subtotal	**5**	**4.83**	**3.51**	**4.31**		**6.30**	**4.94**	**5.90**	
Extensive Total	**1-5**	**4.83**	**3.50**	**4.25**		**6.17**	**4.77**	**5.73**	
DFPZ									
D102	1	5.08	2.42	3.54	5.29	6.42	2.75	5.00	5.92
D107	1	5.83	3.63	3.50	4.25	6.92	5.50	5.25	6.17
D108	1	5.25	6.09	NS	5.89	6.83	7.25	NS	4.67
D110	1	4.63	2.79	NS	NS	6.25	4.08	NS	NS
D111	1	4.88	3.42	NS	NS	6.58	5.33	NS	NS
D112	1	4.58	5.46	NS	NS	5.67	7.08	NS	NS
Subtotal	**1**	**5.04**	**4.27**	**4.58**	**5.17**	**6.46**	**5.61**	**6.29**	**6.90**
D401	4	6.04	2.30	4.21	6.79	7.67	3.33	5.00	8.75
D402	4	4.26	3.05	4.13	4.71	5.83	4.50	5.58	6.75
D403	4	4.21	1.85	3.79	3.71	5.75	2.45	5.58	5.42
D407	4	6.04	3.00	3.46	4.42	7.75	4.83	5.33	6.33
D408	4	4.67	3.70	5.88	4.50	6.08	5.08	7.58	6.75
D409	4	3.38	2.00	1.92	NS	4.42	2.73	3.00	NS
Subtotal	**4**	**4.77**	**2.65**	**3.90**	**4.83**	**6.25**	**3.82**	**5.35**	**6.80**

Species Richness by Treatment Unit

We compared per point mean species richness between treatment units and years (Figure 1). Treatment unit one was the most species rich in both years followed closely by unit five; the two highest elevation units. Richness in units 1, 4, and 5 did not differ significantly ($p>.10$) from each other though all three were significantly higher than units 2 and 3. Annual variation was significant for all units between 2004 and 2005 ($p<0.01$). The greatest difference in richness between years was in unit 2 which increased from 4.17 to 5.95 from 2004 to 2005.

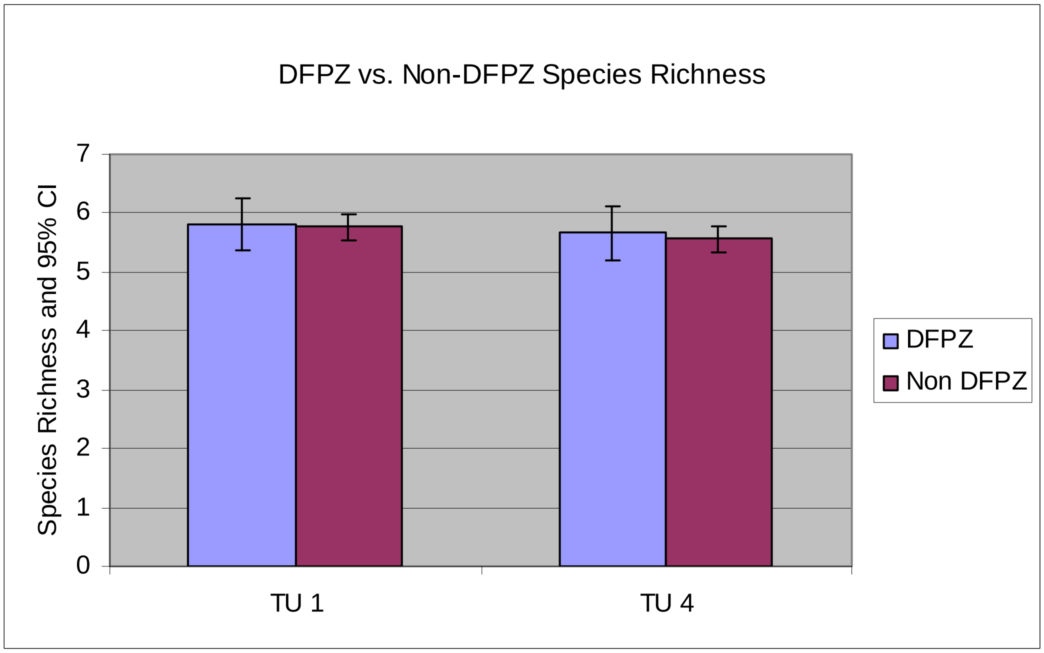
Figure 1. Avian species richness per point average by treatment unit in 2005 in the Plumas Lassen Study, with 95% confidence intervals.



DFPZ vs. Non-DFPZ Abundance and Species Richness

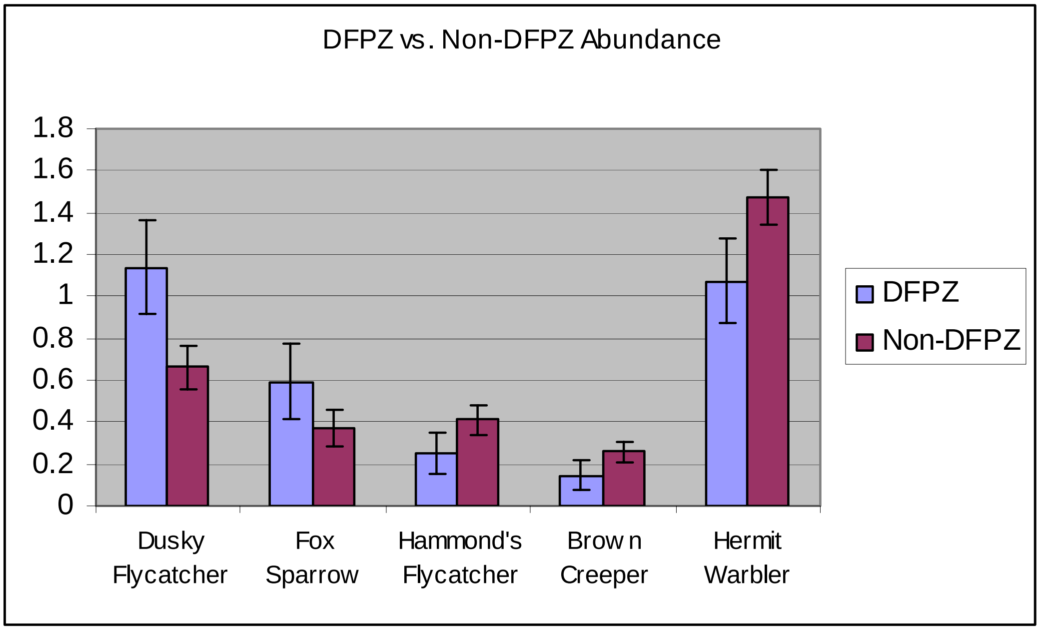
We compared species richness between pre-treatment DFPZ and extensive sites (non-DFPZ's) in TUs 1 and 4 using data from 2004 and 2005 (Figure 2). In both TU-1 and 4 species richness was very similar between DFPZ sites and extensive sites as well as between the units.

Figure 2. Avian species richness per point average (2004-2005 combined) comparing all DFPZ and extensive point count stations in Treatment Units (TU) 1 and 4 with 95% confidence intervals.



We compared the abundance of the 20 most detected species between DFPZ and non-DFPZ point count locations in TU-4 using data from 2004 and 2005. Of those 20 species we found significant differences in the abundance of five species: Fox Sparrow, Dusky Flycatcher, Hermit Warbler, Brown Creeper, and Hammond's Flycatcher (Figure 3). The two species most closely aligned with shrub dominated habitats (Fox Sparrow and Dusky Flycatcher), were both more abundant in areas slated for DFPZ treatment, while the three species significantly less abundant in DFPZ's are all associated with late seral stage forest (Hermit Warbler, Brown Creeper, and Hammond's Flycatcher).

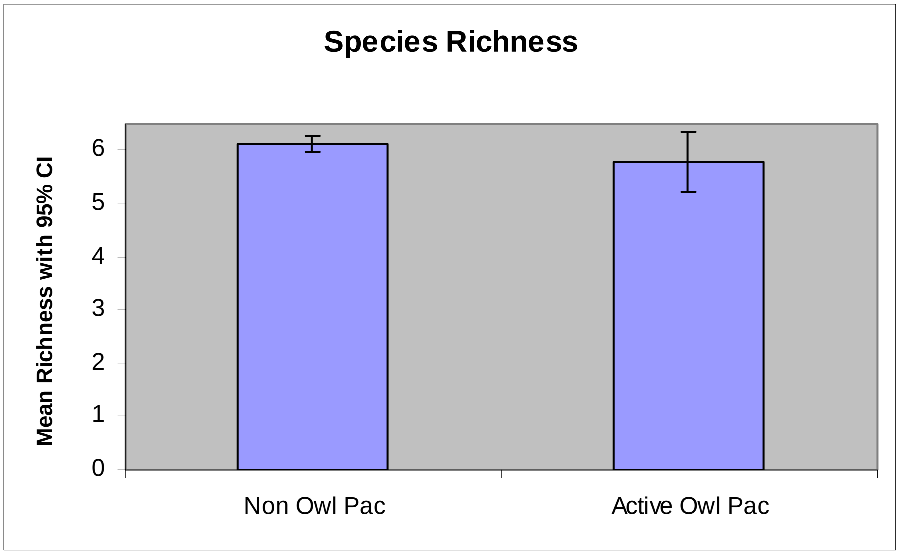
Figure 3. Mean abundance per point (detections <50m) of five avian species at pre-treatment DFPZ and non-DFPZ (extensive) point count stations in Treatment Unit 4 in the PLAS study area, 2004-2005 combined.



Spotted Owl Nest Site Avian Community Composition

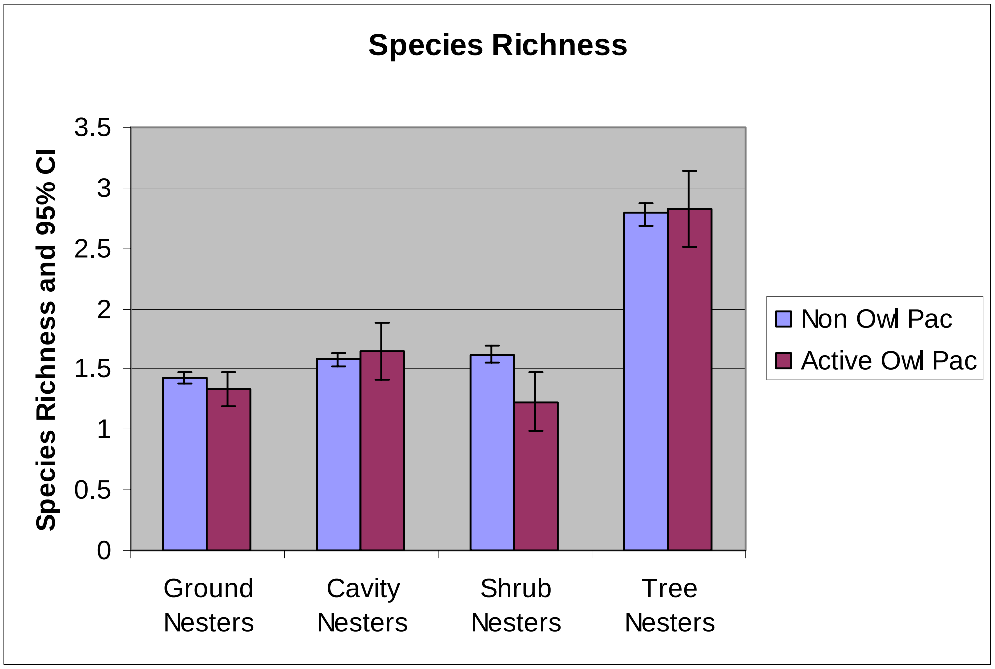
We compared avian community composition between areas in close proximity of known owl nests and roost sites to areas completely outside of owl protected activity centers for 2005 (Figure 4). Mean per point species richness at non-owl points was 6.12 compared to 5.78 at owl sites; this difference was not statistically significant (p=0.11).

Figure 4. Mean per point avian species richness around owl nest and roost sites compared to the surrounding PLAS study area landscape, 2005.



