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Ecological Research at the Blacks Mountain Experimental Forest in Northeastern California

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Abstract

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At Blacks Mountain Experimental Forest in northeastern California, an interdisciplinary team of scientists developed and implemented a research project to study how forest structural complexity affects the health and vigor of interior ponderosa pine *(Pinus ponderosa* Dougl. ex Laws.) ecosystems, the ecosystem's resilience to natural and human-caused disturbances, and how such ecosystems can be managed for sustained resource values. A randomized, split-plot, factorial design has been developed to test the influences of structural diversity, cattle grazing, and prescribed fire on twelve 250-acre study units. A permanently monumented data reference system on a 100-meter (328-ft) grid will facilitate spatial and temporal analysis as well as integration of information at various scales. Intensive preliminary sampling has established baseline data on small mammal and avian diversity and behavior, forest vegetation structures and floristic diversity, historical fire patterns, bark beetle dynamics, soil properties and processes, and genetic structure of pines and understory species.

Retrieval Terms: ponderosa pine, white fir, stand development, stand structure, succession, prescribed fire, thinning, cattle grazing, small mammals, passerine birds, bark beetles, arthropods.

The Author

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Acknowledgments

Cooperators in this research include the USDA Forest Service's Pacific Southwest Region Genetics Unit and Lassen National Forest, Michigan Technological University, Oregon State University, Humboldt State University, University of California, Davis and Berkeley, and the Wildlife Conservation Society.

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In Brief . . .

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Retrieval Terms: ponderosa pine, white fir, stand development, stand structure, succession, prescribed fire, thinning, cattle grazing, small mammals, passerine birds, bark beetles, arthropods.

This paper discusses an interdisciplinary large-scale, long-term ecological research project initiated in 1991 at the Blacks Mountain Experimental Forest (BMEF) in northeastern California. The research goals of the study were to increase our understanding of the effects of forest structural complexity on the health and vigor of interior ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) ecosystems, quantify the ecosystem's resilience to natural and human-caused disturbances, and determine how these ecosystems can be managed for sustained resource values.

Two forest structures were created with various combinations of ground disturbances—with and without prescribed fire—on 12 units of about 250 acres each: high structural diversity without grazing, high structural diversity with grazing, low structural diversity without grazing, and low structural diversity with grazing.

Each treatment was replicated three times in a randomized block design with split plots. In each plot, prescribed fire was introduced into one half and kept out of the other half. Although the design does not include untreated controls, four Research Natural Areas (RNAs) well-distributed within the BMEF were also studied to provide quantitative and qualitative information on undisturbed systems.

All data were referenced to a 100-meter grid, surveyed, and permanently monumented in each treatment plot. This grid facilitated spatial and temporal analyses, as well as integration of information at various scales.

The years between the conception of a study this size and its implementation allowed for collection of baseline data. We gathered data on the pre-treatment vegetation and forest floor conditions, small mammals and birds, and tested various methods of re-introducing fire without killing the large old trees we wished to retain in the high structural diversity plots. The results of our study showed that we don't have a definitive answer about the best time of year to conduct the initial burns. The only mortality observed was in early spring and late fall.

We also wanted information on rates of nitrogen fixation and mineralization and their degree of seasonal and spatial variability. For instance, we found that nitrogen processes within and beneath large, downed woody debris are no greater than beneath other types of ground cover. In fact, the areal importance of downed woody debris as a nitrogen source is less in proportion to its areal cover than other cover types.

The pre-treatment inventory illustrated the well-recognized ability of Jeffrey pine *(Pinus jeffreyi)* to tolerate harsher sites compared to ponderosa pine. Thus, Jeffrey pine was found almost exclusively on the floor of the valley where tolerance of late spring frosts favored Jeffrey pine and on the rocky and shallow soils at upper elevations. Baseline genetic diversity was determined for ponderosa pine, antelope bitterbrush, and Idaho fescue. These baseline data are the genetic control level of reference that will be used to evaluate the impact of management options on genetic diversity of these systems over time.

Soil arthropods were sampled on tree-centered transects in units with completed treatments. Preliminary results suggest that low intensity prescribed fire has little effect on species richness, diversity, and evenness of oribatid mites, but moderate intensity prescribed fire has a more profound effect on the measures of community structure.

As an example of the interdisciplinary opportunities offered by the main study, ornithologists are studying bird use of snags that were created by bark beetles or mechanically girdling. Initially at least, they have found that woodpecker use of bark beetle-killed trees is much greater than for mechanically-killed trees.

BMEF has some of the greatest snag densities to be found anywhere in northeastern California. As a result, it has one of the most abundant and diverse assemblages of sapsuckers and woodpeckers in California.

The interdisciplinary study on the Blacks Mountain Experimental Forest is designed to restore late seral stands to conditions perceived as common before differential cutting of pine and fire exclusion in the eastside pine type. We are attempting within a few years to reverse processes that took decades to develop. Regardless of our success in sustaining uneven-aged ponderosa pine stands, our interdisciplinary study should provide insights into how eastside pine ecosystems have been altered by the loss of late seral structures.

The Forest Service, U.S. Department of Agriculture, is responsible for Federal Leadership in forestry. It carries out this role through four main activities:

- Protection and management of resources on 191 million acres of National Forest System lands;
- Cooperation with State and local governments, forest industries, and private land-owners to help protect and manage non-Federal forest and associated range and watershed lands;
- Participation with other agencies in human resource and community assistance programs to improve living conditions in rural areas; and
- Research on all aspects of forestry, rangeland management, and forest resources utilization.

The Pacific Southwest Research Station

- Represents the research branch of the Forest Service in California, Hawaii, American Samoa, and the western Pacific.

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Introduction

Forest managers are challenged to manage forests for a variety of uses. They must know about the resiliency of ecosystems to the impacts of natural and human-caused disturbances and be able to maintain or re-establish critical ecosystem functions. A forest is a highly complex system of interacting and independent-living and non-living components. Understanding complex ecosystem interactions, at both stand and landscape scales, is essential and can be accomplished only through experimentation and collaboration among scientists.

Results of large-scale field experiments can be very important and relevant in guiding environmental policy. In fact, great progress can be made in ecosystem management when straightforward experiments are performed by relatively small interdisciplinary teams cognizant of the relevant management and scientific issues (Carpenter and others 1995). Such experiments, however, must be at scales that mimic operational management, are sited on dedicated lands, and are provided sustained funding. Such experimental sites, although rare, are essential to conduct selected ecosystem manipulations, provide long-term data for evaluating environmental change and management actions, and develop the indicators and basic understanding necessary to manage ecosystems.

In 1990, the National Research Council (1990) published *Forestry Research—A Mandate for Change.* One of the recommendations to achieve this change was to "Establish research-management collaborations at large spatial scales with an environmental perspective. This would require multidisciplinary activities on large tracts of land" (p. 53). This recommendation has been minimally accomplished, and usually only where large sums of money have attracted scientists.

The USDA Forest Service's Pacific Southwest Research Station (PSW) extended this challenge by undertaking a large *inter*disciplinary study. In contrast to multidisciplinary research in which scientists work independently in the same location and later share results, interdisciplinary research requires a cohesive team of scientists from several disciplines involved at the beginning of the same study. Blacks Mountain Experimental Forest (BMEF) was chosen as the study site. This 10,300-acre forest of interior ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), established in 1934, is 40 road miles northwest of Susanville, Lassen County, California (*fig. 1*). The research approach at the BMEF was to create, by operational scale manipulations, two distinct forest structures: late seral stage

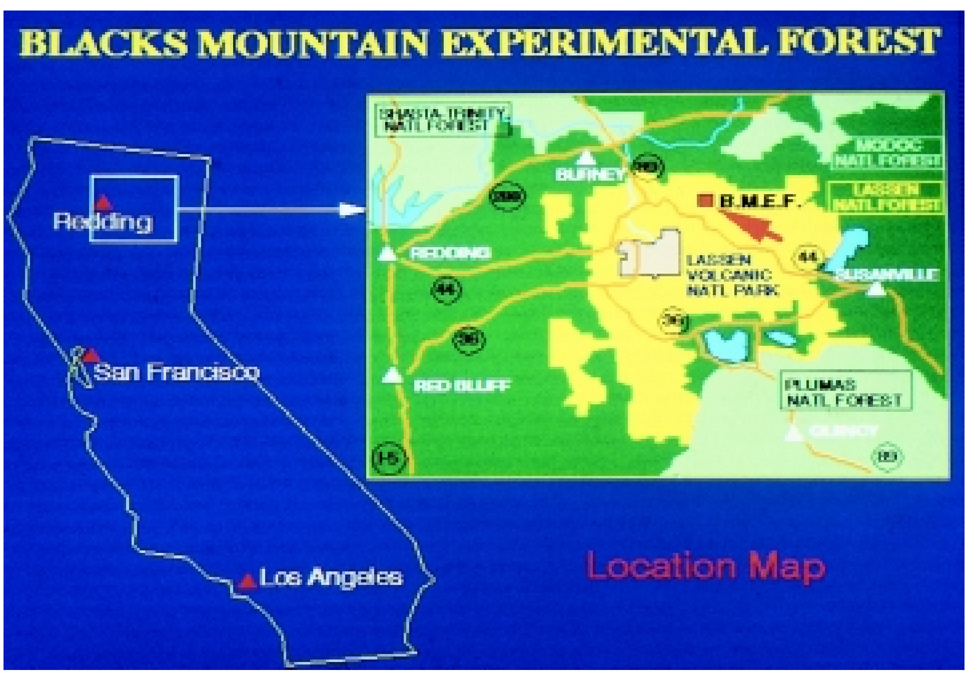


Figure 1—The Blacks Mountain Experimental Forest (BMEF) is 40 road miles from Susanville in northeastern California.

(high structural diversity) and mid-seral stage (low structural diversity). The initial vegetational structures were created by prescribed timber harvesting. Additional vegetation manipulations are being accomplished by cattle grazing and prescribed fire. Over time, the response of various ecosystem components and processes, such as soil quality, nutrient cycling, soil micro-arthropods, decay of coarse woody debris, vegetation, insects, and wildlife to these vegetational structures will be measured. This unique research environment will foster a continuous interchange of ideas, data sets, and management strategies among the science team members.

This paper discusses the interdisciplinary large-scale, long-term ecological research project initiated in 1991 at BMEF in northeastern California to increase our understanding of the effects of forest structural complexity on the health and vigor of interior ponderosa pine ecosystems, quantify the ecosystem's resilience to natural and human-caused disturbances, and determine how these ecosystems can be managed for sustained resource values.

Interdisciplinary Research

The seed for interdisciplinary research was planted in 1985 when Station managers encouraged research units to communicate more widely and explore opportunities for cooperative research. There were barriers, however. Traditional research units studied single disciplines and were geographically separated. Cross-discipline research was rare. Throughout the Station, scientists were fully engaged in studies they considered high priority, and they were reluctant to take on anything new. Management's approach could not dissolve these barriers because scientists who would actually do the research were not involved in the discussions and because no specific project was identified. Cross-discipline research for its own sake was deemed pointless. But the idea persisted. Recognizing that vegetation management was the basis for ecosystem management and that silviculture is the most integrative of all natural resource disciplines, research silviculturists took the lead in pressing the issue.

By 1990, the political and social climates were ripe for new initiatives. The Forest Service was pressured by environmentalists to de-emphasize short rotation, even-aged management and to save all remaining late seral forests. In response to these pressures, the Washington Office offered funding for research on late seral forests. Silviculturists applied for these funds to conduct a 50-year remeasurement of old study plots on the BMEF. This remeasurement was performed during the 1990 and 1991 field seasons and the results were published (Dolph and others 1995). At this time, the agency began a fledgling program called "New Perspectives" (Robertson 1992) in National Forest management that favored other forest values over traditional commodity production. New Perspectives was a well-meaning initiative that encouraged innovation on the ground, but it was seen as a rather nebulous program that needed stronger roots in science.

New Perspectives was the springboard for launching a program of interdisciplinary research. A coordinator who would embrace interdisciplinary research and not favor a particular discipline was thought to be essential to ease the formation and smooth the operation of an interdisciplinary team. The program was in critical need of a coordinator with the knowledge and ability to communicate with the National Forests on the nuts and bolts of the National Environmental Protection Agency (NEPA) process, timber sale contract development, grazing permit administration, and a myriad of other details involved in the large-scale manipulation of vegetation. Few scientists are familiar with these procedures that would compete for time and for which a scientist would receive little credit. Consequently, in August 1990, a forester, Kathy Harcksen, from the National Forest System was hired to coordinate and facilitate our research.

Figure 2—Several field meetings were necessary to craft a plan for a large-scale interdisciplinary study.

Later that same month, silviculturists attempted to gain support for an interdisciplinary study at the BMEF by conducting a field meeting on the Forest (*fig. 2*). Discussions centered on landscape-scale investigations. Nothing substantive evolved from that field meeting except a recognition that more discussion was necessary to formulate a viable plan. Therefore, a follow-up meeting was held in October 1990 at the University of California, Berkeley, Blodgett Forest Research Station, near Georgetown, California. All Station scientists interested in interdisciplinary research and/or long-term ecological research were invited. Much discussion centered on the need and feasibility of establishing a network of long-term ecological research sites (LTERs) in California. Ideally, sites should be located in the major forest types in northwestern California, northeastern California, and the westside Sierra Nevada. BMEF could represent the interior ponderosa pine type in northeastern California, and Blodgett Forest could represent the Sierra Nevada mixed-conifer type of the westside Sierra Nevada. No existing installation was available for the Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco var. *menziesii*) type of northwestern California. Participants were painfully aware that neither a major funding increase nor a reorganization of the Station, both necessary to make this system of LTERs a reality, was likely.

Although a system of LTERs in major forest types in California would remain a dream, the meeting participants believed an interdisciplinary study at the BMEF could be initiated if a sufficient number of Station scientists were interested in participating and contributing their time to the project. A letter calling for participation was given wide circulation in January 1991. Scientists responded positively from a sufficient number of disciplines to allow for an interdisciplinary team formation meeting held in Susanville, California, in April 1991. After three days of discussion and compromise, a general experimental design and treatment description emerged.

Interdisciplinary Team

The most important factor contributing to the development and continued success of this science team is that scientists participated voluntarily. Although Station administrators encouraged cooperative research among disciplines, specific individuals were not targeted and a research topic was not suggested. Except for empowerment by Station administrators, the project benefits from a bottom-up approach with all participants having an equal ownership. The participants were mature scientists who recognized the value of large-scale ecosystem management research. They were the few who were willing to endure the delay in reportable results common in such projects. They were also aware of the difficulties of working with different natural resource disciplines but were willing to compromise to ensure success of the overall plan. Wildlife biologists were especially enthusiastic because they recognized that the field design and size of the treatment units could provide for statistical interpretation of cause and effect research—a unique opportunity.

The original science team was drawn mostly from the PSW and has remained largely intact (*table 1*). The disciplines represented are silviculture, ecology, soil science, entomology, wildlife biology, geography, statistics, mensuration, genetics, and range science.

The April 1991 meeting was important for several reasons. First, the individuals learned they had to compromise if they were to accomplish anything and if they were to maintain the trust of the other individuals. Second, the individuals had to define how decisions were to be made. Most importantly, the individuals realized a sense of elation in knowing they had indeed developed the framework for a true interdisciplinary research project.

Because the consensus decision-making process worked and because trust was built between the members during this process, consensus was the decision-making model of choice for this team. When consensus could not be reached, the team resorted to the informed-consent decision model. This decision-making model was used when the vast majority reached consensus but at least one member did not agree. The dissenting member then consented to the decision, although he or she disagreed with it. This model was effective because the members strongly believed in the team approach to research and realized that sometimes they had to compromise to ensure its health and success.

Table 1—*Participants who attended the April 1991 planning meeting and current participants in the Blacks Mountain Ecological Research Project.*

Participant	Research discipline	Affiliation	Attended planning meeting	Current participant
Leroy Dolph	Silviculturist	PSW, Redding	Yes	No
George Ferrell	Entomologist	PSW, Redding	Yes	No
Luke George	Wildlife Ecologist	Humboldt State University, Arcata	No	Yes
Jim Laacke	Silviculturist	PSW, Redding	Yes	No
Bill Laudenslayer	Wildlife Ecologist	PSW, Fresno	Yes	Yes
Sylvia Mori	Statistician	PSW, Albany	Yes	Yes
Bill Oliver	Silviculturist	PSW, Redding	Yes	Yes
Bob Powers	Silviculturist	PSW, Redding	Yes	No
Nancy Rappaport	Entomologist	PSW, Albany	No	Yes
Ray Ratliff	Range Scientist	PSW, Fresno	Yes	No
Martin Ritchie	Biometrician	PSW, Redding	No	Yes
Pat Shea	Entomologist	PSW, Davis	Yes	Yes
Carl Skinner	Geographer	PSW, Redding	Yes	Yes
Phil Weatherspoon	Silviculturist	PSW, Redding	Yes	Yes
Steve Zack	Wildlife Biologist	Wildlife Conservation Society, Humboldt State University, Arcata	Yes	Yes
Kathy Harcksen	Forester/Team Leader	PSW, Redding	Yes	No

An area of compromise arose when the geographic scale of the research had to be decided. Because different forest attributes respond to treatments at different scales (i.e., woodpeckers versus grasses), different scales were necessary for each of the disciplines. It was immediately apparent that the attribute with the need for the largest geographic scale would dominate the scale of the ecological research project. The minimum size for small mammals and passerine birds was 100 acres. In contrast, the response of vegetation to tree harvest and prescribed fire could be studied successfully on much smaller units.

Although the core team of scientists has been relatively constant from 1991 through 1999, several members have left (*table 1).* Since then the team has broadened to include a geneticist with the Forest Service and scientists at the University of California at Davis, Humboldt State University, and the Wildlife Conservation Society. Cooperators include the Lassen National Forest and scientists from Oregon State University, Michigan Technological University, the University of California at Berkeley, the University of Idaho and the Rocky Mountain Research Station.

Blacks Mountain Experimental Forest

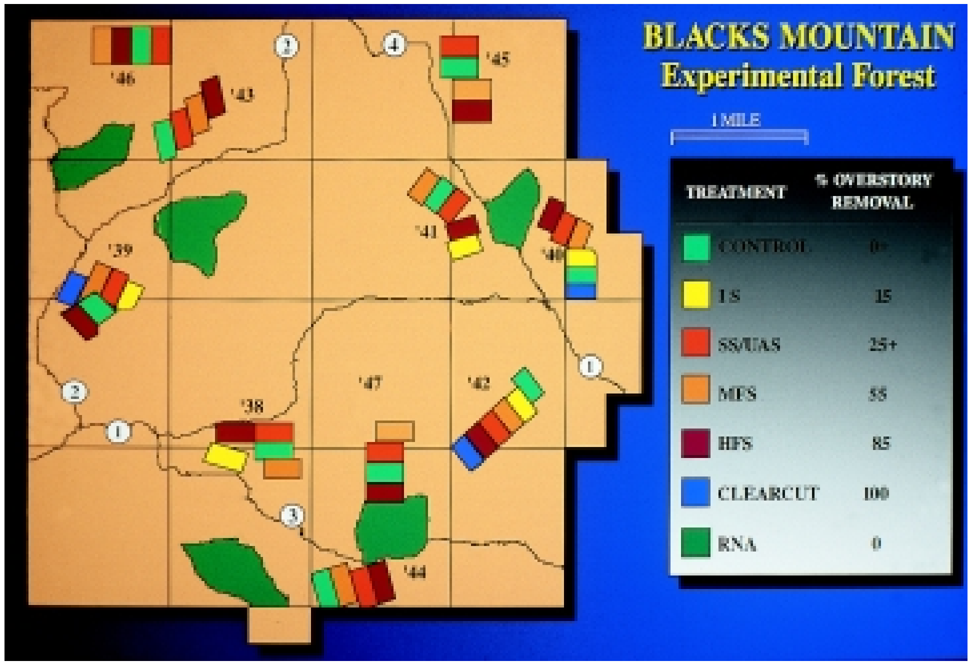
The Blacks Mountain Experimental Forest provides an ideal site for the ecological research project because of the existing forest conditions, opportunities to manipulate and maintain long-term research sites, the extensive and well-designed road and compartment system, and the extensive historical databases. The BMEF was formally designated in 1934 as the Station's principal site for management investigations in the interior ponderosa pine type. Studies going back to 1910 at Blacks Mountain had resulted in new theories of management, silviculture, and insect control. A primary objective of the BMEF in 1934 was to develop these theories into a system of management and to test, demonstrate, and improve the system through continuous operation of a timber tract on a commercial scale.

In 1933 and 1934 before full-scale operations began, the BMEF was subdivided into 100 compartments of about 100 acres each. An intensive road system—the first in the west specifically designed for hauling logs by truck rather than by rail—was laid out such that every compartment was bordered by a road. Also, the BMEF was completely inventoried on a 2.5-acre grid for trees 11.6 inches in diameter at breast height (dbh) and larger. Vegetation type maps and inventories were prepared by compartments.

Early timber harvests were primarily designed to test different silvicultural approaches to control insects. Salmon and Bongberg's (1942) insect risk-rating system was developed and tested at BMEF. When it was demonstrated that the average cut of 2,500 board feet per acre could be logged economically and that the cutting reduced the annual rate of tree killing, sanitation-salvage was adopted widely. Dunning conceived the idea of making the mosaic of small even-aged groups of trees (the prevailing stand structure at BMEF), rather than individual trees, the subjects of management (Hallin 1959). This concept of Unit Area Control (Hallin 1959) was tested operationally during the 1950's. Cuttings in the 1970's and early 1980's were designed to convert large areas of the BMEF to young-growth stands, which were thought to be needed for future research.

An ambitious study of stand growth and development after several intensities of timber harvesting was begun in 1938 (Hasel 1938). Each year for 10 years, four to six 20-acre plots were installed to test various cutting prescriptions. Treatments in this Methods-of-Cutting Study ranged from complete removal of all trees 11.6 inches in dbh and larger (the minimum size for sawlogs at that time) through several degrees of partial harvest to no harvest (*fig. 3*). Before, immediately, and 5 years after harvest all trees were inventoried and the location of all trees 11.6 inches dbh and larger within the experimental plots were mapped. Inventories were repeated at various intervals and intensities during the next 45

Figure 3—Infrastructure of the Blacks Mountain Experimental Forest showing the location of the Methods-of-Cutting Study plots.



years. Although timber has been harvested in other compartments periodically, those compartments that contained the Methods-of-Cutting Study plots were not entered again except for felling of snags in the early 1950's. As a result, 10 groups of 2 or 3 compartments were present, well-scattered throughout the BMEF. Each group, comprising 200 to 300 acres, had been subjected to various degrees of partial harvesting in the Methods-of-Cutting plots, but the majority of the acreage in each group contained large old trees.

Wildlife biologists were also active at BMEF. In a 1-year study, McKeever (1961) of the University of California, Davis, conducted small mammal studies by using the line transect/3-snap-traps/station method at several sites in northeastern California, including BMEF. The purpose of his work was to gain a better understanding of small mammal impacts on reforestation. Several publications on small mammal ecology emerged from this work, including a report on the relative abundance (based on percent of trap success during months when animals were active and captured) of small mammals associated with differences in dominant tree species. Ten species of small mammals were captured in the ponderosa pine dominated sites, including the site within the BMEF. The seven most dominant species were (from most to least abundant) yellow-pine chipmunk (*Tamias amoenus*), golden-mantled ground squirrel (*Spermophilus lateralis*), deer mouse (*Peromyscus maniculatus*), lodgepole chipmunk (*Tamias speciosus*), Townsend's chipmunk (*Tamias townsendii*), northern flying squirrel (*Glaucomys sabrinus*), and Douglas' squirrel (*Tamiasciurus douglasii*). Trowbridge's shrew (*Sorex trowbridgii*), Nuttall's cottontail (*Sylvilagus nuttallii*), and snowshoe hare (*Lepus americanus*) were captured only sporadically.

Methods

Ecological Research Project

Remoteness, aridity, and low human population density describe interior ponderosa pine forests. Because of this, forest management practices on these forests tend to be less controversial than those practices on forests on the western slopes of the Southern Cascade Range and Sierra Nevada near population centers. However, like forest managers on western slopes, managers of interior forests are confronted with a similar mix of problems. Historically, forests have been managed for timber production with a net loss in structural diversity.

Vegetation is the visually dominant component of a forest. Carbon captured through photosynthesis forms the currency that pays for ecosystem processes. Substantial differences in canopy architecture should produce fundamental differences in carbon capture and the way it is apportioned into other ecosystem components (understory, detritus, habitat, forage). In turn, this should result in profound differences in the health, abundance, and variety of animals that depend on organic matter for shelter and sustenance. Thus, the way that carbon is captured, apportioned, and recycled was a starting point for the science team's hypotheses. The team began with a simple null hypothesis: strong differences in canopy architecture should have no effect on emerging properties of ecosystems.

Experimental Design

Two forest structures were created (*figs. 4, 5*) with various combinations of ground disturbances—with and without prescribed fire—on twelve units of about 250 acres each:

- High structural diversity without grazing
- High structural diversity with grazing
- Low structural diversity without grazing
- Low structural diversity with grazing.

Key features of the forest structural treatments are (*appendix A)*:

- High structural diversity:
  - The presence of many large, old trees
  - Abundant snags, especially those with large diameters
  - Multiple canopy layers with dense clumps of smaller trees
  - Many small canopy gaps and forest floor openings.
- Low structural diversity:
  - Single layer, evenly spaced, continuous canopy
  - Few snags
  - Few large canopy gaps and forest floor openings.

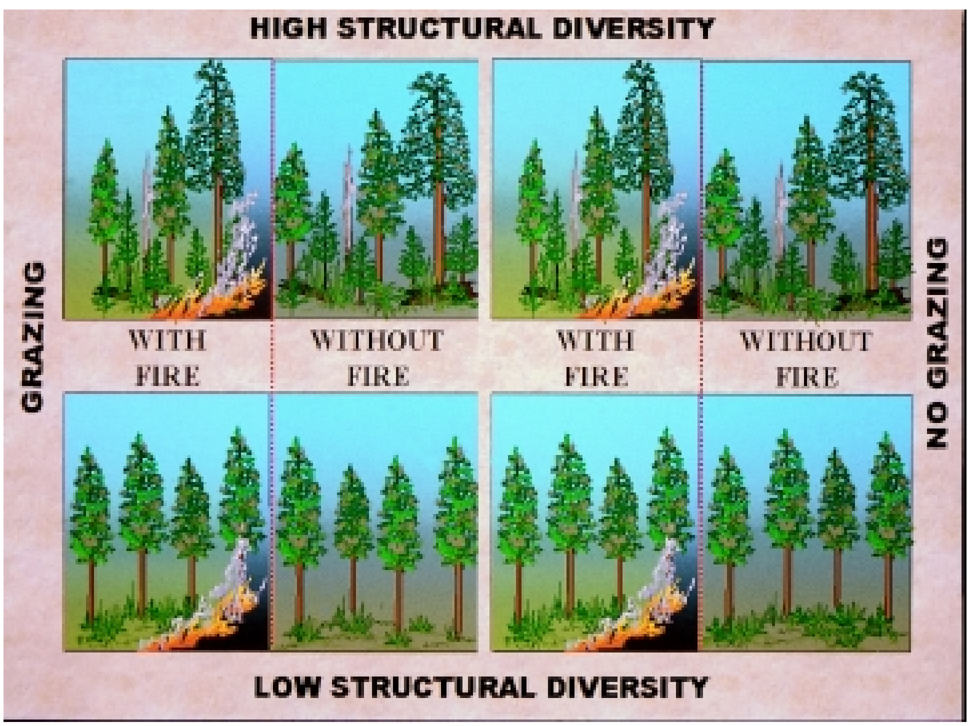


Figure 4—Treatment combinations in the Blacks Mountain Ecological Research Project on the Blacks Mountain Experimental Forest.