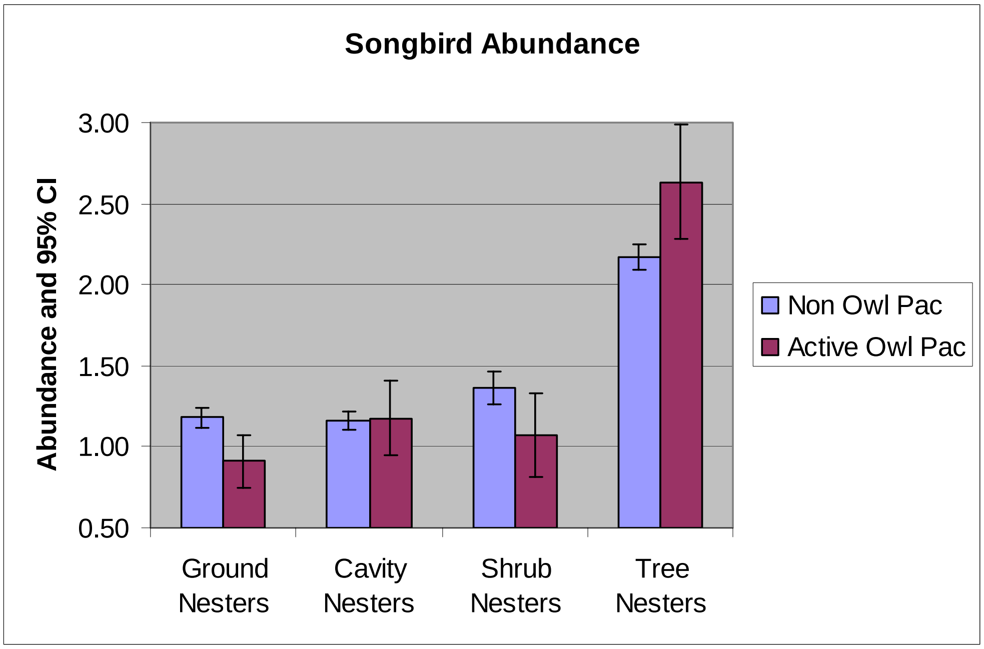
Using the same set of owl and non-owl points we compared the richness and abundance of the four primary nesting guilds in the study area (Figure 5). There was a greater richness of shrub nesting species (1.62 vs. 1.23; $p<0.05$) at non-owl sites than at owl sites. The species richness of the remaining three guilds (ground, cavity, and tree) was not significantly different between sites.

Figure 5. Mean abundance per point of species in four nesting guilds around owl nest and roost sites compared to areas outside Spotted Owl PACS, 2005.



When comparing total abundance we found significant differences with three of the four nesting guilds (Figure 6). Ground (1.18 vs. 0.91; $p<0.05$) and shrub nesters (1.36 vs. 1.07; $p<0.05$) were significantly more abundant at non-owl sites while tree nesters (2.17 vs. 2.64; $p<0.05$) were significantly more abundant at owl sites. Cavity nesters (1.17 vs. 1.18; $p>0.10$) were not significantly different.

Figure 6. Mean abundance per point of species in four nesting guilds around owl nest and roost sites compared to the PLAS study area as a whole in 2005.



GIS Project for Creating Species Maps

We created a GIS project incorporating all bird data collected from 2003 - 2005 (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

Annual Variation in Indices

Mean indices of species richness and total bird abundance were higher in 2005 than in either of the previous two years. Based on our seven years of monitoring in the region, fairly substantial annual variation appears to be the rule and not the exception for the avian community. Annual variation at the level we have documented in the PLAS study area complicates a study attempting to discern effects of treatments. However, with three to four years of pre-treatment data we should still have ample statistical power to detect the signal from treatment effects. Additionally, with enough years of data collection we will be able to analyze the factors influencing annual variation in bird abundance – interesting in its own right – but more importantly it will allow us to control for those factors to discern the effects of treatments.

Abundance and Species Richness by Treatment Unit

While there was considerable annual variation between years, generally transects that had high indices were consistently high across years while transects with low indices were consistently low. Despite annual variation it is clear that treatment units 1, 4 and 5 have significantly higher species richness and total bird abundance than units 2 and 3. It appears that higher elevation sites harbor a greater diversity of avian species per point. However, it is important to consider that species richness and total bird abundance are only on part of managing for a healthy avian community. Ensuring habitat for species of management concern or declining species is critical to ensure that management practices are not leading other species towards threatened status.

DFPZ vs. Non-DFPZ Abundance and Species Richness

Ideally, planned forest thinning would occur in general in areas with lower quality avian habitat. We found species richness in pre-treatment DFPZ's in TU-1 (Creeks project) and TU-4 (Meadow Valley project) to be slightly higher than the surrounding forest.

Though many factors go into determining the placement of DFPZ's, we believe proposed forest treatments would have less negative and more positive effects on the avian community if they were focused in the size class three densely stocked forest that dominates the landscape. Dense thickets of pole sized trees are probably the lowest quality avian habitat in the forest. They have low avian species richness, total bird abundance, and abundance of declining species, such as Olive-sided Flycatcher, Chipping Sparrow, woodpeckers, and Nashville Warbler.

Based on our analysis of species composition it appears planned DFPZ's in TU-4 are more focused on shrub dominated habitats. The two avian species that were significantly more abundant inside of pre-treatment DFPZ's were Fox Sparrow and Dusky Flycatcher. These two species are seldom found breeding away from shrubs. Nesting sites for these species averaged 60% or greater shrub cover in the Almanor Ranger District, and the abundance of both in the PLAS study area was strongly correlated with total shrub cover (Burnett et al. 2005a and b). In the Sierra Nevada region, Dusky Flycatcher decreased 3.63% per year from 1988 to 2003 (P=0.03) while Fox Sparrow had a non-significant declining trend over the same period (-0.33%, p=0.72) (Sauer et al. 2005). We found nest success for Dusky Flycatcher in the Almanor Ranger District to be among the highest ever reported for the species (Burnett et al. 2005a). Thus, we suggest that the observed decline is likely due to a decrease in available nesting habitat as a result of fire suppression coupled with movement away from more management practices that removed the majority of the overstory.

In recent years, there has been considerable discussion on the importance of removing understory ladder fuels to reduce fire hazard in the study area. In the one example of an implemented DFPZ treatment in the study area – the Kingsbury Rush project – a large portion of the treated area was shrub dominated habitat, and the treatment involved near complete mastication of several shrub fields. If the majority of areas outside of planned treatments are being managed for late seral forest conditions and DFPZ's are targeting habitats with high shrub cover, it is paramount to consider the importance of the shrub habitat for birds and other wildlife in these prescriptions. If DFPZ treatments continue to remove the vast majority of shrubs and are managed to minimize shrub regeneration (conifer release, herbicide, mastication) we would expect a precipitous decline in shrub nesting species in the study area in the coming years. Shrub habitats are a vital component of the Sierra forest ecosystem as there are numerous species fully dependent upon them for existence.

Proper management of Sierra Nevada forests involves ensuring that a mosaic of habitat types and conditions are represented on the landscape. While we are strong advocates of open forest and shrub habitats, we don't believe them any more important than old seral forest. However, we believe that current strategies may not be properly managing for these open forest and shrub habitat types. Our results from this and other studies in the region clearly illustrate the value of these habitat types to the avian community. If treated areas are managed for little to no understory structure, they are unlikely to provide for the majority of open forest dependent species. Based on our knowledge, these "park-like" habitats would have suppressed species richness and total bird abundance. More importantly they may not support open forest dependent species that are currently known to be declining and are predicted to be negatively impacted under the Sierra Nevada Forest Plan Amendment (SNFPA 2001, Sauer et al. 2005). We believe it is possible to manage for a balanced ecosystem that includes sufficient old growth and shrub habitat and the myriad of habitat conditions in between.

Spotted Owl Nest Site Avian Community Composition

Initial analysis of the avian community adjacent to owl nesting and roosting sites showed overall species richness to be slightly lower in owl sites. When broken down into different nesting guilds, the abundance and species richness we found significant differences. With the dense canopy and large trees characteristic of owl nest and roost sites, it is not unexpected to find shrub and ground nesters significantly less abundant. We suggest these results are further evidence of the importance of managing areas outside of owl habitat for understory plant diversity and volume that supports shrub and ground nesting species. We will further investigate the differences in avian community composition within several different scales of owl habitat. As Spotted Owls play a major role in forest management and protection, understanding what other avian species may benefit from owl management and which species are likely not to benefit is critical for ensuring the needs of the total complement of avian species that depend upon the Sierra Nevada ecosystem are being met.

CONCLUSION

In order to determine the short term response of the avian community to forest treatments it appears it will be necessary to collect several years of post-treatment data in order to separate out the effects of annual variation from the treatment effects. In order to properly evaluate the impact of forest treatments it will be necessary to monitor the avian community 10 to 20 years post treatment in order to determine the integrated effects of treatment and succesional processes.

Long-term, landscape based ecological monitoring will be critical to determining when an acceptable balance has been struck. 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 recent years fire suppression and timber harvest practices (among others) have tipped the balance of these systems in favor of overstocked forests with small to medium sized trees. Here we present several management recommendations to increase habitat attributes that have been reduced as a result of forest management practices over the past century or more and ones we perceive might disfavored under new management direction.

MANAGEMENT RECCOMENDATIONS

Snags

Our analysis, as well as that of many others, has shown that snags are a critical component of forest ecosystems. A myriad of avian species in these forests are completely dependent upon snags. Retaining four snags per acre should be an absolute minimum guideline; we recommend maintaining as many snags as possible with priority given to the largest ones.

Shrubs

Shrub habitats are a critical component of the forest ecosystem with many avian species fully dependent on them. Allowing group selection treatments and, where appropriate, DFPZ’s to naturally regenerate would ensure this habitat type does not dramatically decline in the next 25 years. Additionally, shrub understory within forested habitats should be valued and managed as an important habitat attribute.

Hardwoods

Thinning projects (both DFPZ and groups) can provide a dual benefit when incorporated into Black Oak and Aspen enhancement projects (e.g. Almanor and Eagle Lake ranger Districts of the Lassen National Forest). Hardwoods in general have suffered from fire suppression resulting in a dramatic decrease in the amount of these habitat types or attributes. Hardwoods and other shade intolerant species can benefit from strategically placing and designing DFPZ and group treatments.

Old Seral Forests

Many bird species are positively correlated with large tree habitat attributes in the study area. Undoubtedly this habitat has been drastically reduced here in the last century. With the abundance of size class 3 and the dearth of size class 4 and 5 forest currently on the landscape, every effort should be given to avoiding placement of groups or DFPZ's in size class 4 or 5 forests that contain old forest habitat attributes. Area thinnings appropriately placed in size class 4 forest that help reduce fuel loads and encroaching white fir could improve avian habitat quality.

Burned Forest

While controversy over salvage logging continues, it is clear from the scientific data that burned forest, including stand replacing burns, provide important bird habitat. The abundance and diversity of woodpecker species generally reaches a peak in recently burned forest. The Black-backed Woodpecker, a rare resident of northern Sierra forest, predominantly occurs in recently burned forest. Olive-sided Flycatcher, a species declining throughout the Sierra Nevada, has been shown to be strongly associated with burned forest as well. Thus we promote the view that burned forest is important wildlife habitat.

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PERSONNEL

This project is coordinated and supervised by PRBO staff biologist Ryan Burnett. Kim Maute was the field crew supervisor. Field work in 2005 was conducted by those listed above as well as Gabriel Cahalan, Jennipher Karst, Tim Ludwick, Shannon Page, Andrew Rothman, and Jim Tietz. Computer programs used to manage and summarize data were created by PRBO staff biologists Grant Ballard and Diana Humple. The study was carried out under the guidance of PRBO Terrestrial Program Director Geoffrey R. Geupel and PRBO Population Ecologist Nadav Nur.