Figure 5—The Blacks Mountain Ecological Research Project before and after applying treatments, (A) before and (B) after application of the high structural diversity treatment without prescribed fire, and (C) and (D) with prescribed fire; (E) before and (F) after application of the low structural diversity treatment without prescribed fire, and (G) and (H) with prescribed fire.

A

B

C

D

E

F

G

H

The structural diversity treatments should not be confused with the classic silvicultural systems of even-aged and uneven-aged management. High structural diversity differs from uneven-aged management in that the emphasis is on maintaining the specific structural features of large old trees, snags, and multiple canopy layers, not necessarily on maintaining three or more age classes of trees. Low structural diversity is simply a contrasting structure. Regeneration is neither provided for nor presently desired in either structure. The terms carried no specific connotation, and they accurately described our treatment objectives. A re-entry in 20 years is tentatively planned, at which time stand structures will be evaluated and may be adjusted to ensure that they remain consistent with the treatment specifications.

The entire forest is included in grazing allotments. Thus, 6 of the 12 units are fenced to exclude grazing. In each unit prescribed fire is introduced to one half and excluded from the other. The team anticipates that a series of three burns, closely spaced, will be required to reduce the fuels to a level more easily maintained.

Each treatment is replicated three times in a randomized block design with split units for prescribed fire. Blocking was considered desirable because of differences in vegetation associated with differences in elevation among units. Interior Ponderosa Pine (Forest Cover Type 237) (Eyre 1980) is the only forest cover type found on the BMEF. Species composition varies within the type, however. White fir (*Abies concolor* [Gord. & Glend.] Lindl. ex Hildebr.) and incense-cedar (*Libocedrus decurrens* Torr.), absent in stands at the lowest elevations, become increasingly abundant at higher elevations. Because the compartment groups are scattered throughout the BMEF, some contained nearly pure pine stands at the lower elevations and others contained substantial quantities of white fir at the higher elevations.

Because the study encompasses 3,100 acres, treating all units in one field season was not feasible. Structural treatments were applied to one block in each of 3 years—the summers of 1996, 1997, and 1998. Non-grazed units were fenced in the summer and fire splits burned in the fall of the following year. Therefore, the randomized block design allows for isolating responses attributable both to differences in vegetational associations and in year of treatment in the block effect.

The 10 compartment groups containing the Methods-of-Cutting Study comprised the nucleus of the ecological research project. The design, however, required 12 units. Two uncut compartments in the northeastern corner of the BMEF formed one additional unit, and an area located on the Lassen National Forest, 0.5 mile from the southeastern corner of the BMEF (*fig. 6*), formed the final unit.

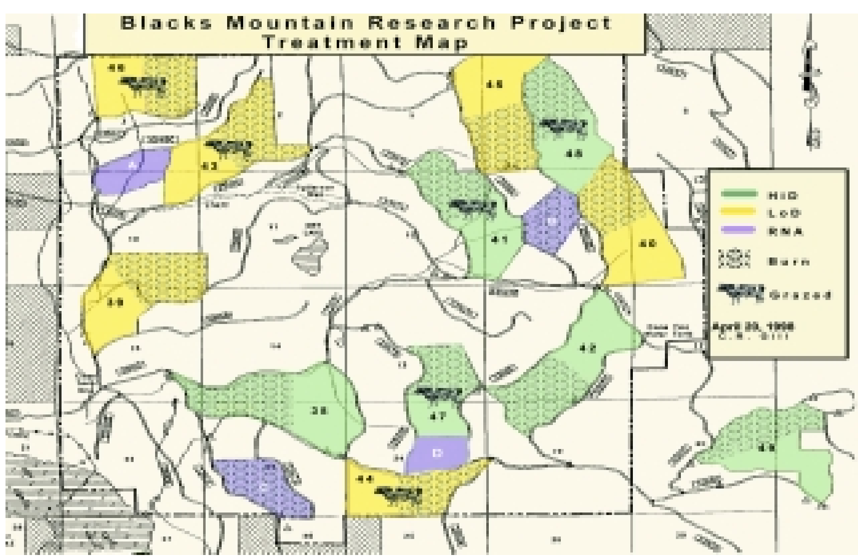


Figure 6—The Blacks Mountain Ecological Research Project treatments on the Blacks Mountain Experimental Forest.

Figure 7—Research Natural Area C on the Blacks Mountain Experimental Forest before re-introduction of fire.

Although the design does not include untreated controls per se, four Research Natural Areas (RNAs), each about 100 acres in size and well-distributed within BMEF, will be studied to provide quantitative and qualitative information on untreated systems (*fig. 7*). The RNAs and the treatments without grazing will be fenced to exclude cattle. Two of the RNAs will have prescribed fire.

The Method-of-Cutting plots are an important legacy, especially because of the intensive measurements taken periodically for more than 50 years and the stem maps of the sawtimber-sized trees. A 10-acre portion of the control and heavy Forest Service cutting treatments were reserved from cutting in the high structural diversity units—units 38, 41, 42, and 47. These treatments were the extremes in the spectrum of treatments installed every year.

If all possible interactions are of interest, overall treatment responses can be analyzed by the following analysis of variance:

Source	***Degrees of freedom***	
Block	2	
Structure	1	
Grazing	1	
Structure x Grazing	1	
Error (a)	6	
Fire		1
Fire x Structure		1
Fire x Grazing		1
Fire x Grazing x Structure		1
Error (b)		8
Total		23

If it is determined *a priori* that the interaction of fire and grazing or fire and structure is not of interest, then the following analysis of variance could be performed:

Source	***Degrees of freedom***
Block	2
Structure	1
Structure x Grazing	1
Error (a)	7
Fire	1
Error (b)	11
Total	23

From the study’s inception, the science team directed substantial funds to foster a truly interdisciplinary project. The team invested in the following spatial databases:

- **Ground control**—Ground control was established through a permanently monumented grid on 100-meter (328-ft) centers throughout each unit (Del Terra, Inc. 1996, 1997, 1999). The monuments were located by conventional survey methods and placed within 15 cm (0.6 ft) of their predetermined Universal Transverse Mercator (UTM) coordinates using the High Precision Geodetic Network (HPGN) (*fig. 8*). The actual location of each monument is known to within 6 inches. The survey was controlled by a survey grade global positioning system (GPS). Monuments are 18-inch rebar with an aluminum cap stamped with the unit number and UTM coordinate. All measurements and other activities will be referenced to this grid.
- **High-resolution aerial photography**—Digital orthophoto and digital terrain models have been developed, both to 0.3-m (1 ft) resolution. Previous research plots and tree locations have been geo-referenced to the digital orthophoto, using the 100-m grid.
- **Ecological Unit Inventory** (EUI) (Alexander 1994)—An EUI is the mapping of ecological units (USDA Forest Service 1991). The ecological units are characterized by relatively homogeneous geology, landforms (relief and drainage), soils, and potential vegetation. The EUI was conducted in 1993 (*fig. 9*). Soils were described by using USDA

Figure 8—Ground control in unit 43 was established through a permanently monumented grid on 100-meter centers.

nomenclature and classified according to soil taxonomy. The BMEF is on the edge of the Modoc Plateau, adjacent to the Cascade Range. Bedrock is basalt. Most of the soils are between 3 and 6 feet deep. The predominant deep soils over basalt are Typic Argixerolls with mesic soil temperature regimes at lower elevations and Andic Argixerolls with frigid soil temperature regimes at higher elevations.

- **Old vegetation type maps**—All compartments were typed for existing vegetation in the 1930's when the BMEF infrastructure was being established (*fig. 10*). These maps are available for digitizing. They provide valuable insights into vegetational changes in an undisturbed interior ponderosa pine ecosystem over a 60-year period.

Three meteorological stations—one with data delivery via satellite—have been installed at three locations at BMEF. The locations span the geographic and elevational range of the study units.

A local vendor assisted in designing a corporate relational database, as well as the spatial database (Vestra Resources, Inc. 1997). Baseline data with the field seasons in which they were obtained are vegetation pre-treatment: 1993, 1994; post-harvest: 1997 to present; small mammals and birds: 1991 to present; bark beetle outbreaks: 1993, 1994, 1995; genetic diversity of key vegetative species: 1995, 1996; and Ecological Unit Inventory: 1993. All data are keyed temporally and spatially to the monumented 100-m grid in all 12 units (Del Terra, Inc. 1996, 1997, 1999) and can be related to data from the digital orthophoto. These data allow researchers to accurately describe current conditions across a broad range of spatial scales, from the point to the forest level. This capability is a key feature of the experiment, allowing changes in forest structure and species composition in response to treatments to be monitored.

Implementing the Research

The Lassen National Forest was crucial to our success and was an active partner in implementing the project. This partnership was formalized by a memorandum of understanding between the Pacific Southwest Research Station and the Lassen National Forest signed on October 30, 1992 *(appendix B)*. This memorandum of understanding described the activities and responsibilities of each party in implementing the research project, with target dates for completion. The Forest took charge of the NEPA process and the sale of the timber. For NEPA, they conducted archeological, and Threatened and Endangered Species

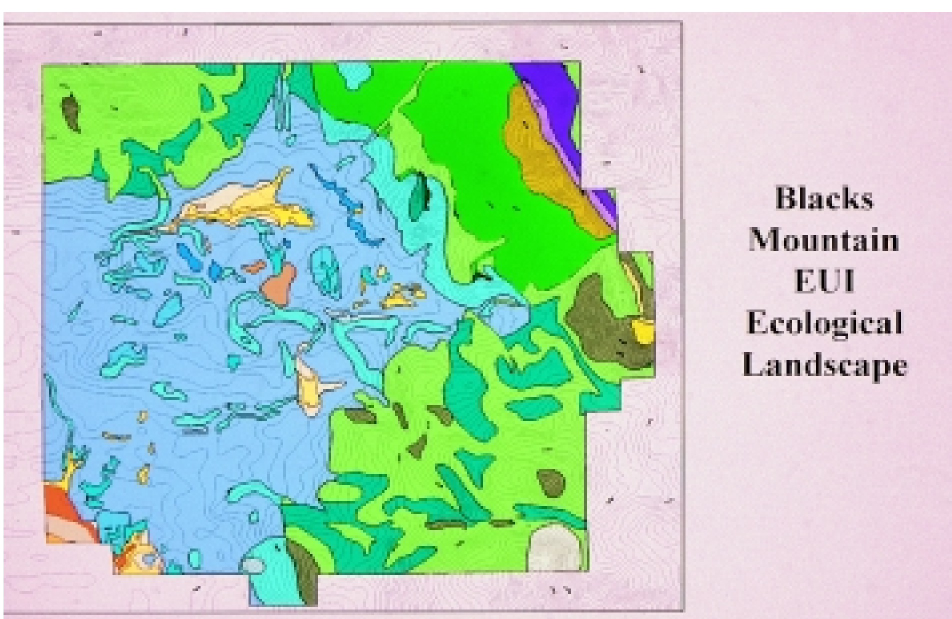


Figure 9—Map of the ecological unit inventory (EUI) of the Blacks Mountain Experimental Forest showing ecological unit boundaries (Alexander 1994).

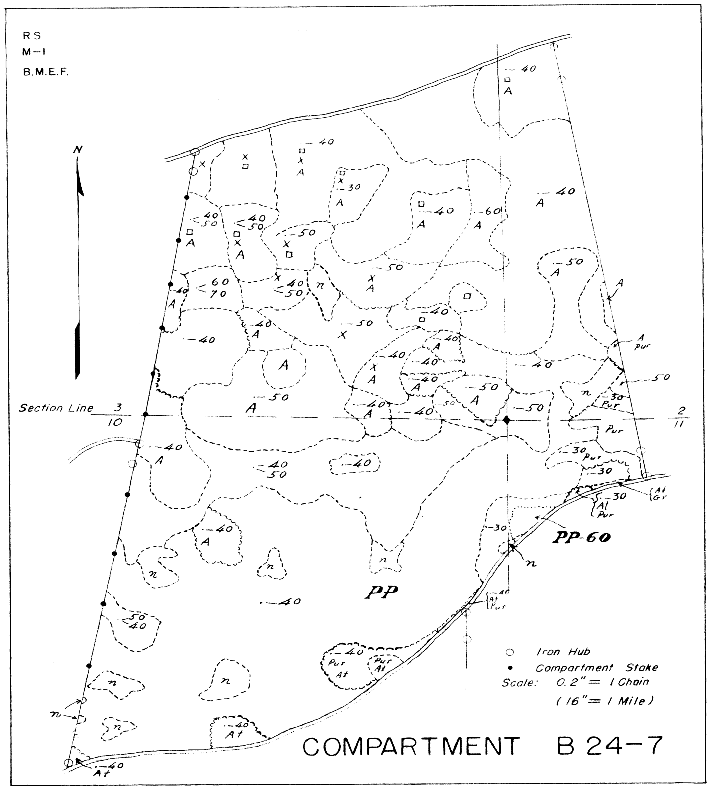


Figure 10—The vegetation type map prepared in the 1930's of compartment B24-7, a portion of unit 43 of the Blacks Mountain Ecological Research Project.

surveys, prepared all documents, and participated with the science team in public meetings and field trips. For the timber sale, they marked and cruised the trees and prepared the contract. Both the Environmental Assessment (EA) and the timber sale contract had features unusual for the Forest. Because the project must be managed on the basis of scientific research, our team insisted that the range of alternatives in the EA be limited to installing the treatments as described or to abandoning the project altogether.