ACKNOWLEDGEMENTS

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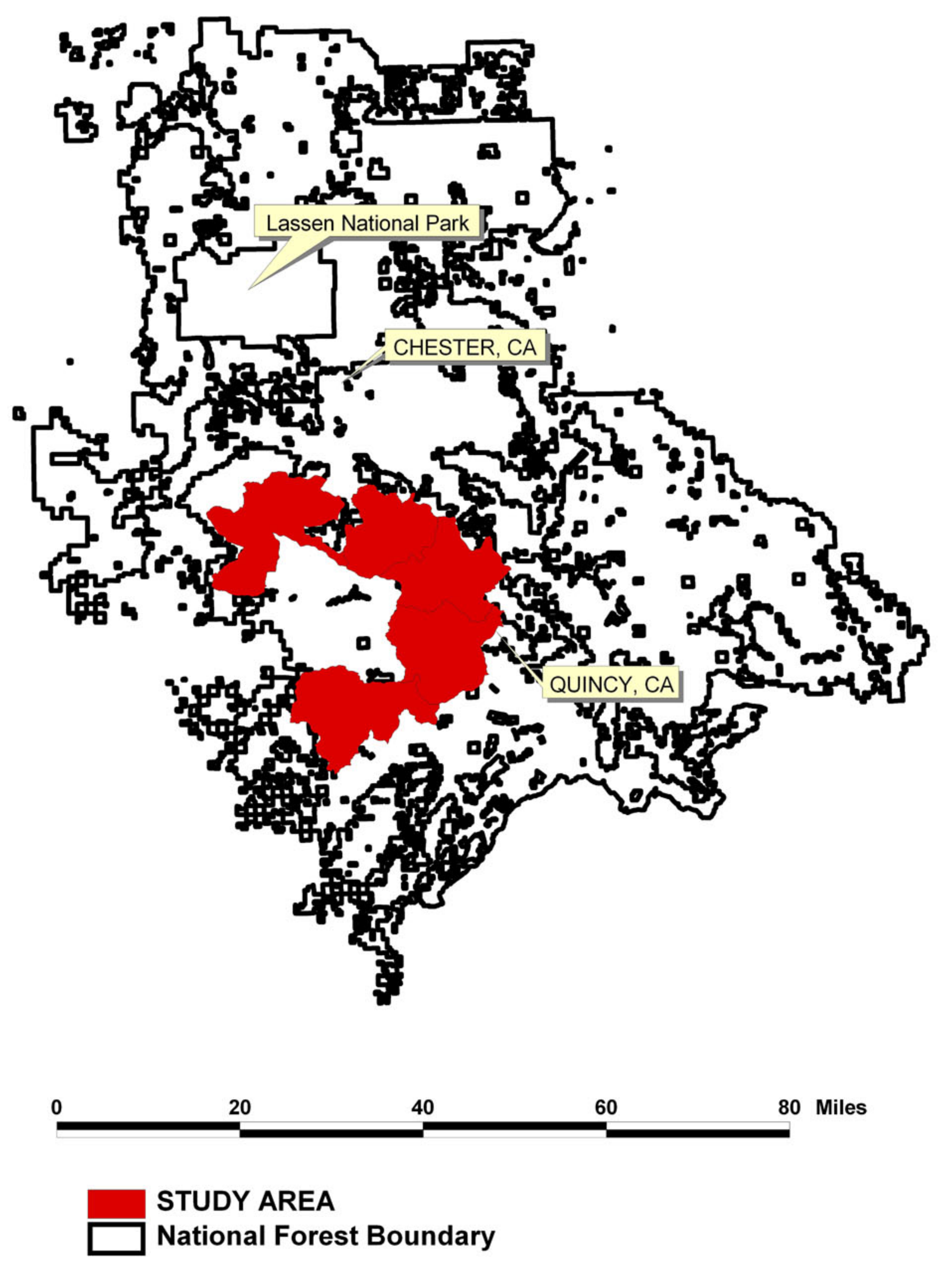
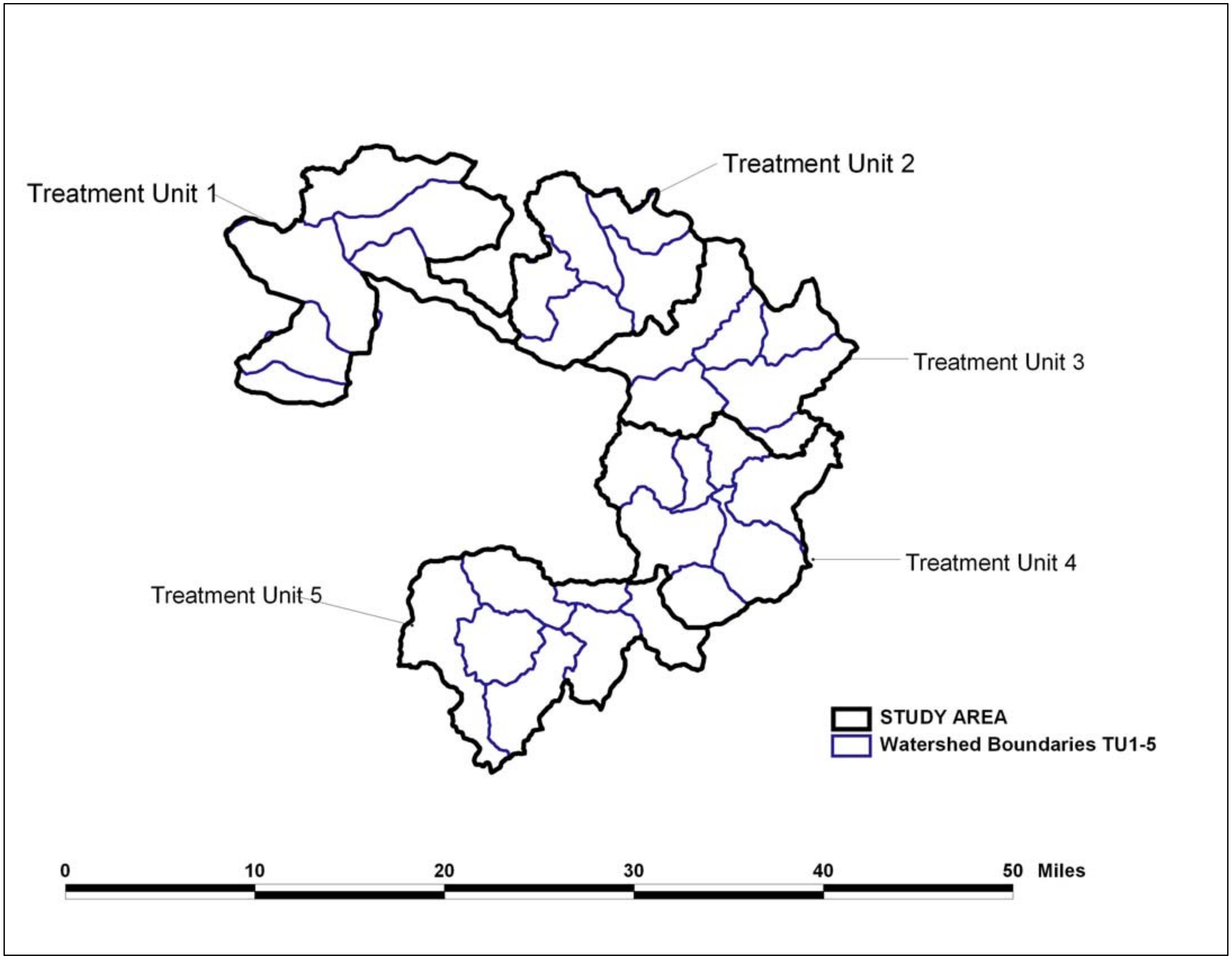
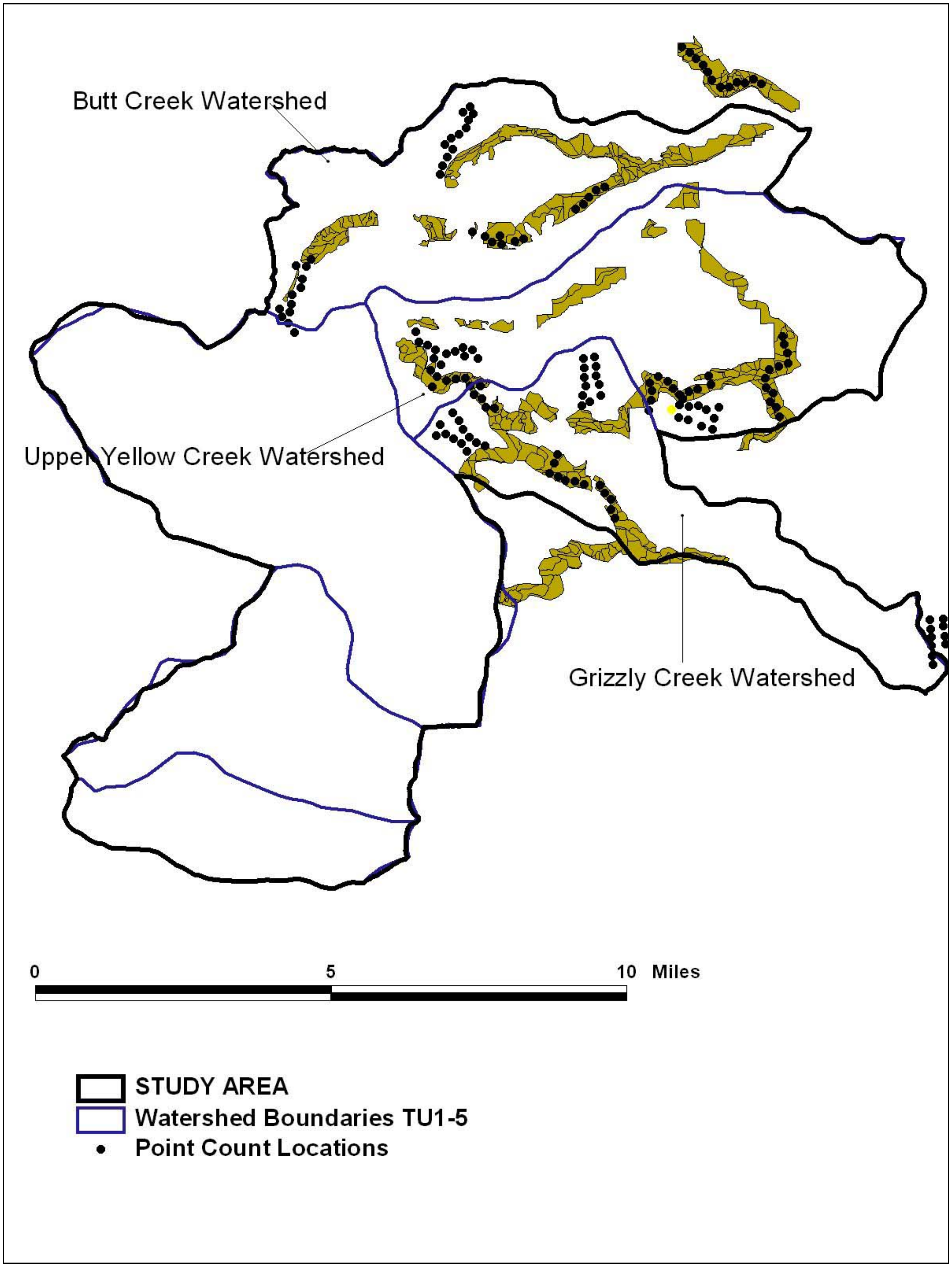
Appendix 1. Study area overview map of the PRBO Plumas Lassen module of the Administrative Study.



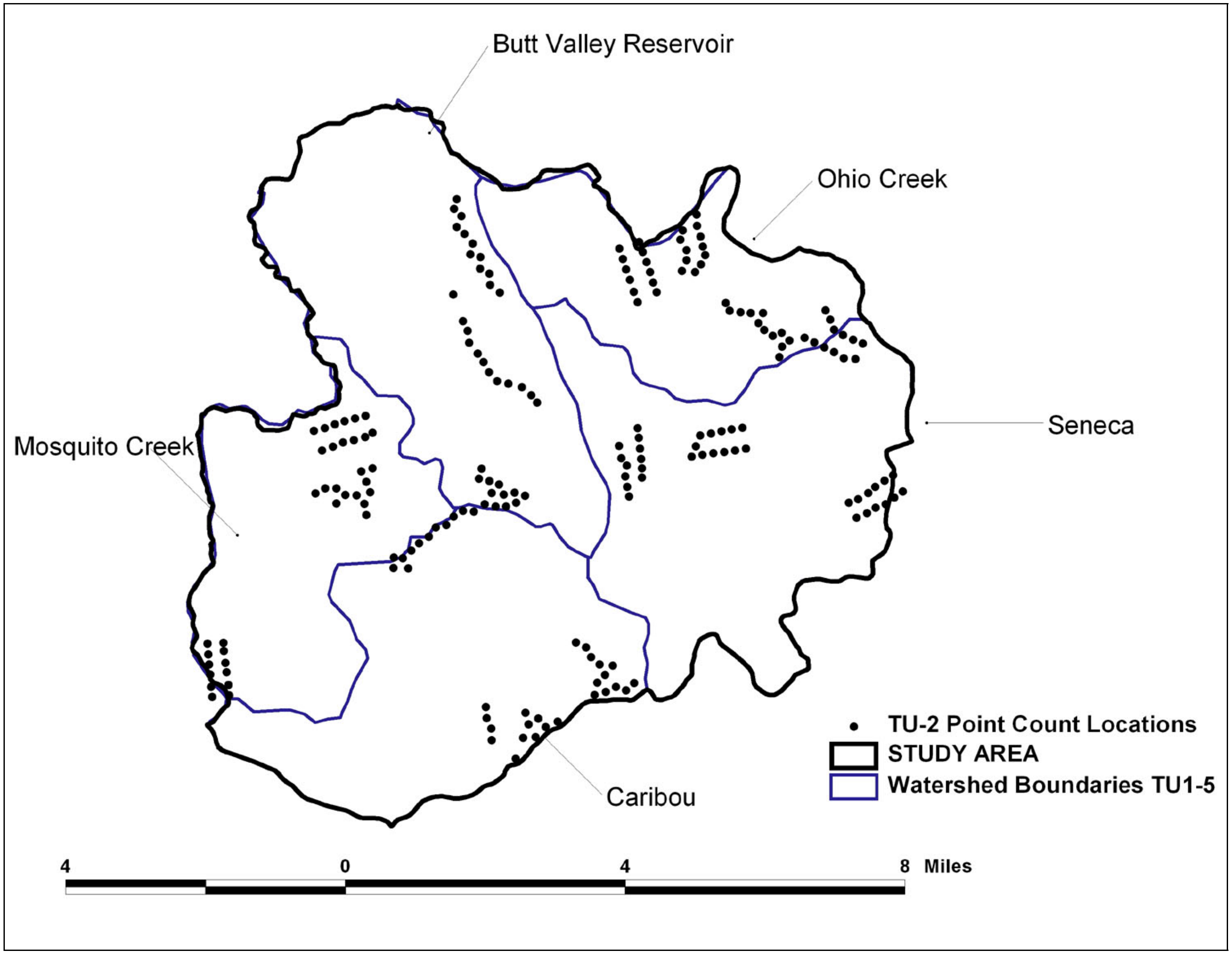
Appendix 2. Treatment Units and Watershed boundaries of the PRBO Plumas Lassen Avian Study Area.



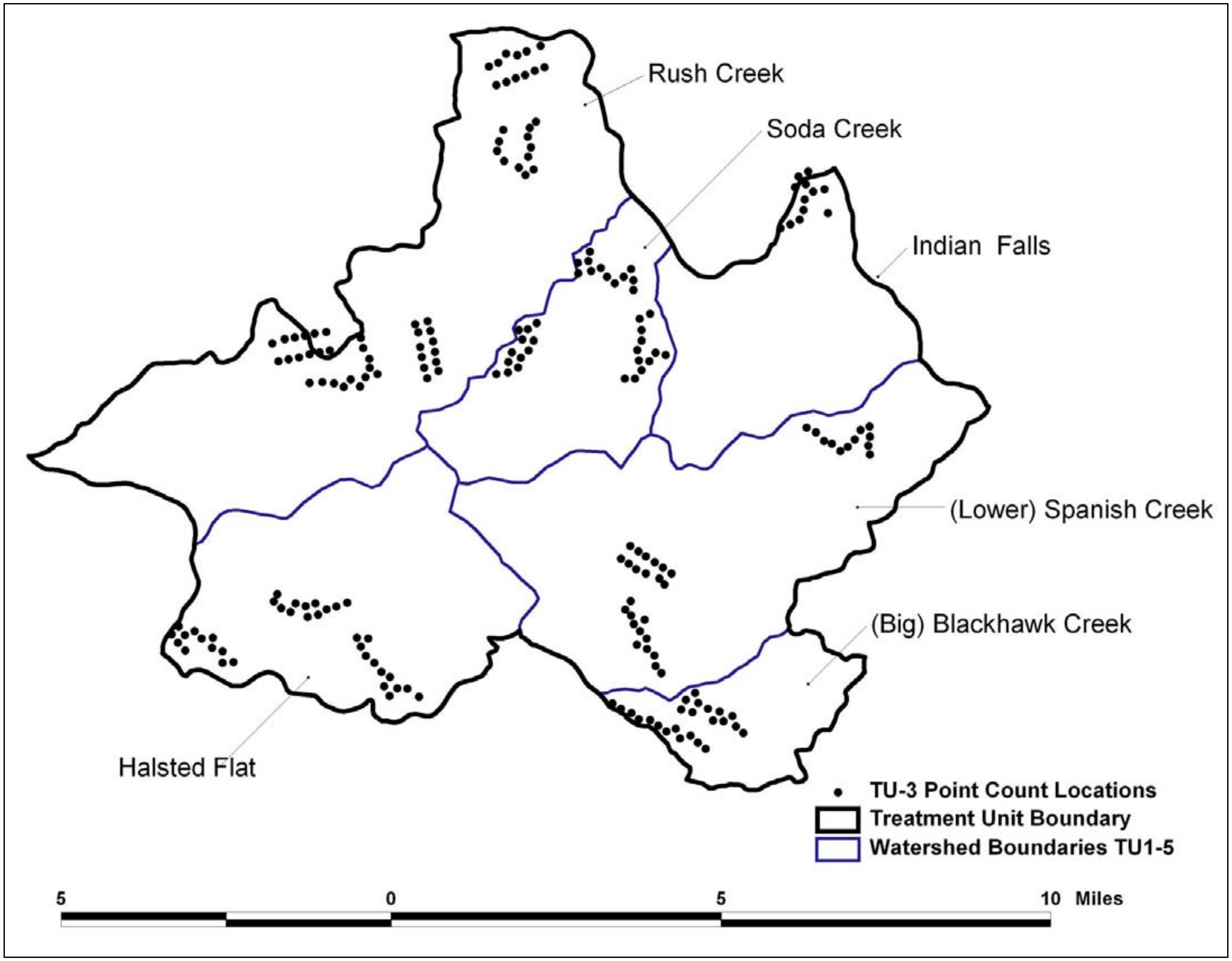
Appendix 3. Treatment Unit 1 Map with watersheds, DFPZ outlines, and locations of point count transects surveyed in 2005 for the PRBO Plumas Lassen Administrative Study.



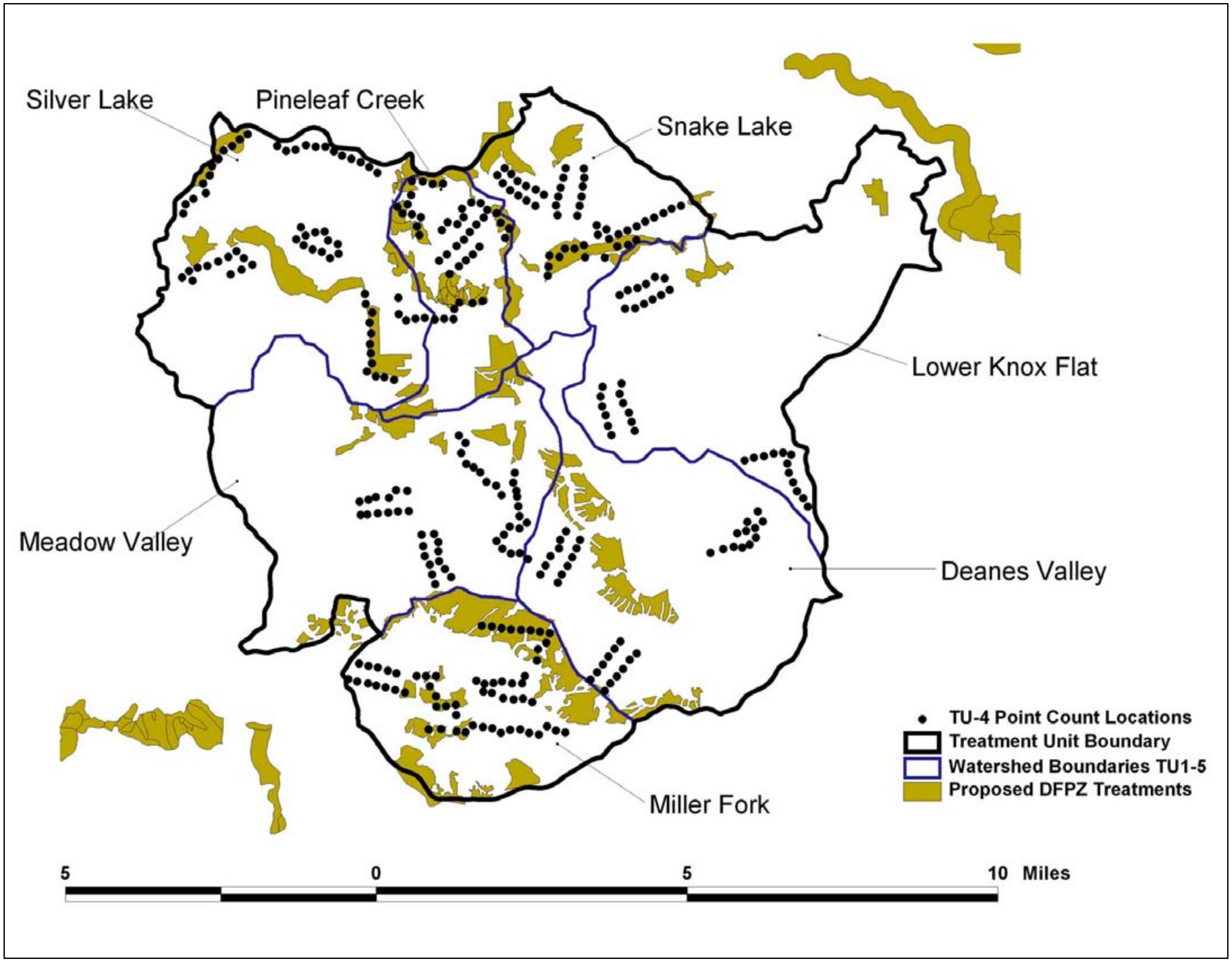
Appendix 4. Treatment Unit 2 map with watersheds, DFPZ outlines, and locations of point count transects surveyed in 2005 for the PRBO Plumas Lassen Administrative Study.



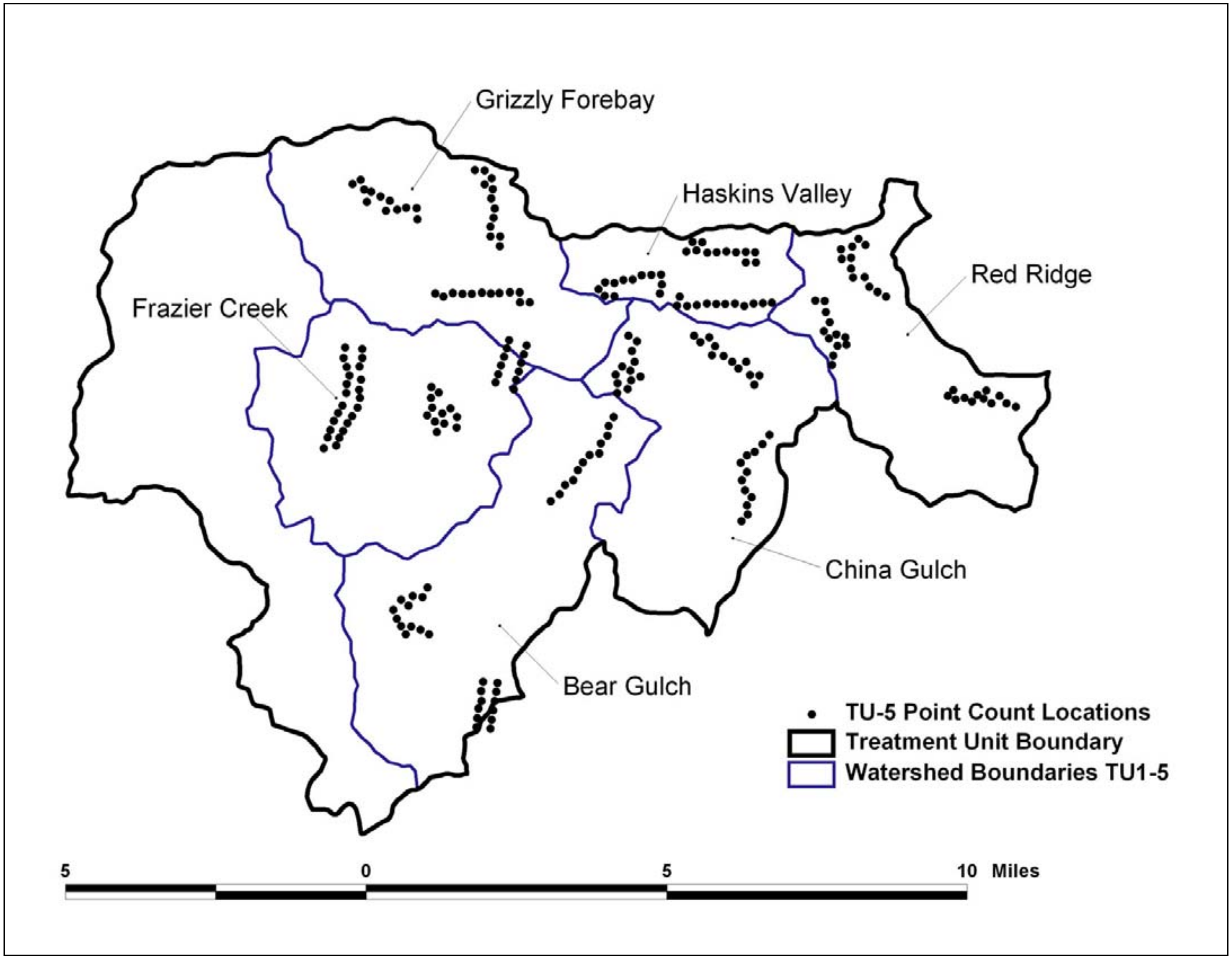
Appendix 5. Treatment Unit 3 map with delineating watersheds and locations of point count transects surveyed in 2005 for the PRBO Plumas Lassen Administrative Study.