Compared with other regions of California, few controversies occur over land use in this part of the state. Therefore, public response to the project was best described as "wait and see"—but this was in sharp contrast to the bidders' response to the timber sale. The oral auction conducted by the Lassen National Forest in spring 1995 was protested by a bidder who, because of the volume of timber to be removed (33 million board feet), wanted the project divided into several smaller sales. Although the science team's insistence on one purchaser was eventually upheld, installation of treatments was delayed 1 year.

The large volume of timber to be harvested over a large area—3,100 acres—necessitated a multiyear operation that began in 1996 *(appendix C)*. Structural treatments were applied to one block of four units in each of 3 years. Non-grazed units were fenced in the summer and fire splits burned in the fall of the next year.

The timber sale contract had several unusual restrictions designed to reduce variation resulting from the harvesting operations, such as a single purchaser, specific target dates for completion of specific units, and low ground pressure equipment. All this was facilitated by our choice of a professional forester to oversee and coordinate such details. To ensure that all treatments were conducted with care and with consistency, PSW provided a full-time sale administrator.

Variation caused by different logging equipment, methods, and care among units with similar treatment designations can mask treatment responses. To reduce this variation, the following restrictions and specifications were imposed on the timber sale:

- **Purchaser**—The entire project was included in one offering. Although the team recognized that subcontractors might change from year to year, one purchaser would tend to minimize variation in logging practices.

- **Completion targets**—The project was too large to be completed in 1 year. Therefore, one entire block was to be logged in each of the 3 years—1996, 1997, and 1998. Any variation due to year logged, such as weather and different subcontractors, could be isolated in the block effect term in a statistical analysis.
- **Landings and skid trail density**—Through optimum use of existing trails and selective designation of additional trails, total density was minimized. Skid trail spacing was no closer than 150 ft, center to center, where parallel trails were used. Skidding equipment for sawlog removal was restricted to these designated trails. The number of landings was kept to a minimum, and they were no larger than 0.25 acre.
- **Required equipment**—Because direct-mount feller-bunchers (*fig. 11*) are driven to each tree, risk of damage to remaining trees and soil is high. To reduce the risk of soil compaction, the ground pressure of the tires used on the feller-bunchers and any skidder used for removal of the biomass was less than 6.5 lb/inch^2. Equipment with greater ground pressure was restricted to skid trails.
- **Restricted operations**—Feller-bunchers and other motorized equipment were not operated off the skid trails when the soil moisture was sufficient to permit a sample from the wettest part of the 3 to10 inches soil depth zone to be molded by hand compression. Also, all skidding operations ceased on designated skid trails when the potential for puddling existed. Usually, soils were too wet before June 15 and after early November.

Budget

In 1993, the science team competed successfully for $111,000 in Ecosystem Management Research dollars from the Washington Office. Although this initial funding was crucial to the success of the project, it was insufficient to fund research by all team members each year. Therefore, important team decisions have been how the dollars were to be allocated. The team makes these decisions by first determining which activities must be accomplished (fixed costs) within the budget allocations for that year, and then which activities could be accomplished that same year (variable costs). The variable costs are prioritized by team consensus. The fixed costs are subtracted from the allocation, and the remaining funding is then distributed, by priority, until exhausted. Each team member has contributed his or her time to the project. The research proposals they develop for consideration utilize only bare bones costs. Significant additional funds are needed to capture the full research potential.

The search for interdisciplinary opportunities is a continuing struggle that is hampered by the geographical separation of many team members and the lack of expertise in geographic information systems (GIS). In large-scale projects, GIS can be a valuable tool for discovering spatial patterns and ecosystem linkages. Although the present budget might allow for contracting specific tasks, the team's use of GIS is largely exploratory and a GIS expert is needed. Most of the disciplines important to the study are represented on the science team with the exception of forest pathology, botany, and sociology, but these may be acquired as needed from the National Forest System or academia.

Predicted Outcomes

To aid in designing inventory and monitoring schemes for the various cooperating disciplines, it was judged useful to anticipate the responses of various ecosystem components to the treatments (*tables 2, 3, and 4*). Several members of the science team participated in this exercise. Although there was general agreement on most outcomes, several were controversial.

Figure 11—Treatment installation for the Blacks Mountain Ecological Research Project was performed by a tree shear with a circular sawhead that cut small sawtimber trees from 10 to 16 inches dbh.

Table 2—*Projected short-term vegetational and soil responses anticipated by members of the science team within the first 5 years after treatment compared to pre-treatment conditions at the Blacks Mountain Ecological Research Project.*[1]

Tree growth	Mortality	Crown cover	Shrub cover		Coarse woody debris	Grass and forb cover		Soil fertility	
No grazing			No grazing	Grazing	No grazing	No grazing	Grazing	No grazing	Grazing
Low diversity with fire									
+	-	-	-	0	-	+	+	0	+
-	+	—	-	-	—	++	+	+	-
-	0	-	0	-	—	++	+	+	0
0	0	-	-	-	-	+	0	+	+
?	+		?	-	+	?	0	+	+
	+			0					+
Low diversity without fire									
+	-	—	+	+	—	+	+	0	0
++	-	—	+	0	-	++	+	0	0
+	-	-		?	-	++	0	+	0
+	-	-	+	0	—	+	0	0	0
?	-	-	+	0	+	?	0	0	0
	-		0	+			+		0
	+								
High diversity with fire									
0	0	—	0	0	-	+	+	+	+
0	0	-	-	-	—	+	+	+	+
-	0	-	-	-	-	+	+	+	+
0	+	-	0	-	-	+	+	+	?
0	+	-	-	0	0	+	0		0
						?	+		
High diversity without fire									
+	-	-	+	0	0	0	+	0	0
+	-	-	+	0	0	+	0	+	0
+	-	-	+	0	0	+	0	0	0
+	-	-	+	0	—	0	0	0	0
0	-	-	?	0	+	?	0	0	0
	+								

[1]Response codes: 0 = no change; + = moderate increase; ++ = large increase; - = moderate decrease; — = large decrease; and ? = cannot project.

Table 3—*Projected mid-term vegetational and soil responses anticipated by members of the science team 10 to 20 years after treatment compared to immediate post-treatment conditions at the Blacks Mountain Ecological Research Project.*[1]

Tree growth	Mortality	Crown cover	Shrub cover		Coarse woody debris	Grass and forb cover		Soil fertility	
No grazing			No grazing	Grazing	No grazing	No grazing	Grazing	No grazing	Grazing
				Low diversity with fire					
+	—	++	0	+	-	+	0	0	0
+	-	++	0	-	-	+	+	0	0
+	-	+	0	?	-	++	0	0	0
++	-		0	?	-	+	0	0	-
+	-		0	?	-	0	0	0	-
				Low diversity without fire					
+	-	++	+	+	0	0	-	0	0
+	-	++	0	+	0	0	-	0	0
+	0	+	+	+	0	0	-	0	0
+	0		0	+	0	0	-	0	0
+	0		+	+	0	0	-	0	0
				High diversity with fire					
+	-	++	-	-	0	0	0	0	0
+	-	++	-	0	0	0	0	0	0
+	0	+	-	0	0	0	0	0	0
++	-		-	-	-	0	0	0	0
+	0		0	0	-	+	0	-	-
				High diversity without fire					
+	+	++	-	+	+	-	-	+	+
-	+	++	+	+	+	-	-	0	0
0	0	+	0	+	+	-	-	0	0
-	0		0	+	+	-	-	0	0
0	0		+	+	+	-	-	0	0
+									

[1] Response codes: 0 = no change; + = moderate increase; ++ = large increase; - = moderate decrease; — = large decrease; and ? = cannot project.

Table 4—*Short- and mid-term wildlife responses projected by consensus of the science team for the two extreme treatments at the Blacks Mountain Ecological Research Project. Short-term response is within the first 5 years after treatment compared to pre-treatment condition. Responses 10 to 20 years after treatment are compared to immediate post-treatment conditions.*[1]

Species	High structural diversity without grazing and without fire		Low structural diversity with grazing and with fire	
	1-5 years	10-20 years	1-5 years	10-20 years
Birds				
Bark probers:				
Williamson's Sapsucker		++		—
Pileated Woodpecker		++		—
Bark gleaners:				
Mountain Chickadee		0		0
Red-breasted Nuthatch		+		—
Leaf gleaners:				
Yellow-rumped Warbler		-		++
Plumbeous Vireo		-		-
Terrestrial feeders:				
Dark-eyed Junco		-		+
Chipping Sparrow		++		+
Aerial Sally:				
Dusky Flycatcher		+		-
Mammals				
Yellow-pine chipmunk	++	+	+	0
Shadow chipmunk	-	0	-	-
Golden-mantled ground squirrel	++	+	+	0
Deer mouse	+	0	++	+
Voles	+	0	++	+

[1]Response codes: 0 = no change; + = moderate increase; ++ = large increase; - = moderate decrease; — = large decrease.

Activities of the Component Disciplines

Fire Ecology

Fires burned frequently and usually lightly through the interior ponderosa pine type before the mid-19th century, strongly influencing the structure, composition, and function of these forests. Changes in the fire regime (frequency, severity, size, and distribution) since that time, associated mainly with human activities (including sheep grazing, logging and fire suppression), have brought about major changes in these ecosystems (*fig. 12*).

Activities by fire ecologists at BMEF have focused on studies that are designed to provide information to increase the potential that the initial large-scale prescribed burns will be implemented successfully (i.e., without excessive damage), or address important fire-related questions not dependent on the large-scale burns. In the first category, we evaluated the effects of season of burning on duff consumption, soil heating, and mortality in old pine trees. In the second category, we have completed data collection for a study of factors influencing decay rates in large downed logs (summarized later in the "Soil Processes" section) and are collecting data in a large study of spatial patterns of age-class structure of trees at BMEF as related to historic fire regimes.

Season of Burning—Under pre-European settlement fire regimes in the interior ponderosa pine type, fires occurred frequently (*fig. 13*), kept duff and other fuels at relatively low levels, and therefore, usually burned at low to moderate severity and did little damage to large trees. The negligible occurrence of fire at BMEF since the early 20th century, however, has caused substantial increases in duff depth, especially around the bases of large old trees (because of bark sloughing

Figure 12—Vegetative structure and species composition changed dramatically in the interior ponderosa pine type as a result of the exclusion of fire and sheep grazing at the Blacks Mountain Experimental Forest. Understory vegetation was sparse beneath open stands in 1920 (A). By 1946 pine seedlings were abundant and created a two-storied stand (B) that by 1994 had become very dense with abundant white fir (C).

A

B

C

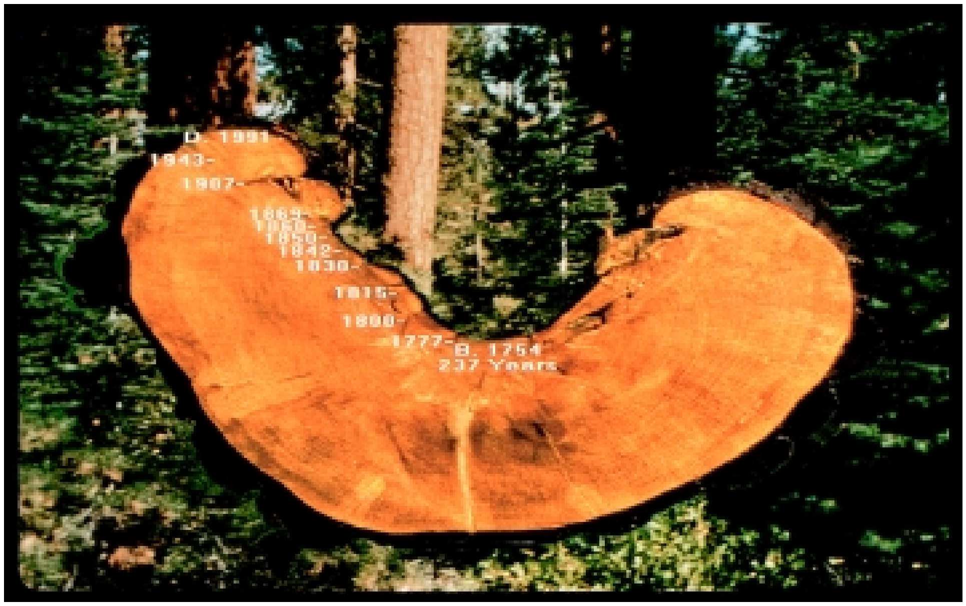


Figure 13—Interior ponderosa pine forests burned frequently before fires were excluded early in the 1900's. The dates of fire scars on large, old trees tell the story.

and other litter deposition). Some studies elsewhere in the west have indicated that initial prescribed burns in conifer forests from which fire has been excluded for long periods can cause delayed mortality in such old trees, especially pines. The mortality evidently is associated with consumption of duff accumulations around tree bases, probably at least in part because of damage to shallow roots. Prominent parts of the experimental design at BMEF involve reintroduction of fire and retention of large old trees as a key part of the high diversity structure (*fig. 14*). To increase the probability that these two parts will be compatible, we undertook a preliminary study of the effects of season of initial fire reintroduction.