Appendix 6. Treatment Unit 4 map delineating watersheds, DFPZ outlines, and locations of point count transects surveyed in 2005 for the PRBO Plumas Lassen Administrative Study.



Appendix 7. Treatment Unit 5 map delineating watersheds and locations of point count transects surveyed in 2005 for the PRBO Plumas Lassen Administrative Study.



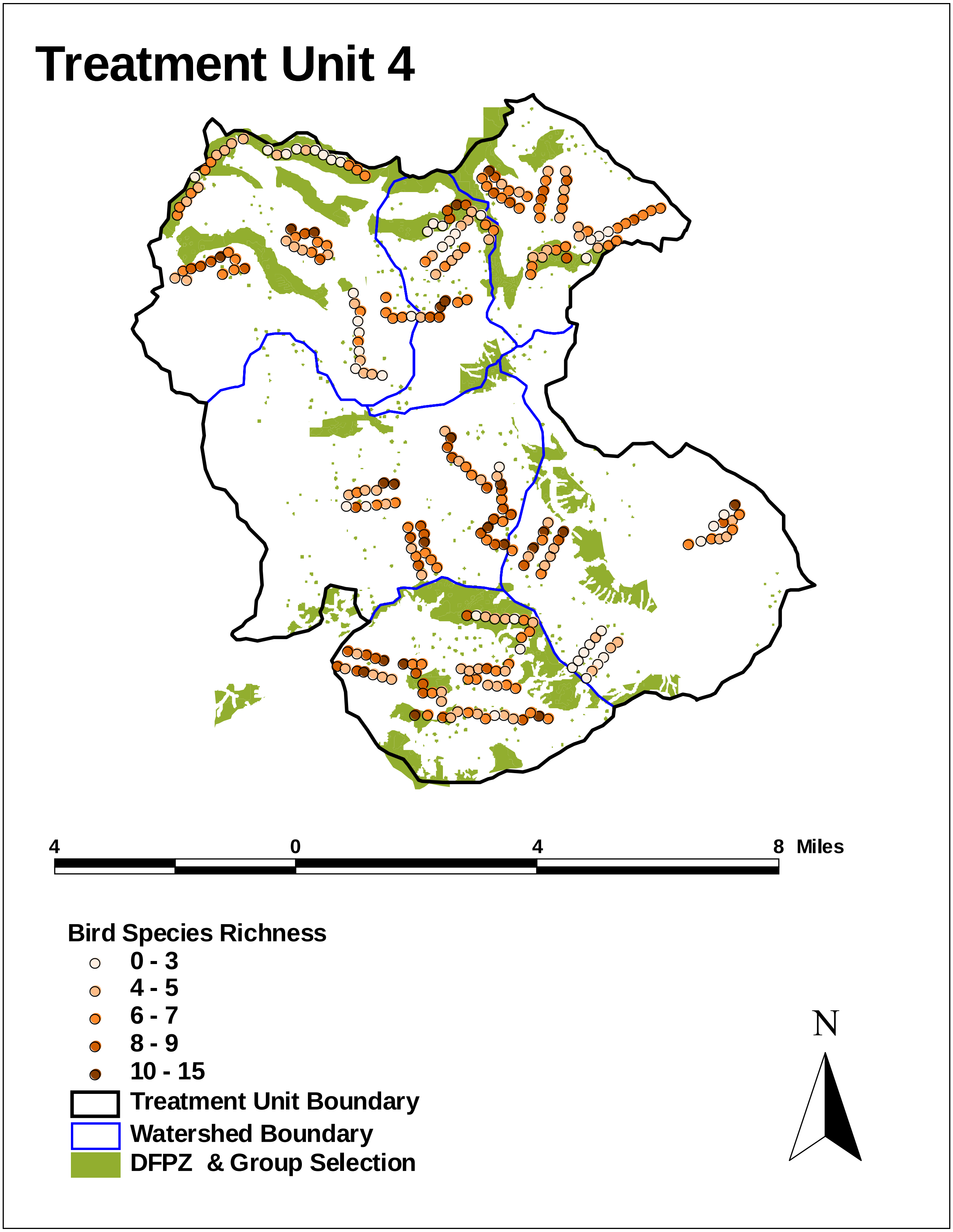
Appendix 8. List of all bird species detected by PRBO on point count surveys (common, AOU code, scientific name) in the PLAS in 2002 - 2005.

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*

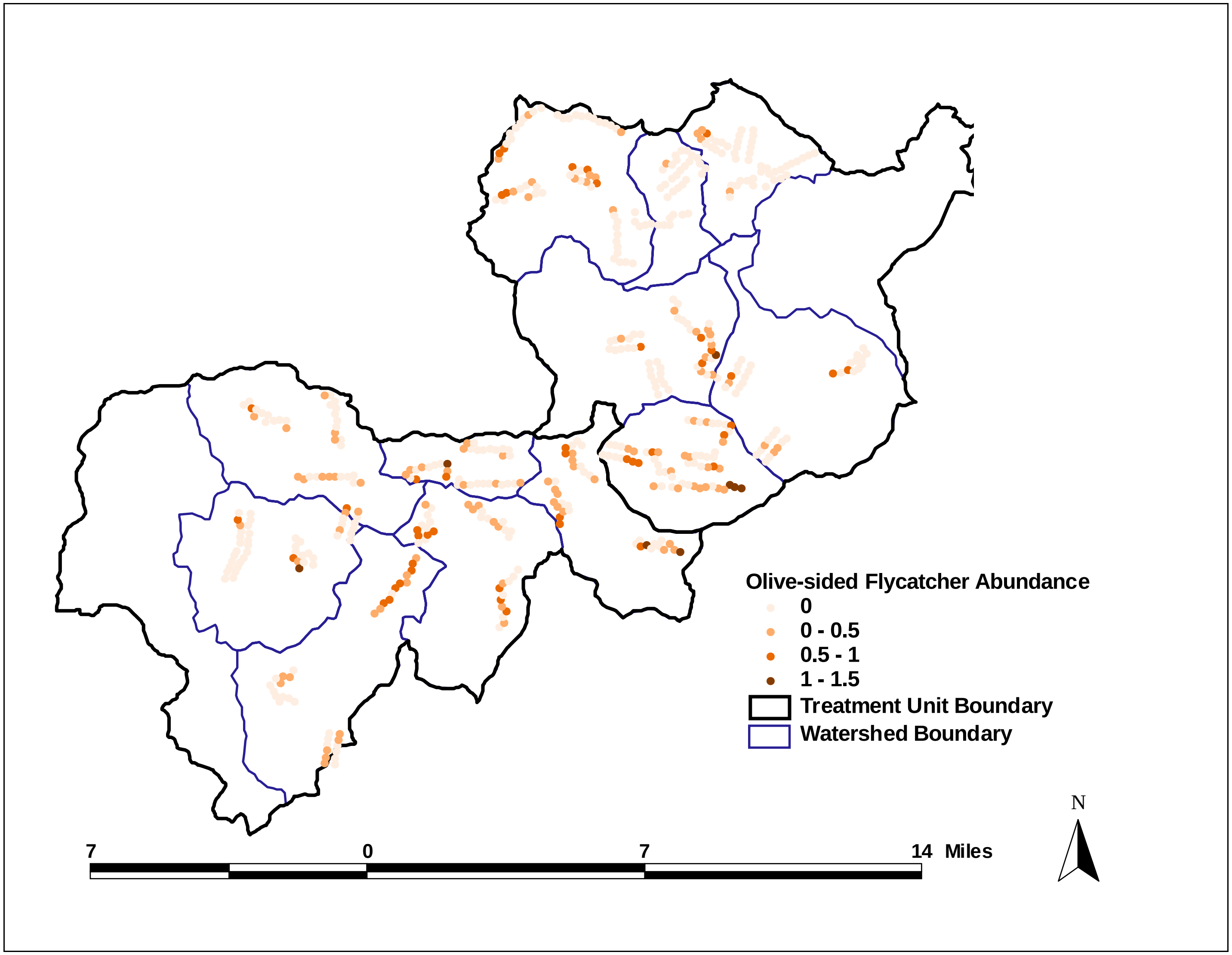
Common Name	AOU Code	Scientific Name
Great Blue Heron	GTBH	*Ardea herodias*
Green Heron	GRHE	*Butorides virescens*
Green-tailed Towhee	GTTO	*Pipilo chlorurus*
Hairy Woodpecker	HAWO	*Picoides villosus*
Hammond's Flycatcher	HAFL	*Empidonax hammondii*
Hermit Thrush	HETH	*Catharus guttatus*
Hermit Warbler	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*

Common Name	AOU Code	Scientific Name
Steller's Jay	STJA	*Cyanocitta stelleri*
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_PSWreportsupplement05.apr – ArcView project file. Double click this file to open the project.

PLASabsum05_allGIS.dbf – table which contains one line of data per point with all associated bird data from the 2005 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".

PLASabsum05_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."

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 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_PSWreportsupplement05.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 (PLASabsum05L50.dbf, PLASabsum05all.dbf, or 2003/2004 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)

Chapter 5:
California Spotted Owl Module

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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. Our focus in 2005 was to complete collection of CSO surveys and continue banding to provide the required baseline information to meet the objectives of Research Questions 1-4 identified above. Complete landscape inventory surveys were conducted across 11 survey areas in 2005 (Figure 1). 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. 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

CSO Numbers, Reproductive Success, and Density:

A total of 103 territorial CSO sites were documented in 2005 across the study area (Figure 2). This total consisted of 76 confirmed pairs, 17 unconfirmed pairs (i.e., one member of pair confirmed as territorial single plus single detection of opposite sex bird), and 10 territorial single CSOs (single owl detected multiple times with no pair-mate detected). Seventeen pairs successfully reproduced in 2005 (22% of confirmed pairs). A total of 26 fledged young were documented (1.53 young per successful nest).

We estimated the crude density of CSOs based on the number of territorial owls detected in each of the 11 survey areas during 2005 surveys at the Treatment Unit and Cal-Planning Watershed spatial scales (Table 1, Figure 3). The estimated crude density across the study area was 0.068 territorial owls/km^2 (Table 1). Estimated mean crude density across 60 CAL-Planning Watersheds that were completely surveyed was 0.070 territorial owls/km^2 (Figure 3).

Table 1. Crude density of territorial California spotted owls across survey areas on the Plumas National Forest in 2005. Locations of survey areas are identified in Figure 1.

Survey Area	Size (km^2)	Crude Density of Territorial CSOs
SA-2	182.5	0.132 /km^2
SA-3	218.5	0.082 /km^2
SA-4	238.3	0.050 /km^2
SA-5	260.3	0.069 /km^2
SA-7	210.4	0.062 /km^2
SA-1A	190.5	0.058 /km^2
SA-1B	130.4	0.023 /km^2
SA-11	180.0	0.044 /km^2
SA-12	192.4	0.094 /km^2
SA-13	193.4	0.072 /km^2
SA-14	331.2	0.063 /km^2
SA-15	317.4	0.060 /km^2
Total Study Area	2,645.3	0.068 /km^2

Vegetation Sampling – Nest Plots

Vegetation plots were measured at eighty CSO nest territories in 2005. Vegetation plots were centered on nest 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

Eighty-three owls were captured and banded in 2005. This included fifty new CSOs (i.e., owls banded for the first time) and 33 recaptures. Blood samples were collected from 76 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.

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

We detected the presence of 1 barred owl and 3 sparred owls during 2005 surveys within the overall study area. Our synthesis and update of barred-sparred owl records through 2005 based on Forest Service and California Department of Fish and Game databases indicates that there are a minimum of 33 individual site records across the northern Sierra Nevada (Figure 4). The first barred owl in the region was reported in 1989. Twenty-one of the 33 site-records were recorded and known occupied between 2002-2005. The pattern of records suggests that barred/sparred owls have been increasing in the northern Sierra Nevada between 1989-2005.

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 2).

Current Research: 2005-2006

In addition to continuing field surveys in 2006 designed to address our six research questions, our emphasis will broaden to focus on the development of predictive habitat relationship models as described in the module study plan. Baseline information collected in 2002-2005 forms the foundation for this phase of the research. These models should be completed in Winter 2005-2006. We also are expanding the scope of our study to fully collaborate and integrate our work with the ongoing Lassen Demographic study. This collaboration and integration will broaden the base of CSO distributional and demographic information that can be used to develop predictive habitat models for our use in an adaptive management framework and to directly monitor implementation of the HFQLG project.