Duff consumption was more spotty in the early spring burns than in later burns: the surface litter in many cases was simply too wet to carry fire. Significantly, however, where the litter carried fire, and where more than the surface couple of millimeters was consumed, the duff invariably was consumed entirely to mineral soil. We observed no intermediate levels of duff consumption—for instance, 10 to 90 percent—around the old pines. We had hoped for such intermediate levels of consumption. Simply skimming the very top of the litter off, even if we had been able to do that uniformly, would not lead to better conditions (i.e., reduced duff levels) for the second round of operational burns.

As expected, in areas where the duff was consumed, burns conducted with wetter duff and cooler soil had lower maximum temperatures at any given depth in the upper soil. Nevertheless, the heat generated by duff consumption seems to have been sufficient, regardless of season of burn, to kill most fine roots in the zone where most of them occur—lower duff and mineral soil to about 4 inches in depth. Limited sampling suggests that growth of fine roots is probably active even at the earliest time of our burns (March) and probably less active in late summer/early fall. If this is confirmed by more intensive sampling, damage to fine roots from spring burning might well be expected to affect the old trees more adversely than burning in early fall. Spring burning may be riskier also from the standpoint of potential bark beetle-caused mortality after prescribed burns.

The study has not given us a definitive answer about the best time of year to conduct the initial burns. The only mortality observed, however—3 out of 34 sample trees—was in early spring and late fall. These results suggest that the possible advantages of early spring initial burns that we originally had hypothesized (less duff consumption, lower soil temperatures), for old pines with deep duff mounds around them, may not be real. The "natural" late summer/early fall burn season may be safer after all, and we have adopted that season for the large burns.

Figure 14—Preliminary testing of prescribed fire techniques focused on preventing mortality of large old ponderosa pines.

Tree Age-class Structure and Historic Fire Regimes—It is recognized in general terms that recurring fire historically played a key role in influencing the species composition, stand structure, and landscape mosaic of most forest types in western North America, including the interior ponderosa pine type. There are no published studies that describe historical forest development and the role of fire in that development for the interior ponderosa pine of California.

A detailed fire history is being developed from the analysis of fire scars in tree rings from BMEF. Cross-sections of stumps and logs are being collected that exhibit multiple fire scars from each unit. The location of each cross-section is referenced to the nearest grid point so that the spatial pattern of past fires can be mapped. The fire scars are being crossdated using standard dendrochronological techniques to precisely date each fire scar to the year and season of occurrence.

To determine the past influence of fires on stand development, approximately 375 trees have been cored on sample plots associated with the grid in each of the low-diversity treatment units. These cores will provide age data that will be compared to the fire history. Each tree sampled in this way has cores or cross-sections taken at three different heights—ground line, 20 cm (0.7 ft), and 100 cm (3.3 ft) above ground line. This will provide data on stand development and responses to historical fires.

These data will provide detailed background information on the development of the original forest at BMEF. Tree responses to fire and climate will be developed. The scheduling of prescribed fires in the prescribed fire splits will be driven by the variation of the historical fire regime found in the fire history analysis.

Standing Biomass and Nutrient Content

On the BMEF, 43 trees were felled for biomass and chemical analysis. Sample tree diameters spanned the full range of those recorded in the pre-treatment inventory, and species were sampled roughly in proportion to their contribution to basal area. BMEF trees were pooled with those sampled on two Lassen National Forest Long-Term Soil Productivity (LTSP) sites, bringing the total to

100 trees (50 percent ponderosa pine, 35 percent white fir, and 15 percent incense-cedar). Once felled, biomass was estimated using standard LTSP protocols.

Power function correlations between biomass and nutrient content and tree dbh were very strong (R^2 often exceeded 0.9). Ponderosa pine had the greatest biomass for a given tree diameter, except in pole and smaller size classes where white fir was slightly heavier because of more massive crowns. This is logical because ponderosa pine is less shade-tolerant than white fir, which means that small understory pine would have sparser crowns than fir (or incense-cedar). For large overstory trees (dbh 40 inches), pines have 27 percent more total biomass than white fir, and 148 percent more than incense-cedar. Crown biomass increases with tree size for ponderosa pine and white fir (1,506 lbs and 812 lbs for pine and fir, respectively, at a dbh of 40 inches), but declines for larger incense-cedar. This indicates the upper canopy position and relatively high vigor of large pine and fir, but a decadent condition for large incense-cedar (which remain in a subdominant canopy position). Ponderosa pine crowns contain one-fifth of total tree biomass for dbh's of 20 inches and greater. But for incense-cedar, the proportion of crown to total tree biomass declines from 56 percent at 10 inches dbh to only 9 percent at 40 inches. Nutrient contents increase steadily with tree size. Nitrogen (N) contents of ponderosa pine range between 1 lb per tree at a dbh of 10 inches to 33 lb per tree at 40 inches. For larger pine, about 75 percent of the N is in the commercial bole. White fir has lower absolute amounts of N than pine, but a higher proportion (about one-third) is in the crown. Regression equations developed from these data can be used to estimate the nutrient drain (or retention) occurring during tree harvest operations.

Plant Ecology

Second only to the soil resource, vegetation is the foundation for sustained productivity and diversity in the ecosystem. Permanent plots keyed to the 100-meter grid were installed to estimate the structure, density, and species composition of the flora in the 250-acre units (*appendix D)*. In 1994, an extensive survey of 25 percent of the grid points documented pre-treatment conditions. Post-treatment conditions were sampled in Block I in 1998.

Snags and Living Trees—Two nested, fixed-area plots centered on the grid intersections were used to measure the characteristics of trees and snags before treatments were installed. Live trees and snags 11.6 inches dbh and larger were sampled on a 0.2-acre plot. Poles, saplings and seedlings were sampled on a 0.01-acre plot.

The pre-treatment inventory illustrates the well-recognized ability of Jeffrey pine to tolerate harsher sites compared to ponderosa pine (*table 5*). Thus, Jeffrey pine is found almost exclusively on the floor of the valley where tolerance of late spring frosts favor Jeffrey pine (the High Pine Block) and on the rocky and shallow soils at upper elevations (the High Fir Block). White fir and incense-cedar are largely absent in the High Pine Block. The pre-treatment inventory also shows the similarity between the Pine/Fir and High Fir Blocks and their dissimilarity to the High Pine Block (*table 5*). Stand density in the RNAs is noticeably greater, especially as measured by number of pole-sized and larger trees per acre, than it is in the treatment units. This may reflect the cutting in the old Methods-of-Cutting plots or some stand characteristic used in selecting the RNAs.

In 1998 after the treatment was installed in Block I (vegetation manipulated and prescribed fire applied), this block of units was remeasured (*table 6*). RNA-C was remeasured after prescribed fire. The post-treatment inventory was more intensive. Half rather than one-quarter of the grid points were sampled, and measurements on smaller trees were intensified. Pole-sized trees (3.5 to 11.5 inches in dbh) were measured on a nested 0.05-acre plot and seedlings and

Table 5—*Large snag and living tree characteristics before installing treatments in the Blacks Mountain Ecological Research Project.*

Unit	Snags > 24 inches dbh: Number/acre			Living trees > 3.5 inches dbh: Basal area (ft²/acre)				Living trees > 3.5 inches dbh: Number/acre			
	PIPO[1]	ABCO	LIDE	PIPO	PIJE	ABCO	LIDE	PIPO	PIJE	ABCO	LIDE
High Pine											
High diversity											
38	2	< 1	0	124	8	2	0	283	18	3	0
41	1	0	1	78	26	4	14	177	84	9	42
Low diversity											
39	2	0	0	72	18	0	0	176	37	0	0
43	1	1	0	73	11	32	21	190	17	125	42
Pine/Fir											
High diversity											
42	1	2	0	80	0	121	10	143	0	287	20
47	2	2	<1	50	7	8	35	125	12	31	43
Low diversity											
44	2	2	0	104	0	32	14	177	0	112	22
45	2	1	< 1	86	9	54	8	185	14	142	20
High Fir											
High diversity											
48	2	1	0	57	37	97	1	91	55	223	4
49	1	2	0	81	0	38	12	122	0	117	25
Low diversity											
40	1	3	< 1	88	6	54	24	180	19	293	27
46	2	3	0	40	14	61	19	110	37	180	29
RNA-C[2]	3	0	0	125	6	11	2	316	18	21	4
RNA-B	3	1	1	69	17	23	50	200	70	83	129
RNA-A	2	1	0	138	2	15	32	368	4	50	55
RNA-D	2	1	1	105	0	58	24	294	0	198	50

[1] Species codes are: PIPO = *Pinus ponderosa*, ABCO = *Abies concolor*, LIDE = *Libocedrus decurrens* and PIJE = *Pinus jeffreyi*.
[2] RNA = Research Natural Area.

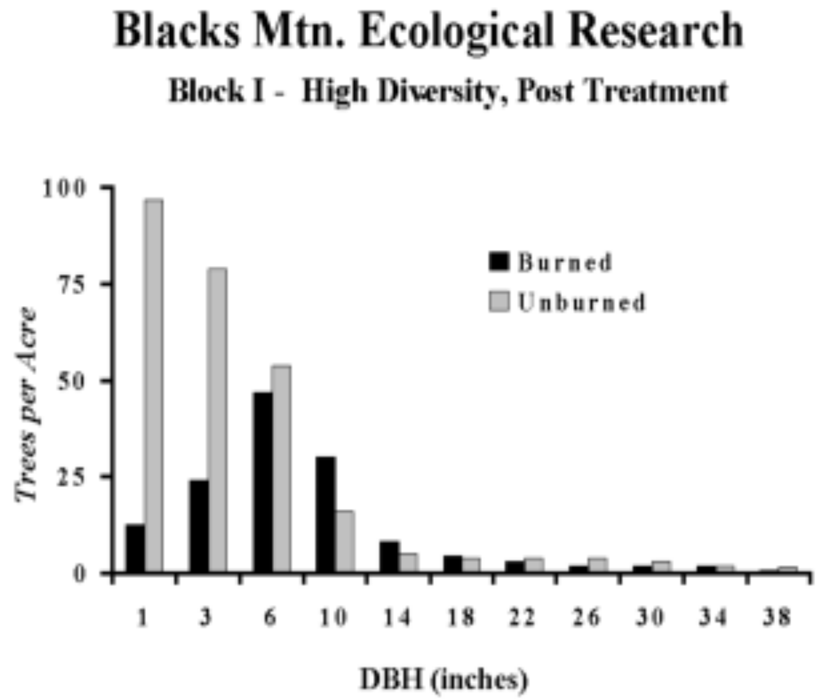
saplings on a nested 0.01-acre plot. Also, each seedling and sapling was measured rather than coded by groups of 10.

Stand densities after vegetation manipulation are noticeably greater in the high diversity treatment (*table 6*). Prescribed fire, on the other hand, has not affected the density of pole-sized and larger trees, at least after the first growing season *(fig. 15)*.

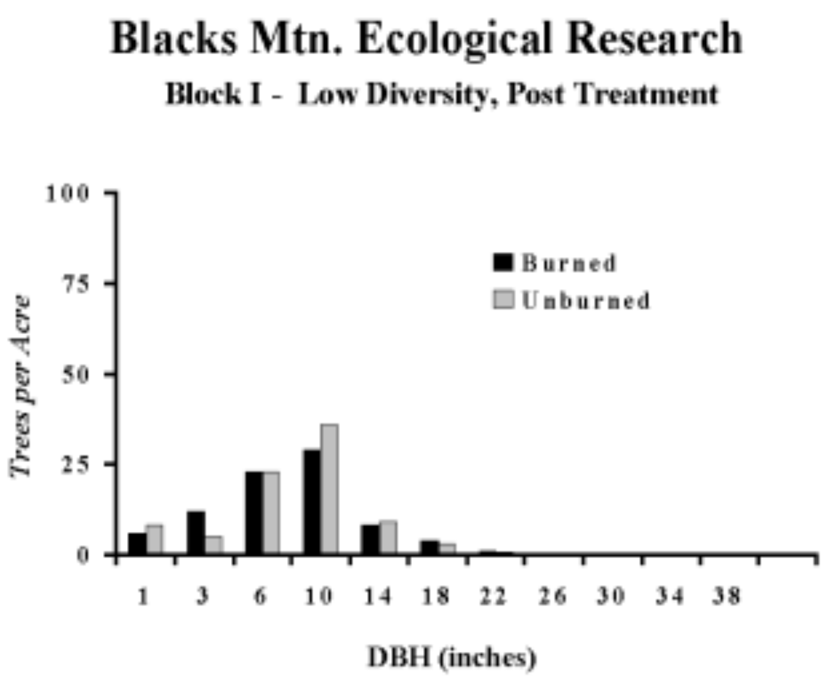
Transects form the basis for forest floor characteristics, foliar cover and species frequency for understory species (*fig. 16*), and woody debris. Transects are 328 feet (100 meters) in length, oriented in either a northwest or northeast direction (randomly chosen) and centered on the same grid intersections where the tree plots are established.

Forest Floor—Forest floor characteristics, foliar cover, and species frequency were sampled on ten 0.5-m^2 (5.38ft^2) plots randomly located along the 100-m transect. The overwhelming impression of pretreatment forest floor conditions is that variation among units and among blocks is surprisingly small (*table 7*). Although differences are subtle, the following trends are apparent: nearly three

Figure 15—Diameter distributions for Block I after treatment installation. High structural diversity treatment without and with prescribed burn (A). Low structural diversity without and with prescribed burn (B).