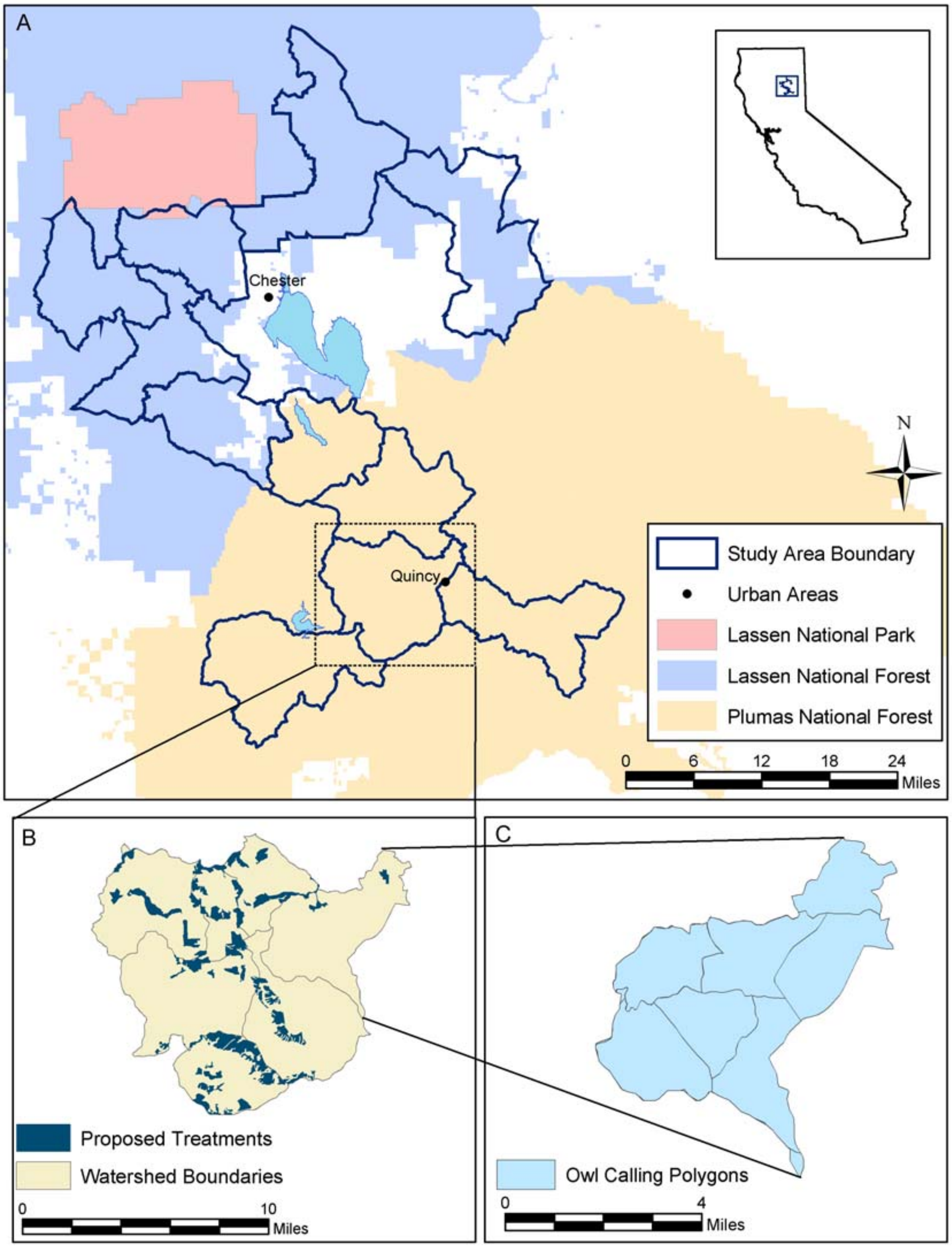

Figure 1. (A) Location of CSO Survey Plots surveyed in 2005. (B) Example of original survey plot consisting of multiple Cal-Planning watersheds. (C) Example of Primary Sampling Units for surveying for CSOs. See text and study plan for further details .

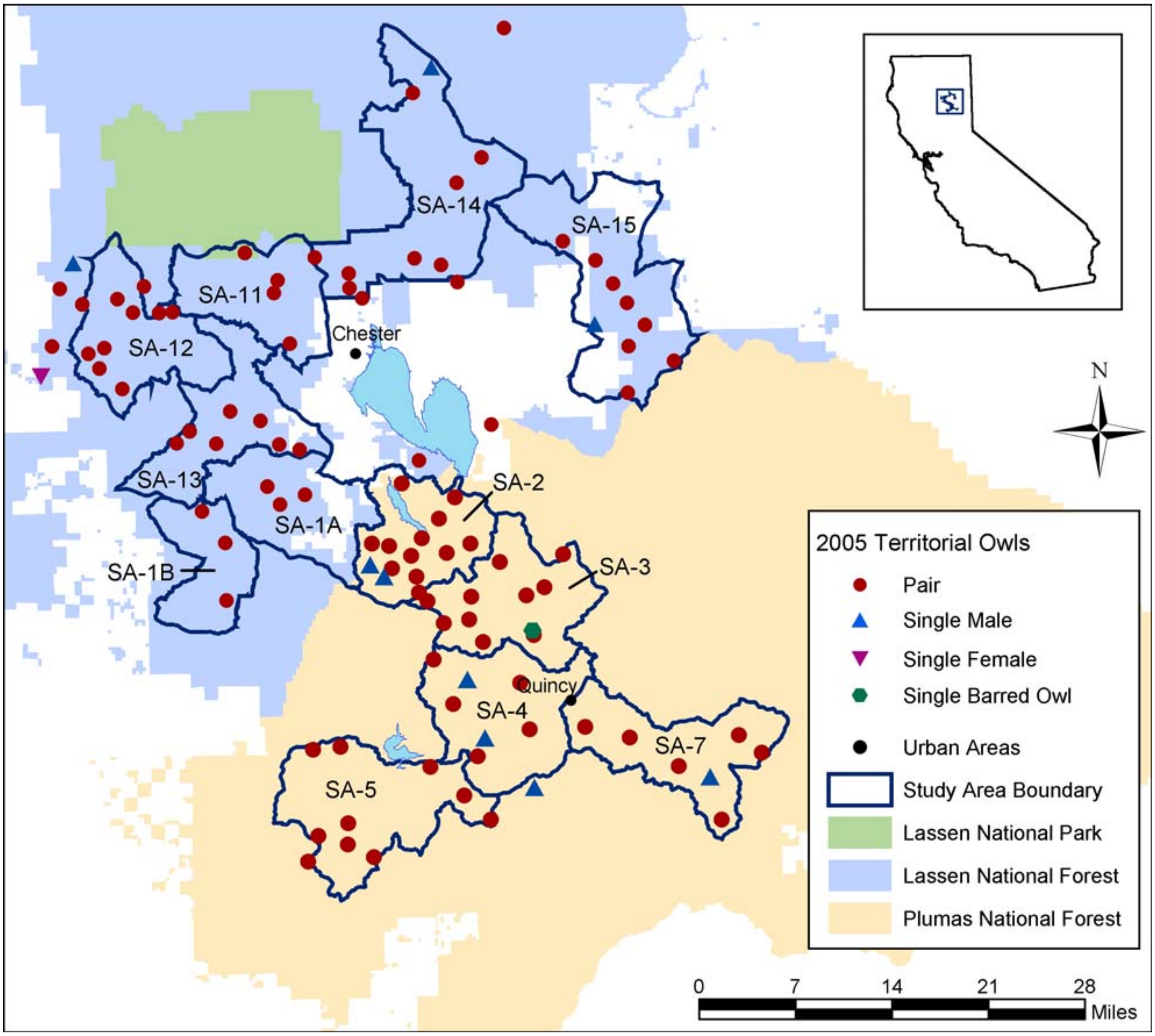

Figure 2. Distribution of California spotted owl territories within CSO survey plots across the Plumas National Forest, 2005.

Figure 3a.

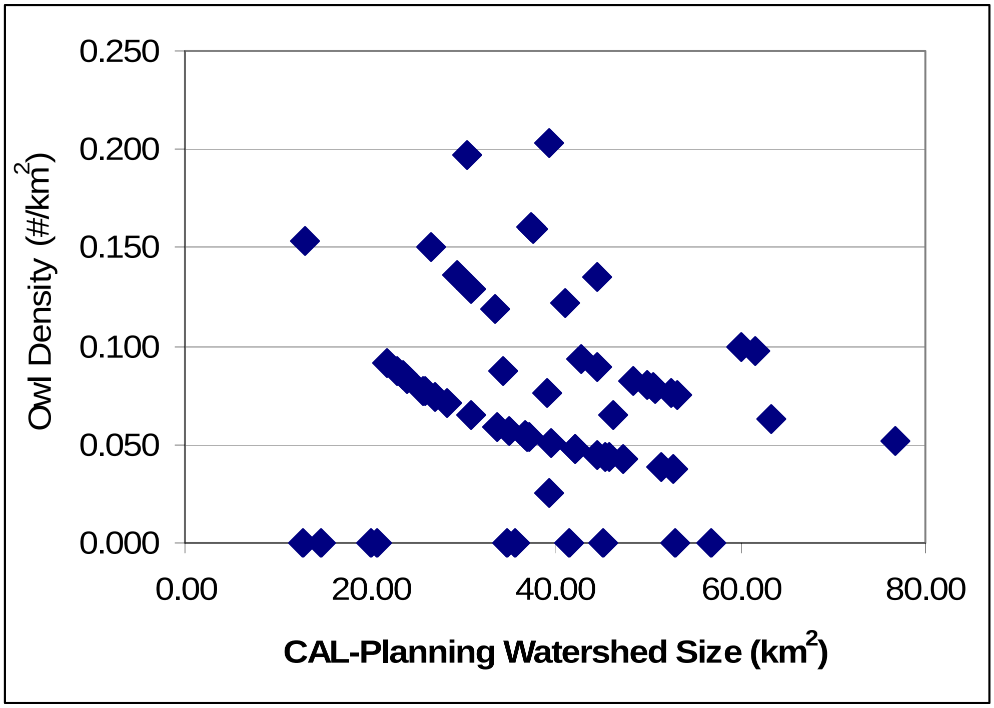

Figure 3b.

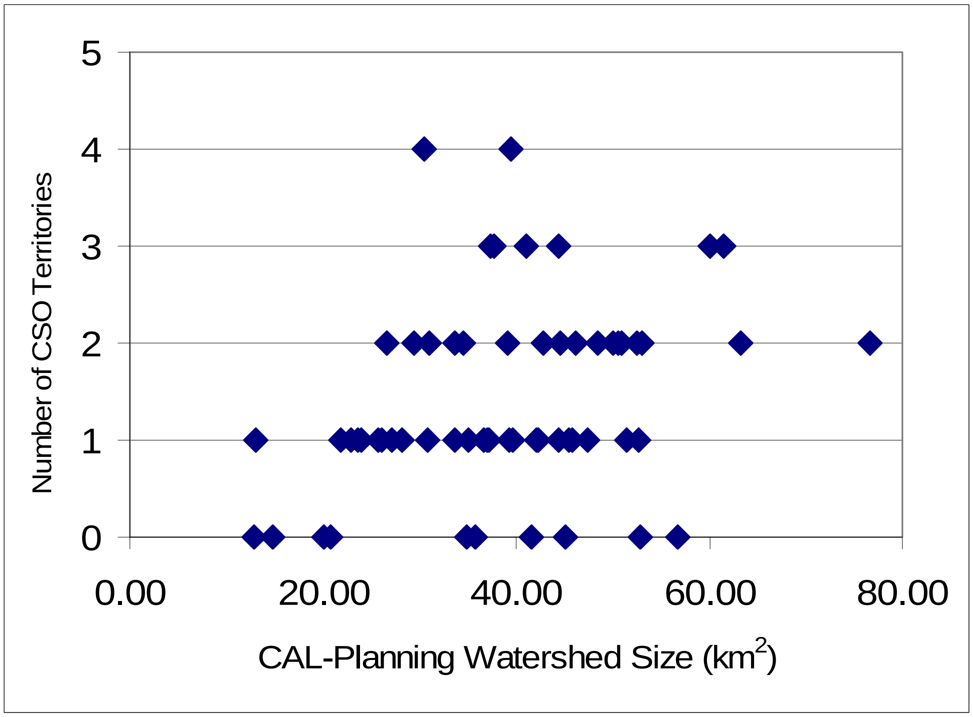

Figure 3. (a) Estimated crude density of territorial California spotted owls across CAL-Planning Watersheds, and (b) number of California spotted territories across CAL-Planning Watersheds on the Plumas National Forest during 2005.