A



B

Table 6—*Large snag and living tree characteristics after installing treatments in Block I and Research Natural Area-C (RNA-C).*

Unit	Burn	---Snags > 24 inches dbh--- Number/acre			------Living trees > 3.5 inches dbh------ Basal area (ft^2/acre)				Number/acre			
		PIPO/PIJE[1]	ABCO	LIDE	PIPO	PIJE	ABCO	LIDE	PIPO	PIJE	ABCO	LIDE
					High Pine							
High diversity												
38	Yes	< 1	0	0	84	6	0	0	105	11	0	0
	No	< 1	0	0	84	2	3	1	98	3	6	1
41	Yes	0	0	0	71	12	4	9	75	14	7	19
	No	2	0	1	67	4	7	13	92	4	18	21
Low diversity												
39	Yes	< 1	0	0	18	11	0	0	53	14	0	0
	No	< 1	0	0	71	12	4	9	54	14	0	0
43	Yes	< 1	0	0	18	2	11	2	38	8	19	4
	No	1	0	0	20	2	6	5	49	3	13	9
RNA-C	Yes	1	0	0	122	5	7	1	293	9	17	2

[1] See *table 5* for acronyms.

Figure 16—Understory vegetation and forest floor conditions were sampled on 0.5 m^2 circular plots along a 100 meter transect.

quarters of the forest floor is covered by litter in all units and blocks; the RNAs have an even greater proportion of litter than the treatment units; and more mineral soil is exposed in the High Pine Blocks.

After treatment installation in the High Pine Block (*table 8*), the proportion of the ground exposed to mineral soil increased as expected. The decrease in the proportion of the ground covered with small woody debris and partially decomposed large woody debris was unexpected, however. Prescribed fire strongly increased the proportion of mineral soil, as expected. But its affect on the proportion of litter was weaker.

Foliar Cover—*Ceanothus prostratus* dominates foliar cover in all units and RNAs (*table 9*). In general, the High Pine Block has a greater amount of perennial

Table 7—*Forest floor characteristics before installing treatments in the Blacks Mountain Ecological Research Project.*

Unit	Burn	Percent of the forest floor in condition categories[1]							
		LITT	SMWD	LAWD-U	LAWD-P	ROCK	SOIL	GRAV	ALIT
					High Pine				
High diversity									
38	Yes	78	11	1	4	3	3	0	< 1
	No	75	11	< 1	3	2	9	0	< 1
41	Yes	63	13	2	6	9	5	< 1	< 1
	No	71	11	2	3	5	6	1	1
Low diversity									
39	Yes	71	15	< 1	2	6	5	0	< 1
	No	73	12	< 1	2	4	8	0	< 1
43	Yes	75	16	< 1	3	1	4	0	0
	No	72	18	< 1	5	2	3	0	< 1
					Pine/Fir				
High diversity									
42	Yes	61	17	1	8	2	5	< 1	0
	No	72	15	< 1	8	1	3	< 1	< 1
47	Yes	74	8	3	5	6	3	1	0
	No	74	11	2	4	6	2	0	0
Low diversity									
44	Yes	62	16	< 1	13	2	5	< 1	0
	No	68	20	1	8	1	2	0	< 1
45	Yes	65	11	1	6	10	5	< 1	< 1
	No	65	17	1	6	9	1	0	< 1
					High Fir				
High diversity									
48	Yes	71	19	1	3	5	1	0	< 1
	No	68	13	< 1	7	8	4	0	< 1
49	Yes	67	18	3	5	3	4	< 1	< 1
	No	67	12	3	6	7	3	< 1	< 1
Low diversity									
40	Yes	62	25	1	6	4	1	0	< 1
	No	67	20	3	5	3	1	0	< 1
46	Yes	62	15	2	10	6	6	< 1	0
	No	57	17	1	7	10	8	0	0
RNA-A[2]	No	86	1	3	4	3	1	0	0
RNA-B	Yes	80	4	1	7	5	2	< 1	0
RNA-C	Yes	91	1	4	0	2	2	< 1	< 1
RNA-D	No	87	2	1	4	1	4	0	0

[1] Forest floor categories are LITT = litter, SMWD = small woody debris (1-3 inches), LAWD = large woody debris (> 3 inches), U = undecomposed (structure intact, includes charred remains), P = partially decomposed (crumbly, brown cubical rot present with structural materials), ROCK = rock, SOIL = soil, GRAV = gravel, and ALIT = animal litter.
[2] RNA = Research Natural Area.

Table 8—*Forest floor characteristics after installing treatments in the Blacks Mountain Ecological Research Project.*

Unit	Burn	Percent of the forest floor in condition categories[1]								
		LITT	**SMWD**	**LAWD-U**	**LAWD-P**	**ROCK**	**SOIL**	**GRAV**	**ALIT**	**ASH**
					High Pine					
High diversity										
38	Yes	68	1	< 1	2	4	24	< 1	< 1	0
	No	72	6	1	< 1	2	16	< 1	< 1	0
41	Yes	40	2	< 1	2	8	39	5	< 1	3
	No	63	3	0	2	2	28	0	0	0
Low diversity										
39	Yes	52	4	< 1	1	7	36	< 1	< 1	0
	No	64	3	1	3	4	23	< 1	0	0
43	Yes	40	4	< 1	< 1	3	50	1	0	0
	No	62	5	2	6	0	26	0	0	0
RNA-C	Yes	59	2	< 1	< 1	3	34	< 1	0	0

[1] See *table 7* for acronyms.

grasses than did the other blocks. Perennial grasses were entirely absent in the RNAs probably because of the high stand densities and the high proportion of litter cover. *Purshia tridentata* was more abundant in the High Pine Block, whereas *Arctostaphylos patula* was more common in the Pine / Fir Block.

The most noticeable change in foliar cover after installing the treatments seems to be the greater proportion of annual grasses and forbs (*table 10*).

Frequency of Common Understory Species—The frequency of *Festuca idahoensis* and the diversity of other common understory species was noticeably greater in the High Pine Block than in the other two blocks and the RNAs (*table 11*).

After treatments were installed in the High Pine Block, forbs became more abundant (*table 12*). Little effect of prescribed fire was noted in the frequency of common understory species.

Large Woody Debris—Woody debris larger than 3 inches in diameter was estimated by the line intercept method along the 100-m transect. The diameter of each intercepted piece was measured perpendicular to its long axis. Volume of large woody debris was calculated by using the following equation for each transect (Brown 1974):

$$\text{Volume / ha} = 0.01233(\text{sum of diameters}^2)$$

Table 13 seems to indicate that differences among blocks and RNAs are surprisingly small in both cover and volume of large woody debris. A careful analysis, however, may show a greater volume of partially decomposed debris in the High Fir Block.

Complete treatment installation in the High Pine Block seemed to have little influence on the coverage and volumes of large woody debris (*table 14*).

Vegetation Ground Photography—Pre-treatment conditions were photographed in 1995 and 1996 and post-treatment conditions of Block I in 1998. At each grid point sampled for vegetation, a 35 mm color slide was taken with a 35 mm lens on the same azimuth as the 328 ft (100 m) transect location that sampled the forest floor and understory vegetation. The direction of most slides is northwest or northeast. The lower third of each photograph shows the forest floor and the upper two-thirds shows the trees (*fig. 5*).

Table 9—*Proportion of the forest floor covered by foliage of common understory plant species before installing treatments in the Blacks Mountain Ecological Research Project.*

Unit	Burn	Percent of the forest floor in condition categories[1]									
		CEPR	GRAP	OTSH	ABCO	FORP	PUTR	ARPA	LIDE	PIPO	GRLK
						High Pine					
High diversity											
38	Yes	8	4	< 1	0	< 1	2	0	0	< 1	1
	No	5	4	< 1	< 1	< 1	2	< 1	0	0	< 1
41	Yes	8	2	< 1	< 1	1	1	< 1	3	0	1
	No	7	2	1	< 1	3	1	2	1	< 1	1
Low diversity											
39	Yes	2	7	< 1	0	< 1	3	1	0	< 1	< 1
	No	3	7	< 1	0	< 1	3	< 1	0	< 1	< 1
43	Yes	4	3	1	< 1	1	< 1	< 1	0	< 1	< 1
	No	4	1	1	< 1	1	< 1	< 1	< 1	< 1	< 1
						Pine/Fir					
High diversity											
42	Yes	3	1	3	3	< 1	0	1	< 1	0	< 1
	No	6	1	5	4	1	> 1	1	< 1	0	< 1
47	Yes	10	1	1	1	1	< 1	4	2	0	< 1
	No	10	1	< 1	3	1	0	2	4	0	1
Low diversity											
44	Yes	6	1	< 1	1	1	0	1	1	0	1
	No	5	< 1	0	2	< 1	0	1	< 1	0	< 1
45	Yes	4	1	2	1	1	< 1	2	1	< 1	1
	No	2	1	4	3	1	0	< 1	< 1	< 1	< 1
						High Fir					
High diversity											
48	Yes	3	< 1	3	2	1	0	< 1	0	< 1	< 1
	No	5	1	4	1	3	< 1	< 1	< 1	< 1	1
49	Yes	4	1	1	2	1	< 1	< 1	< 1	0	1
	No	6	1	1	3	1	0	1	1	< 1	1
Low diversity											
40	Yes	5	< 1	3	< 1	< 1	0	< 1	< 1	0	< 1
	No	3	< 1	2	1	< 1	0	< 1	< 1	0	< 1
46	Yes	3	< 1	1	1	< 1	< 1	2	1	0	1
	No	5	< 1	1	1	< 1	0	1	< 1	0	1
RNA-A	No	18	0	0	< 1	0	2	< 1	< 1	2	1
RNA-B	Yes	17	0	< 1	1	0	< 1	1	< 1	0	0
RNA-C	Yes	14	0	< 1	< 1	< 1	< 1	< 1	0	1	3
RNA-D	No	9	0	0	1	< 1	0	1	< 1	1	0

[1]Foliar cover categories are CEPR = *Ceanothus prostratus*, GRAP = perennial grasses, OTSH = other shrub species, ABCO = *Abies concolor*, FORP = perennial forbs, PUTR = *Purshia tridentata*, ARPA = *Arctostaphylos patula*, LIDE = *Libocedrus decurrens*, PIPO = *Pinus ponderosa*, and GRLK = grass-like species (*Carex rossii*, primarily).

Soil Processes

Decay Rates of Downed Logs—Large downed logs have potential significance in forested ecosystems, including habitat for a wide range of organisms, cycling of carbon and other elements, water retention, and reduction of soil erosion (*fig. 17*). One of the characteristics of interest is rate of decay, because of practical concerns about how rapidly highly-decomposed logs can be replaced in the system, and whether significant quantities of such logs could even exist in a regime of frequent fires. The study was made possible by the existence of data from the Methods-of-Cutting plots that date back to the 1930's and 1940's. Data analysis is not complete but a few general observations are possible.

Table 10—*Proportion of the forest floor covered by foliage of common understory plant species after installing treatments in the Blacks Mountain Ecological Research Project.*

Unit	Burn	Percent of the forest floor in condition categories[1]									
		GRAA	CEPR	FOR A	PUTR	GRLK	FORP	ARTR	SYMO	GRAP	ARPA
						High Pine					
High diversity											
38	Yes	4	6	0	2	0	0	0	< 1	0	0
	No	2	9	1	2	1	1	0	0	< 1	< 1
41	Yes	1	1	2	1	< 1	< 1	0	< 1	< 1	0
	No	—	—	—	—	—	—	—	—	—	—
Low diversity											
39	Yes	5	1	2	2	1	1	1	0	< 1	0
	No	8	4	4	6	< 1	1	3	0	0	1
43	Yes	2	5	1	0	0	0	0	< 1	0	0
	No	1	1	1	0	0	2	0	2	0	0
RNA-C											
	Yes	2	8	< 1	0	0	< 1	< 1	0	0	0

[1] Species codes not identified previously are GRAA = annual grasses, FOR A = annual forbs, and SYMO = *Symphoricarpos mollis*.

Figure 17—The rate of decay of downed logs is being studied as part of the Blacks Mountain Ecological Research Project.

The downed logs spanned a wide range of decay classes—from class 2 to class 5 (Thomas and others 1979). Clearly, 100+ years are not required to reach decay class 5, even in the relatively cold/dry environment of the interior ponderosa pine type. As expected, white fir decays more rapidly than the other conifer species at the BMEF. A section of log in contact with the soil apparently decays significantly more rapidly than one suspended off the ground. This certainly makes sense because of proximity to soil-inhabiting decomposers and greater retention of moisture during the summer for a log in contact with the soil.

Nutrient Cycling—Forest vegetation depends on adequate nutrition for growth and vigor. Throughout the interior ponderosa pine region, the cool dry climate has produced soils that are weakly developed.

Nitrogen (N), the principal nutrient limiting the growth of western forests, is in short supply. This limits the abundance, diversity, and vigor of vegetation. The two primary sources of N for all terrestrial ecosystems are ammonium and nitrate ions dissolved in rainfall and biological N fixation by microorganisms.