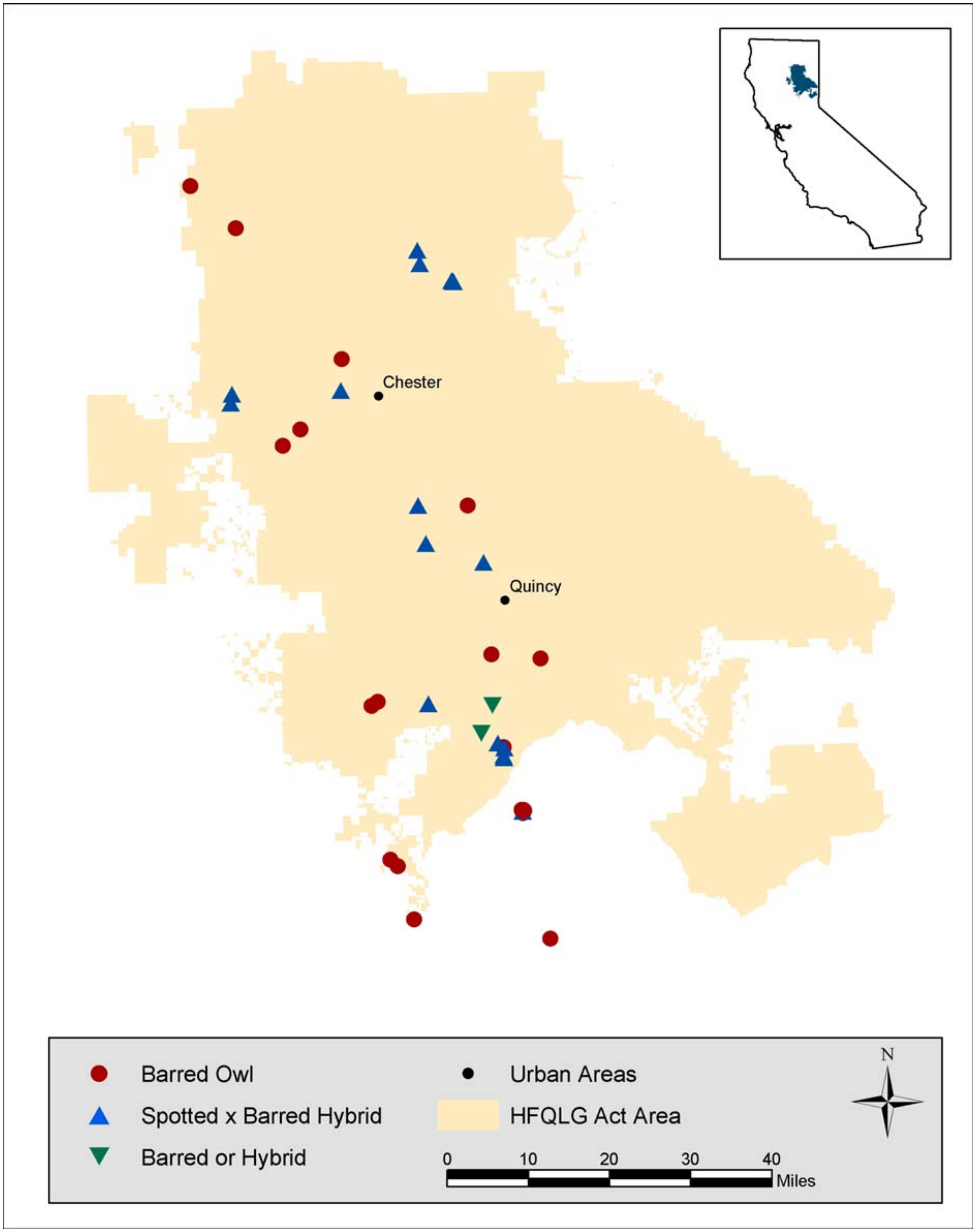

Figure 4. Distribution of Barred and Sparred (Spotted-Barred hybrids) Owls between 1989-2005 within the HFQLG Project area.

Table 2. 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 2. (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

Appendix A:

Fire Climbing in the forest: a semi-qualitative semi quantitative approach to assessing ladder fuel hazards

Title: Fire climbing in the forest: a semi-qualitative, semi-quantitative approach to assessing ladder fuel hazards

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Abstract

Ladder fuels carry fire from the forest floor to the canopy and thereby may turn low-severity, low-intensity fires into severe, catastrophic fires. Attempts at assessing ladder fuels have been either expensive and spatially-limited quantified approaches, or unrepeatable and variable expert opinion efforts. We have developed a mixed semi-quantitative, semi-qualitative approach using a flowchart that systematizes observations and constrains judgments and decision making. The ladder fuel hazard assessment (LaFHA) approach leads to ladder hazard ratings and some quantified observed data; it can be repeated across a very large area at relatively low cost, and due to the systematic and constrained approach, produces results that are mostly consistent and repeatable. Key attributes assessed are clumping of low aerial fuels, height to live crown base, and maximum gaps in vertical fuel ladders. Three field seasons of testing and implementing the LaFHA approach resulted in almost 4,000 observations. For the study area in the northern Sierra Nevada, California (USA), more than a quarter of sites were rated high hazard and about 40% more were moderate risk. Data are presented on heights to live crown base and maximum gaps for each of the rated hazard categories.

Key Words

Fire ecology; fire behavior; ladder fuels; fire hazard

1. Introduction

Many forest fires spread along the ground, only occasionally climbing up into the canopy (Agee, 1993; Pyne et al., 1996). Under most fire conditions, forest canopies are unable to sustain fire due to a low effective fuel load (kg dry mass/m^3) and large gaps between fuels (Agee, 1993; Pyne et al., 1996; Agee, 1998). An arrangement of fuel—woody material or vegetative matter—is typically required to convey flames from ground and surface fuels to the low, mid and high aerial fuels of the canopy. These low aerial fuels are called ladder fuels for the function they serve in forest fires; fire climbs up the aerial fuel matrix as a person might climb a ladder. The hazard of ladder fuels is that they can change the nature of the fire itself. A fire climbing from the forest floor up to the canopy may turn low-severity, low-intensity fires into severe, catastrophic canopy fires.

Ladder fuels are often discussed conceptually (Agee, 1993; MacCleery, 1995; Stephens, 1998; Meyer and Pierce, 2003; Brown et al., 2004; Sturtevant et al., 2004; Thacker, 2004; Peterson et al., 2005; Stephens and Moghaddas, 2005a; Stephens and Moghaddas, 2005b; Stephens and Fule, in press) but descriptions of actual measurements are less common (Ottmar et al., 1998; Scott and Reinhardt, 2001; Pye et al., 2003; Stephens and Moghaddas, 2005a; 2005b; Stephens and Fule, in press). Cruz et al. (2003) describes several definitions of ladder fuels as being somewhat useful but too vague for quantification (Ottmar et al., 1998).

Attempts to characterize or rank ladder fuel hazards typically use one of two approaches. Quantitative efforts entail measuring a number of physical attributes in a forest (Pye et al., 2003). Such measurements are challenging to conduct on a broad spatial scale because so many different measurements must be made; there are many different kinds of fuel and vegetation structures that can act as ladders from the ground to the canopy. While a quantified full-measurement approach might be the most repeatable and precise, it is also likely to be quite expensive, slow and difficult to apply across a large area.

Due to the difficulty of quantitatively measuring fuel ladders managers have generally relied upon a second approach: expert opinion. Experienced or trained technicians visually assess the conditions in an area and provide a rating or evaluation of risk. This approach is useful in that it is rapid, adapted to local conditions, and easy to apply across a large area. Unfortunately, it also has the drawbacks of being inconsistent and hard to repeat. Two "experts" may rank similar fuel structures differently or even inconsistently with themselves at different times such as in successive years.

We have attempted to devise a semi-quantitative, semi-qualitative approach that utilizes element of both prior approaches. We utilize a flow chart that guides trained technicians to rate ladder fuel hazards (LaFHAs) at a site. The flow chart helps ensure consistency in site evaluation by systematizing the approach while constraining the range of possible outcomes. Necessarily, this requires technicians to use their judgment to an extent. The approach attempts to limit the range of possible outcomes, however, by providing a limited set of evaluation criteria.

The success of a fuel ladder for conducting fire depends on burn-time conditions as well as the fuel structure itself. Only the fuel structure can be assessed in the field prior to the fire event and it is what we are attempting to measure. Ladder fuels are a function of several factors: vegetation type—sparse oak (*Quercus spp*.), for example, would generate less flame length than dense dry fir (Abies spp.) branches; clumping of low aerial fuels; vertical continuity of fuels from the ground to the canopy; and slope, which has a non-linear effect due to its effect on air flow and fuel pre-heating.

The LaFHA approach combines attributes of two general approaches. As with expert opinion approaches, we require a technician to visually identify key attributes of the fuel structure and it requires the technician make judgments. Also, it is rapid and adapted to local conditions. As with quantitative assessments, we systematize observations and constrain both the range of data taken and the types of judgments that can be made by the technicians. The results are mostly repeatable and quantified, as a result. The LaFHA flowchart guides technicians to identify clumping and vertical continuity of fuels. Vegetation type and slope are recorded and may be used to modify ratings at a later time in a systematic fashion covering the entire study area.

2. Methods

Field site and plot locations

The LaFHA method is designed to work in a variety of forested environments, from dense, low scrubs of young bishop pine (Pinus muricata) to tall redwoods (Sequoia sempervirens) with few ladder fuels. The system has been developed, however, in a mixed conifer forest in the Plumas National Forest located in the northern Sierra Nevada, California (USA). The climate is Mediterranean with a predominance of winter precipitation totaling about 1600mm per year. Elevation of the forest varies from approximately 1000-1500m.

Vegetation is primarily Sierra Nevadan mixed conifer forest, a mix of conifers and several hardwoods: white fir (Abies concolor), Douglas-fir (Pseudotsuga menziesii), sugar pine (Pinus lambertiana), ponderosa pine (P. ponderosa), Jeffrey pine (P. jeffreyi), and California black oak (Quercus kelloggii). Montane chaparral and some grasslands are interspersed with the forest (Schoenherr, 1992; Barbour and Major, 1995). Tree density varies by fire and timber management activity, elevation, slope, aspect, and edaphic conditions. The typical fire regime is frequent, low-severity fire with patches of high-severity canopy fire (Caprio and Swetnam, 1995; McKelvey et al., 1996; Sierra Nevada Ecosystem Project, 1996; Skinner and Chang, 1996; Stephens and Collins, 2004).

Site locations were determined three ways. First, several hundred plots locations were assigned based on a random stratification of the landscape using slope, elevation, aspect, and vegetation type to create unique strata. Vegetation data were derived from a coverage provided by the Plumas-Lassen Administrative Study (PLAS). Second, field technicians on the Small Bird research module of the PLAS collected data at their field locations across the Plumas National Forest. Third, the PLAS vegetation crew collected data at research sites coordinated by the California Spotted Owl, Small Mammal, and Vegetation Plot modules. As a result, plot locations are dispersed across a wide range of slopes, elevations, aspects and forest types and conditions.

Any method for determining ladder fuel hazards must have a defined area of observation. For our purposes, plots were deemed to be 12.6m in radius (1/20th ha) and were divided into four quadrants. Independent observations were made in each quadrant.

Ladder Fuel Hazard Assessment Flowchart Method

The LaFHA flowchart method involves six steps (Figure 1) and a number of definitions (Table 1). First, the technician is required to judge whether the site has forest covering part of the plot. A single tree in a field is not considered a forest as it does not have a canopy linked to other trees. A single tree extending over part of the plot that is near other trees is part of a forest. If no forest is present, the technician may declare the whole plot “non-forest” and give it a rating of E indicating no canopy for fire to reach.

If there is any forest covering part of the plot, the technician must then consider each quadrant one at a time. In this step two, the technician determines whether low aerial fuels are clumped in sufficient volume to produce flames that could reach up off the forest floor. Low aerial fuels typically are shrubs, short trees, low hanging branches, draped pine needles and other fuels arrayed in the air just above the ground. We define clumping as shrubs or small trees covering an area of at least four square meters (2m x 2m) with gaps of less than 50cm. If the fuel 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.

After determining whether fuels are clumped, the technician proceeds to the third step: assessing the continuity of the fuel ladder from the ground to the canopy (steps 3a and 3b, Figure 1). Ladders are considered continuous if vertical gaps of less than 2m are present. This number could be modified for other fire regimes.

In the fourth step, the technician records the rating to which the flowchart has led. Category A is high risk, with clumped aerial fuels leading to a continuous ladder. Categories B and C are moderate risk for different reasons. B has clumped fuels but the ladder, if present, is discontinuous. Flames would get off the ground but they wouldn't have a good ladder to climb. Sites rated C have no clumping of low aerial fuels, but if flames were to get off the ground and reach the lower canopy a ladder would conduct flames higher. Category D sites have no clumping and no ladder, so represent low fire laddering risk. The technician records measurements of height to lower live crown (HTLCB, or a large mass of clumped dead fuel on the tree) and the maximum gap in the best ladder in the quadrant. These data are used later to verify the classification (an A rating cannot have a gap of more than 2m, for example) and should be useful for evaluations of actual fire behavior. Potential values are shown in the flowchart itself.

Step five is to repeat the process for the next quadrant. Finally, step six may involve post-data collection processing: modification of ratings with additional factors such as slope, vegetation type, and aggregate values from the four quadrants of each plot.