Table 11—*Frequency of common understory plant species before installing treatments in the Blacks Mountain Ecological Research Project.*

Unit	Burn	Percent of the forest floor in condition categories[1]									
		FEID	CEPR	CARO	SYMO	SIHY	MOOD	PUTR	PHGR	COPA	PIPO
						High Pine					
High diversity											
38	Yes	63	31	39	1	20	4	28	11	4	9
	No	56	28	37	0	24	8	26	16	8	8
41	Yes	25	34	29	4	9	4	5	0	0	1
	No	19	34	28	12	14	8	4	0	0	0
Low diversity											
39	Yes	79	14	18	0	18	8	39	10	17	5
	No	74	25	24	0	19	2	29	14	18	7
43	Yes	44	26	23	3	34	13	4	6	12	12
	No	36	35	16	3	13	7	4	6	9	13
						Pine/Fir					
Highdiversity											
42	Yes	3	9	12	27	12	11	0	0	0	1
	No	4	25	14	50	13	19	0	0	0	1
47	Yes	17	39	23	17	11	13	1	0	0	1
	No	9	49	23	9	16	3	0	0	0	0
Low diversity											
44	Yes	8	17	17	20	6	4	0	0	0	0
	No	12	17	30	7	2	0	0	0	0	0
45	Yes	10	26	9	20	9	13	1	1	6	1
	No	8	12	8	31	0	9	0	4	1	6
						High Fir					
High diversity											
48	Yes	9	10	9	17	4	12	0	3	2	1
	No	19	18	8	28	3	16	0	14	9	2
49	Yes	11	19	18	26	4	11	0	0	2	2
	No	11	32	20	11	8	8	0	0	1	2
Low diversity											
40	Yes	9	22	14	30	6	8	0	6	4	0
	No	10	20	10	28	4	9	0	8	8	0
46	Yes	6	19	26	24	11	16	3	0	0	0
	No	8	17	25	15	8	6	0	0	2	0
RNA-A	No	18	46	31	3	0	24	6	3	0	25
RNA-B	Yes	0	47	14	18	0	< 1	1	9	11	27
RNA-C	Yes	38	53	31	0	1	3	2	1	14	10
RNA-D	No	7	37	42	2	0	10	0	5	0	5

[1] Species codes not identified previously are FEID = *Festuca idahoensis*, CARO = *Carex rossii*, SIHY = *Sitanion hystrix*, MOOD = *Monardella odaritissima*, PHGR = *Phlox gracilis*, and COPA = *Collinsia parviflora*.

Since 1992, an interdisciplinary team of scientists has been studying rates of N fixation, N mineralization, and root development patterns under contrasting forest conditions. One is a simple forest structure consisting of many openings and a limited overstory cover. Within the openings are shrub communities containing antelope bitterbrush *(Purshia tridentata*), a plant associated with N fixing bacteria that has nutritional value as a forage species for deer and livestock. The second is an undisturbed, complex, multilayered forest structure. Openings are few and much of the ground cover consists of fallen trees in advanced stages of decay (*fig. 18*). Such trees are the principal habitat for free-living microorganisms that fix nitrogen. Investigations include nitrogen fixation by free-living bacteria beneath antelope bitterbrush, grasses and pine needle litter, and downed trees in advanced stages of decay. Also studied beneath the same ground cover classes are N mineralization and leaching in the forest floor and surface soil horizons, root development and mycorrhizal presence, and seasonal patterns of these.

Table 12—*Frequency of common understory plant species after treatment installation in the Blacks Mountain Ecological Research Project.*

Unit	Burn	CEPR	CARO	FEID	GASP	COPA	ACOC	PUTR	VIPU	LUAR	PHGR
		Percent of the forest floor in condition categories[1]									
		High Pine									
High diversity											
38	Yes	42	40	54	17	20	13	15	5	6	1
	No	29	51	44	26	38	29	29	9	6	17
41	Yes	52	35	16	25	24	9	7	5	15	7
	No	—	—	—	—	—	—	—	—	—	—
Low diversity											
39	Yes	51	56	40	28	33	21	20	15	6	3
	No	13	35	50	27	40	35	33	17	6	4
43	Yes	64	55	34	36	15	31	2	5	3	1
	No	67	39	6	22	28	33	0	17	6	11
RNA-C	Yes	72	28	39	15	5	16	1	3	1	1

[1] Species codes not identified previously are GASP = *Gayophytum* species, ACOC = *Achnatherum occidentalis*, VIPU = *Viola purpurea*, and LUAR= *Lupinus argenteus*.

Figure 18—The contribution of downed trees in advanced stages of decay to tree root development, nutrient cycling, and other soil processes is being intensively studied.

Soil physical and nutritional properties and processes have been documented at 18 spatially referenced locations. Included are N fixation and mineralization rates associated with the three major categories of ground cover classes (pine needle litter, antelope bitterbrush, and large woody debris). The biomass, chemical content, and aerial distribution of large woody debris and the most ecologically important shrub, antelope bitterbrush, have also been described. Field sampling has been completed for estimating the biomass and nutrient content contained in crowns and boles of ponderosa pine, white fir, and incense-cedar in the pine type.

The soil cover / process work centered on the Methods-of-Cutting plots. Two contrasting treatments were selected: the heavy Forest Service (HFS) cut that mimics the low structural diversity treatment and the control that mimics the high structural diversity treatment.

We found that the total biomass of large, woody debris in advanced stages of decay is conservatively one and a half times greater on the control plots than on

Table 13—*Percent cover and volume of large woody debris by categories of decomposition before installing treatments in the Blacks Mountain Ecological Research Project.*[1]

Unit	Burn	Undecomposed Cover (percent)	Undecomposed Volume (m^3/ha)	Partially decomposed Cover (percent)	Partially decomposed Volume (m^3/ha)	Fully decomposed Cover (percent)
				High Pine		
High diversity						
38	Yes	0.60	3.70	1.79	15.00	2.33
	No	0.23	1.69	2.04	13.70	1.67
41	Yes	0.58	3.17	2.31	19.80	4.84
	No	1.07	5.70	1.57	10.40	1.85
Low diversity						
39	Yes	0.37	3.40	1.07	11.40	0.64
	No	0.27	2.68	1.46	10.80	1.16
43	Yes	0.59	2.56	0.62	7.12	1.58
	No	0.35	2.52	2.94	15.55	3.25
				Pine/Fir		
High diversity						
42	Yes	1.14	4.90	2.34	22.26	5.45
	No	0.23	4.12	1.73	12.6	5.16
47	Yes	0.64	6.71	2.02	14.88	3.57
	No	0.90	5.41	1.45	9.76	3.97
Low diversity						
44	Yes	0.46	11.09	2.31	9.67	10.16
	No	0.91	5.64	1.95	14.68	8.04
45	Yes	0.68	4.95	3.54	22.98	3.44
	No	2.81	4.25	4.12	25.36	1.59
				High Fir		
High diversity						
48	Yes	1.55	5.54	0.80	5.95	2.72
	No	0.64	2.34	3.84	31.46	3.56
49	Yes	1.39	5.89	2.83	18.61	4.22
	No	1.73	11.68	1.42	7.70	5.52
Low diversity						
40	Yes	0.89	7.89	1.93	16.64	6.40
	No	1.62	10.36	1.69	14.70	5.50
46	Yes	0.96	3.38	3.02	15.58	6.29
	No	1.11	7.92	1.89	10.44	5.95
RNA-C	Yes	1.61	2.63	2.20	10.3	1.37
RNA-B	Yes	2.46	10.82	4.08	20.44	2.94

[1]Volumes for fully decomposed large woody debris are not given because the volume equation assumes that the structure is largely intact.

HFS. An obvious conclusion from this is that there is far less recruitment from snag fall on the HFS (so we can conclude that the same will be true for the low diversity treatments). The results also showed that the lignin content of the downed trees on the control plots was higher than on HFS, indicating a higher degree of decomposition. This is supported by consistently higher nutrient concentration.

N processes within and beneath large, downed woody debris are no greater than beneath other types of ground cover. In fact, the areal importance of downed woody debris as an N source is less in proportion to its areal cover than other cover types. Although large roots of pines do utilize the brown cubical stage of decay in downed trees, the importance of this as a rooting medium is apparently no greater than that for mineral soil. Downed trees in advanced stages of decay are home to many fungal species. Nearly 200 individual species were identified, including one new species (Larsen and others 1996). Zoologically, however, downed logs seemed deserts. Few, if any, soil or litter fauna were found in logs in advanced stages of decay.

Table 14—*Percent cover and volume of large woody debris by categories of decomposition after installing treatments in the Blacks Mountain Ecological Research Project.*

Unit	Burn	Undecomposed		Partially decomposed		Fully decomposed
		Cover (percent)	Volume (m^3/ha)	Cover (percent)	Volume (m^3/ha)	Cover (percent)
				High Pine		
High diversity						
38	Yes	0.36	1.32	0.81	2.87	0.10
	No	0.52	1.43	2.23	12.53	2.69
41	Yes	1.06	3.50	0.74	2.46	0.39
	No	0.98	1.91	3.25	11.69	2.21
Low diversity						
39	Yes	0.52	2.51	0.69	2.70	0.30
	No	1.46	2.97	1.33	5.18	1.27
43	Yes	0.59	1.96	0.37	1.15	0.28
	No	0.21	2.36	4.20	22.62	6.29
RNA-C	Yes	1.04	2.71	0.64	4.73	0.22

Antelope bitterbrush, although relatively rich in protein (giving it browse value), adds very little nitrogen to either ecosystem through symbiotic fixation. Primarily, this is due to its low coverage, and not to age or to overstory cover. *Ceanothus prostratus* (which has little if any browse value) has twice the coverage and fixes more than twice as much nitrogen.

Coarse Woody Debris Arthropods—Arthropods are crucial to the biodegradation of down woody debris. Beetles open the interior surfaces of standing and down woody material to decomposition by microbial decomposers. Other groups of arthropods, such as fungivorous flies, oribatid mites, termites, and ants, participate in the further recycling of coarse woody debris. At BMEF, we are assessing the effects of differences in stand structure and prescribed fire on this crucial community of arthropods and their functional role in the ecosystem. Consumption rates, colonization by arthropods and fungi, and changes in physical characteristics of standardized samples are being assessed on each unit. Also, we are sampling the arthropod community in the existing down woody debris and the forest floor using pitfall traps.

Soil Arthropods—A study comparing the sensitivity of two sampling protocols for detecting effects of forest stand structure on soil-dwelling Coleoptera was conducted in 1997. The intent was to determine whether tree-centered transects, by accommodating heterogeneity induced in the below-ground habitat by the presence of trees, provide a more sensitive test of effects of tree harvest on soil and litter-dwelling Coleoptera than do spatially random transects. Samples were taken in September 1997 soon after harvest operations were completed. The two sampling protocols consisted of 20-foot long east-west transects centered on randomly selected 14-inch dbh ponderosa pines, and identical transects centered on spatially random stakes (*fig. 19*). Tree-centered transects, by most measures, captured more of the beetle diversity and abundance than spatially random transects. Preliminary results from oribatid mite sampling using tree-centered transects in the units in Block I with and without prescribed fire suggest that low intensity prescribe fire has little effect on species richness, diversity, and evenness. Moderate intensity prescribed fire, however, has a more profound effect on the measures of community structure.

Forest Genetics

Biodiversity maintenance is essential to protect the health, productivity, and sustainability of ecosystems. At the basis of biodiversity is the genetic component: the diversity of the gene pool and its distribution within and among populations.

Figure 19—Soil arthropods were collected from litter samples along tree-centered and randomly located transects.

Changes in genetic diversity may result in forest composition and structure changes. These changes may impact wildlife, forest productivity, forest health, insects and diseases, and all other ecosystem processes.

Baseline genetic diversity has been determined for ponderosa pine, antelope bitterbrush, and Idaho fescue (*Festuca idahoensis*). Tissue samples were collected and referenced to the 100-meter grid. Starch gel electrophoresis of isozymes was used to assess genetic variation of each of the three species. Data were analyzed to quantify the level of genetic diversity and its structure. These baseline genetic data are the genetic control level of reference that will be used to evaluate the impact of management options on genetic diversity of these systems over time.

The genetic experimental design for the sampling strategy is in place. During the summer 1994 and before treatment implementation, the collection of conifer, antelope bitterbrush, and Idaho fescue samples began. These preliminary data and the post-treatment response data will be compared to determine the effects of and differences between the treatments. Also, this genetic information will assist managers in developing strategies that sustain or enhance genetic diversity and ecosystem health.

Forest Entomology

Bark Beetles—Bark beetles are a major cause of tree mortality in the interior ponderosa pine type, particularly during periods of extended drought (*fig. 20*). Thus, they are important in forest dynamics and nutrient cycling and in creating critical wildlife habitat. Changes in patterns of tree mortality over time and space in response to forest treatments are being monitored by ground survey and aerial photography.

From 1993 to 1996 data were collected on the distribution, impact, and year-to-year variation of bark beetle-caused tree mortality. The spatial distribution and rate of tree mortality has been censussed on all 12 units. Stem maps have been generated that display percent mortality by tree species, insect species, diameter distribution by tree and insect species, mortality group size, and insect species composition within mortality groups. These data have been entered into

Figure 20—A ponderosa pine at Blacks Mountain Experimental Forest that has been killed by bark beetles. Bark beetles play an important role in forest dynamics, nutrient cycling, and in creating wildlife habitat.

the relational database for spatial analysis and corporate use by other researchers (wildlife / snag research, dynamics of coarse woody debris, soil nutrient cycling).

Tree mortality from 1991 to 1996 ranged from 5 to 15 percent during any one year. Although four species of primary tree-killing bark beetles predominate, at least two other species of bark beetles were discovered killing trees. The eastside pine type is unique in North America for the number of primary tree killing bark beetles.

In 1993, members of the interdisciplinary research team initiated a study of the responses of insects, fungi, and wildlife to two different causes of tree death: ponderosa pines baited with bark beetle attractant and killed by the beetles (*fig. 21*) compared to pines killed by mechanical girdling. In addition to pheromone versus mechanical girdling, subtreatments include spring versus fall treatments and small (15 to 25 inches dbh) versus large (35 to 50 inches dbh) target trees. Variables of interest include insect, fungal, and cavity-dependent species responses to different snags, and the relationship of insects and fungi to the process of snag deterioration. Results of this controlled experiment will be of great interest and benefit to other members of the interdisciplinary team, especially those involved with wildlife, soil nutrient cycling, fire ecology, and entomology.

Wildlife Ecology

Small mammals and birds are key components of interior ponderosa pine forests. They distribute fruits of various plants and fungi and provide part of the food base for predatory species, and birds, in particular, are predators of insects.