Training

Training was conducted by the authors on most occasions and by experienced field technicians who had worked with the authors for some time. Feedback from the training sessions and the field crews has resulted in a number of improvements in the flowchart and its definitions (see discussion). Ideally, in an area, the same individual, or groups of individuals, would conduct training to make assessments as consistent as possible.

The amount of training time varied depending on the field technicians involved. Key factors include degree of previous experience with fire assessments and fuel measurements, knowledge of local area and vegetation, and basic understanding of fire behavior. As a result of these differences, some training sessions might be as short as several hours, and others took continued supervision over the course of a week.

3. Results

Almost four thousand (3824) observations were made over the course of three summers (2003-5) in the Plumas National Forest. Just over a quarter of the observations indicated sites had a high risk of conducting fire to the canopy, while just under 40% were in the moderate range. Low risk sites (D) and non-forest sites comprised the remaining 35% (Table 2).

4. Discussion

The data indicate that category A sites are clearly at high risk of passive crown fire torching as low aerial fuels are clumped, the live crown extends to within 0.65m of the ground, on average, and the maximum gap in the best fuel ladder is less than a meter (0.93m). Such conditions are conducive to fire spreading vertically.

At the opposite end of the spectrum, ratings D and E clearly represent low ladder fuel risk sites. D sites have no clumping of low aerial fuels and have high height to live crowns (mean 4.7m) and large gaps in the ladder (mean 4.93m). Category E sites have, by definition, no risk of laddering as there is no forest into which fire may spread.

Key functional differences occur in the moderate range between categories B (clumping on ground, no clear ladder) and C (no clumping, but good ladder). The actual risk of fire crowning in these two scenarios probably depends on fire conditions: in the absence of strong winds, there is probably little chance of a fire reaching the canopy in a category C site because there are simply few low aerial fuels to get flames up off the ground. During extreme fire weather, however, the presence of these ladder fuels could produce flame lengths long enough to move convey fire into the overstory.

In contrast, areas rated with the moderate B rating could produce moderate flame lengths under many conditions, but the ladder is not present to carry fire higher. This structure is probably more resistant to passive crown fire than category C areas.

Issues in the field

Data returned by field crews did need to be examined and sometimes corrected. For example, some technicians would record a larger HTLCB than maximum gap. This is not possible—if the height to the lower live crown is 5m and the gap in the canopy above is 3m, then the largest gap from the ground to the upper canopy is still 5m. In other words, the height to live crown is a gap to consider, as well. This happened frequently and so maximum gap values were changed to the HTLCB values if they were less than HTLCB. A long-term solution is to cover this more thoroughly in training. Also, a definition to this effect has been added directly to the flowchart.

Occasionally, technicians would record values impossible for a category. An “A,” for example, cannot have a maximum gap of greater than 2m by definition. So, if a technician quantified an “A” as having a gap of 4m then the correct classification should have been a “B.” These values were changed for the statistical analysis, as well. This was always well covered in training and so the solution has been to add explicit “possible values” ranges in the flow chart.

Ratings analysis

Overall, the system of categories seems useful for managers in pre- and post-treatment or post-fire settings. The biggest difficulties at this stage are in modifying the results with additional information and in verifying the actual ratings categories themselves. Combining the four evaluations from each site into a single value and modifying ratings based on slope and vegetation are made difficult by the nature of the ratings themselves. Ratings are ordinal: they have order (A represents higher risk than B) but the relationship is of an unknown (and variable) quanta. While ratio and interval data have distinct relationships between values (4 is twice as much as 2; 32°F is 8 degrees colder than 40°F), ordinal data may not be modified mathematically. At what point, for example, does a C site have as much ladder fuel risk as an A because its slope is much steeper: 20°, 30°, 45°, or 60°? Further, what is the difference between a category C with ponderosa pine (Pinus ponderosa) and a category C with white fir (Abies concolor)? Is the white fir 15% or 70% more likely to conduct fire, and under what conditions?

A second limitation of these ordinal ratings is that they have not yet been verified with real fire behavior. It is our intent to evaluate areas with LaFHA ratings prior to prescribed fire (or possibly a wildfire), and then analyze the relationship between the assessed ladder fueling risks and the actual fire behavior under known conditions. Such verification will make the system more powerful and useful. We hope that such testing over time will allow us to overcome some of the difficulties of working with ordinal data so that the ratings may be modified with slope and vegetation-type information.

5. Conclusion

The LaFHA approach has advantages in that it is rapid and can be applied extensively across an area. Due to the flowchart that systematizes and constrains judgments and decision-making, the results are mostly consistent and repeatable. The quantitative measures taken allow for analysis of the ratings and their values. All of these represent advantages over traditional expert opinion approaches. In comparison to quantified methods, it is much more rapid and cost-effective compared to detailed field measurements conducted across a broad spatial area.

We anticipate that this approach may be used by managers to characterize pre- and post-fuels treatment conditions to describe change in ladder fuel conditions. Verification of the ratings with real fire events may allow the data to act as input into landscape fire behavior and risk models. And we hope that the flexibility of this system will allow it to be applied across a range of forest types.

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Tables used in text

Table 1: Practical definitions for LaFHA flowchart decisions. These definitions are provided with Figure 1 to provide clarity for field technicians. They are encouraged to refer to these definitions often to ensure consistency in evaluating ladder fuel hazards. Reference letters in Figure 1 correspond with the letters in the first column.

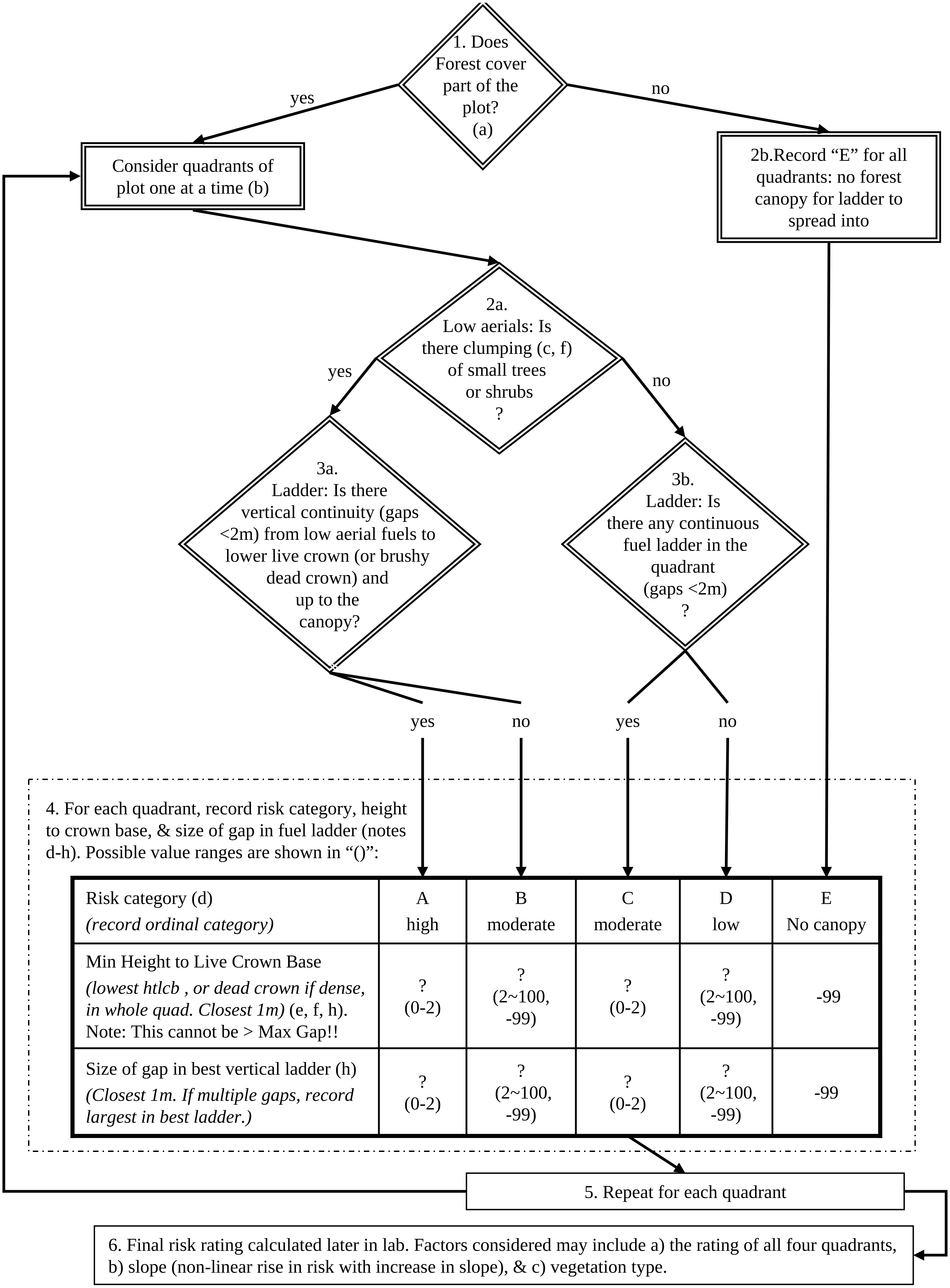
Flowchart Reference	Feature	Description
a	Forest & shrub fields	A single tree in a field is not a forest. A single tree extending over part of the plot that is near other trees is part of a forest. Even though shrub fields are "clumped" as low aerial fuels there may not be any canopy to which to spread fire. In that case, the rating should be "E" (if all quadrants lack forest) or "D" if one to three quadrants lack trees. Follow the flow chart.
b	Division of plots	Quickly divide plots into four quadrants. Use trees for reference and proceed in an arc, sweeping one direction until you return to the starting point. Be sure to consider the entire quadrant. Walk around if necessary.
c	Clumping	Defined as shrub 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 smaller 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. Remember to ask yourself, "is this a dense clump of potential fuel?"
d	Rating categories	Ratings are given letters (A-E) 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?" Probably not). Also, final ratings depend on additional information (see Step #4 at bottom of flowchart page).
e	HTLCB	Height to live crown base: The live crown base is the lowest extent of the live canopy. Note: if the crowns of small trees are completely separate from the overhead canopy do not consider them. If they touch, or are close to touching, do consider them.
f	Dead crown	Include dead branches in consideration of a tree's crown if they are particularly branchy or brushy. This will almost never happen in pines, but is common in white fir and Douglas-fir. If the branches radiate laterally and are well spaced (common with incense-cedar) do not consider them to be part of the ladder fuel matrix. In order to be considered part of a ladder, the branches should be dense and mostly vertical (pointing or arching down). Lichens, moss and needles increase the fuel hazard. Consider this in your assessment.
g	Ground and surface fuels	Do not adjust your assessment of the risk category by the presence or absence of ground or surface fuels (litter and duff with branches and cones mixed in). Consider only clumping and the presence of ladder fuels.
h	Canopy or No Canopy?	Consider only conifer and oak tree species as part of the canopy. Do not consider shrubs to have a canopy for this analysis. If there is no higher canopy, then record the gap as –999. This is important to distinguish from empty fields which may mean a datum was or was not recorded. A –999 value indicates that data were recorded and that the gap was infinite because there was no crown.

Table 2: Data from ladder fuel hazard assessments in mixed conifer forests of the northern Sierra Nevada. Data from all observations are shown in the column indicating

Rating	Count	Percent of plots in this category		Height to live crown base, or dense dead aerial fuels (excluding E sites)		Maximum gap in best ladder in quadrant (excluding E sites)	
		Including category E	Excluding category E	Mean (m)	st. dev.	Mean (m)	st. dev.
A (high)	986	25.3	25.8	0.65	0.76	0.93	0.77
B (moderate)	579	14.9	15.1	4.83	3.45	5.58	3.24
C (moderate)	897	23.0	23.5	0.89	0.75	1.17	0.73
D (low)	1362	35.0	35.6	4.70	3.01	4.93	2.92
E (no forest)	72	1.8	n/a				
Total with E	3896	100.0	n/a				
Total without E	3824	n/a	100.0				

Figures used in text

Figure 1: Ladder Fuel Hazard Assessment (LaFHA) flow chart. A trained technician uses this flowchart to categorize ladder fuel hazards at a site and record relevant data at each observation point. Reference letters in the flowchart correspond with definitions in Table 1.



Risk category (d) *(record ordinal category)*	A high	B moderate	C moderate	D low	E No canopy
Min Height to Live Crown Base *(lowest htlcb , or dead crown if dense, in whole quad. Closest 1m)* (e, f, h). Note: This cannot be > Max Gap!!	? (0-2)	? (2~100, -99)	? (0-2)	? (2~100, -99)	-99
Size of gap in best vertical ladder (h) *(Closest 1m. If multiple gaps, record largest in best ladder.)*	? (0-2)	? (2~100, -99)	? (0-2)	? (2~100, -99)	-99