These wildlife are responsive to changes in composition and structure of forests as well as environmental gradients, such as elevation. The bird and small mammal study includes:

- Measuring and interpreting responses to experimental treatments.
- Changes in the vertebrate assemblages relative to changes in elevation.
- Relationships to variation in microhabitat characteristics.
- Home range patterns and sizes related to vegetation structure and spatial pattern.

Figure 21—A satellite study is testing the responses of insects, fungi, and wildlife to two different causes of ponderosa pine mortality. The organisms living in this tree baited with bark beetle attractant and killed by beetles are being compared to pines killed by mechanical girdling. The funnel traps are capturing insects entering and leaving the tree.

- Basic biological patterns relative to time (using time as a variable that includes other variables such as weather, disease incidence, population level changes, vegetation change, etc.) and time since treatment.

The BMEF small mammal and bird pre-treatment research work began in the spring 1992. Each year the siting of traps and trapping begins in late spring and runs until late fall to ensure that a maximum amount of information is collected on the variation in populations of certain mammals. Bird point counts begin in the early spring and terminate before summer. Nest searches, observations of foraging, and collection of microhabitat information around nest sites and foraging locations continue through the spring and into the summer to develop information on the productivity of birds and microhabitat use in the experimental units. This set of data will aid in understanding population fluctuations without treatments and wildlife responses to the research treatments.

Birds—From 1989 to 1991, the relations of breeding birds to snag densities were studied in interior ponderosa pine forests in northeastern California, including BMEF. Approximately 100 species of birds were detected during this study with the majority of species being detected at least once at one of the BMEF sites *(appendix D)*. The most commonly detected birds were (order is phylogenetic not in order of abundance): Hairy Woodpecker (*Picoides villosus)*, White-headed Woodpecker (*Picoides albolarvatus*), Northern Flicker (*Colaptes auratus*), Dusky Flycatcher (*Empidonax oberholseri*), Mountain Chickadee (*Parus gambeli*), Red-breasted Nuthatch (*Sitta canadensis*), White-breasted Nuthatch (*Sitta carolinensis*), Pygmy Nuthatch (*Sitta pygmaea*), Brown Creeper (*Certhia americana*), American Robin (*Turdus migratorius*), Yellow-rumped Warbler (*Dendroica coronata*), Chipping Sparrow (*Spizella passerina*), and Dark-eyed Junco (*Junco hyemalis*).

In 1995, a series of point count stations were established and breeding bird counts made in each of the experimental units (*fig. 22*). To date, 72 species have been encountered. A baseline of density and diversity of these species has been assessed. In addition, detailed data collection on foraging microhabitat of some 20 core species has been gathered. Together, the data on avian abundance and diversity with microhabitat use patterns will provide the baseline for

Figure 22—Breeding birds were counted, including this incubating Townsend's solitaire (*Myadestes townsendii*), on each study unit.

comparisons and contrasts with the forest manipulations underway. The result will be a novel and important data set on how the avian assemblage responds to interior ponderosa pine forest structure attributes.

Snags (standing dead trees) are important habitat for wildlife, especially cavity-nesting birds. Larger diameter snags seem to be more desirable than smaller ones. Recent work in interior ponderosa pine forests confirm these relationships but also indicate that many apparently suitable snags are not as desirable for nest sites as others. Snag demography has been examined on eight units beginning in 1989 and is expected to continue in future years. Snag recruitment and loss and change in characteristics caused by deterioration has been documented. This information provides insights into the number of snags expected in interior ponderosa pine forests through time and the characteristics of recruitment and loss. Currently, the major cause of tree mortality is bark beetles, and we initiated an experiment in 1993 to evaluate the differences between bark beetle-killed trees and girdled trees.

Small Mammals (Rodents)—Beginning in 1992, small mammal populations were sampled by using Sherman XLK[1] live traps and, to a lesser extent, pitfall and larger mesh Tomahawk live traps. Resulting information provided a better understanding of the small mammals found within BMEF, information about the patterns of movement of animals on study units (*fig. 23*), a baseline for the ecosystem management experiment, and information to develop hypotheses relative to the responses of small mammals to the experimental treatments. Small mammal species detected in the forested plots to date include (in phylogenetic order): Trowbridge's shrew (*Sorex trowbridgii*), yellow-pine chipmunk (*Tamias amoenus*), Townsend's chipmunk (Shadow) (*Tamias townsendii*), lodgepole chipmunk (*Tamias speciosus*), Belding's ground squirrel (*Spermophilus beldingi*), California ground squirrel (*Spermophilus beecheyi*), golden-mantled ground squirrel (*Spermophilus lateralis*), western gray squirrel (*Sciurus griseus*), Douglas' squirrel (*Tamiasciurus douglasii*), northern flying squirrel (*Glaucomys sabrinus*), mountain pocket gopher (Thomomys monticola), deer mouse (*Peromyscus maniculatus*), bushy-tailed woodrat (*Neotoma cinerea*), western red-backed vole (*Clethrionomys californicus*), montane vole (*Microtus montanus*), and long-tailed vole (*Microtus longicaudus*).

[1] Trade names and commercial products are mentioned solely for information. No endorsement by the U.S. Department of Agriculture is implied.

Figure 23—Baseline information was obtained on the movement patterns of small mammals. Golden-mantled ground squirrels were the most numerous of the animals studied.

Bats—A survey of the bat fauna within BMEF was conducted in 1995 (Philpott and Petersen 1995). Bats were sampled using acoustical and mist-netting methods at four sites within the BMEF and two sites at lower elevations outside the BMEF. The six sampling sites were selected by evaluating potential for bat activity through presence of habitat characteristics, such as water and riparian vegetation, and determination of bat presence through acoustical sampling. Nine sites within the BMEF were considered to be potential sites to conduct mist netting for bats because of the presence of water and riparian vegetation. Subsequent acoustical sampling determined that five of the sites had insufficient bat activity to warrant mist net installation and sampling and acoustical sampling. Sampling at sites was conducted for a minimum of 4.5 hours each night from approximately 1230 and 0100 hours. Thirteen of California's 23 species of bats were predicted to be found in the vicinity of the BMEF. Eight bat species using the BMEF as a flight corridor or foraging area were detected in this survey. Thirty-three bats were captured during the survey: 26 (79 percent) were males and 24 (72 percent) were adults; the remainder were juveniles (7 to 21 percent) or of unknown age (2 to 6 percent). The bat fauna was dominated by long-eared myotis (*Myotis evotis*) (15 to 45 percent), with fewer numbers of little brown myotis (*Myotis lucifugus*), long-legged myotis (*Myotis volans*), California myotis (*Myotis californicus*), small-footed myotis (*Myotis ciliolabrum*), big brown bat (*Eptesicus fuscus*), silver-haired bat (*Lasionycteris noctivagans*), and pallid bat (*Antrozous pallidus*).

Herpetofauna—Amphibians and reptiles have been studied by using 5-gallon pitfall traps and serendipitous detections. Information collected provides insights into animals found on the BMEF and their presence on study units. Amphibians and lizards detected at BMEF to date include (in phylogenetic order): Great Basin spadefoot (*Scaphiopus intermontanus*), western toad (*Bufo boreas*), Pacific treefrog (*Hyla (Pseudacris) regilla*), western fence lizard (*Sceloporus occidentalis*), and sagebrush lizard (*Sceloporus graciosus*).

Grazing Science

The maintenance of complex understory vegetation is critical to maintaining biological diversity. Plant communities at the BMEF evolved with large herbivores (deer and pronghorn) and have been grazed by cattle and sheep for decades. The effects of grazing on plant communities need to be evaluated in terms of plant species diversity, plant abundance, and plant species development. The effects of grazing on soil need to be evaluated in terms of nutrient cycling, compaction, and erosion.

Little is known about the effects of grazing on multi-layered tree, shrub, and herb communities where livestock forage preference certainly varies seasonally depending on grazing intensity. Although there are many complex mechanisms acting to create mosaics of trees, shrubs, and herbs in the interior pine / antelope bitterbrush / Idaho fescue association, accurate plant biodiversity responses of sites to forest management, prescribed fire, and grazing intensity would contribute to an understanding of grazing effects in this ecosystem. The array of replicated treatments coupled with an accurate measure of grazing intensity for the cattle grazing treatments would allow development of predictive models for grazing effects in this ecosystem. The opportunity to investigate ecosystem responses, especially the presence and abundance of small mammals, reptiles and amphibians, to cattle grazing in a replicated field design is unique.

Conclusions

The interdisciplinary science team studying the forest structural complexity and ecosystem responses to disturbances at the BMEF has built a solid foundation for continued progress. The uniqueness of the research project is that all disciplines participated from the beginning in designing the study and, as a result, all participants had equal ownership. Also, participation is based on the interest and time availability of the scientists rather than assignment to the team by supervisors. Salary support for Forest Service scientists and consistent base funding were critical early components.

This dedicated science team is willing to compromise to ensure the success of the overall project, and is committed to its long-term success. Silviculturists took the lead in organizing the project because they are the experts in vegetation management and because silviculture integrates the other disciplines. The team was quick to recognize that an independent team coordinator with meeting-facilitation skills, a knowledge of NEPA and Forest Service contracting procedures, and without a history of being affiliated with one discipline at PSW was an essential position. The science team also considered that a full-time sale administrator during the harvest period was essential to ensure that the prescribed vegetation treatments would be applied with accuracy and uniformity.

In spite of criticism that the low structural diversity treatment was an obsolete management practice, the science team insisted on selecting it as an extreme treatment to create strong contrasts that should elicit significant responses. Combining treatments in a factorial way to examine all possible interactions was considered important, as well.

The interdisciplinary study on the Blacks Mountain Experimental Forest is designed, in part, to restore late seral stands to conditions perceived as common before differential cutting of pine and fire exclusion in the eastside pine type. We are attempting within a few years to reverse processes that took decades to develop. Whether or not we are successful in sustaining uneven-aged ponderosa pine stands, our interdisciplinary study should provide insights into how eastside pine ecosystems have been altered by the loss of late seral structures.

How To Get Involved

New team members are always welcome. Because treatments are largely in place, more university faculty are expressing interest in BMEF and the experimental units for graduate student studies. Within the past year the team has received proposals from graduate students in entomology and ornithology.

For those interested in participating, a written research proposal should be submitted to: Blacks Mountain Interdisciplinary Team Coordinator, Silviculture Laboratory, Pacific Southwest Research Station, 2400 Washington Ave., Redding, CA 96001. The coordinator will circulate the proposal among team members for information and critique and schedule its presentation at the next team meeting for a formal decision.

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Appendix A—Treatment Descriptions

I. Overall Objectives

A. Compare the responses of a variety of forest attributes in twelve 250-acre treatment areas to the following items:

1. The creation of two distinct forest structures: high vertical structural diversity, and low vertical structural diversity.

2. The disturbances of grazing compared to no grazing, and burning compared to no burning.

B. Maintain the integrity of 10 acres in each of two contrasting 1930's treatment areas (control and heavy Forest Service Method-of-Cutting plots) in the plots designated for high structural diversity treatments (plots 38, 41, 42, and 47).

II. Treatments

A. Harvest treatment: Descriptions for each treatment are described in full and contain the following:

1. Objectives of and complete strategy for each treatment, including opening, snag, and dense clump criteria; slash treatment methods; regeneration and thinning methods and timing.

2. Objectives for each tree layer (high structural diversity, only).

B. Prescribed fire treatment: Each of the twelve treatment plots will be split into "burn" and "no burn" fire treatments. Initially, the fire treatments were to be initiated with a three-stage fire re-introduction, to facilitate retention of the large, old trees on the "burn" half of the treatment plots. On September 30, 1996 the Pacific Southwest Research Station and Lassen National Forest personnel met to evaluate the effects of the timber harvest treatments and revise the prescribed fire treatment. The results of some tests to determine the best method and timing of fire re-introduction to retain the large, old trees and an assessment of the slash left from the timber harvest treatments necessitated a revision of the fire re-introduction plan.

1. Optimally, fire will be re-introduced in the fall after the completion of timber harvest in each replication. Fire lines will be constructed anytime after harvest activities and prior to ignition. Use of power equipment to establish the line will be permissible. As timber harvesting will be completed in the first replication in the fall of 1996, fire will be re-introduced in the fall of 1997. Retention of all standing snags will be encouraged by constructing a handline around each snag before fire re-introduction in the fall.

2. If the fall burning window is too narrow to allow completion of fire re-introduction for an entire replication in the same season, then the entire replication must be burned the next fall.

C. Grazing treatment: Conducted on three of the six high diversity plots and three of the six low diversity plots.

1. The grazing treatment will alternate annually between early and late season grazing.

2. The six treatment plots not grazed will be fenced to exclude cattle. Fences will consist of 3 strands of barbed wire and 1 strand of smooth wire on the bottom. Fence posts will be metal.

3. Grazed plots will be fenced after harvest treatment, but BEFORE the burning treatment.

III. Treatment Prescriptions

A. High structural diversity: The objective is to create and / or maintain two or more tree layers throughout the six high structural diversity treatment areas, while meeting snag, dense clump, opening criteria and slash methods.

1. Snag criteria: Retain all existing snags and tally by the following designations: hard versus soft, species, and stem diameter ranges: > 24 inches dbh, 15 inches – 24 inches dbh, and < 15 inches dbh.

2. Dense clump criteria: Maintain 10 to 15 percent of the area in unthinned dense clumps of Layer 3 and 4 trees. These clumps should have minimal leader growth and crown differentiation (most stagnate). The maximum size of a dense clump is usually 2 acres, and minimum size is 0.25 acre.

3. Opening criteria: Create and / or maintain 10 to 15 percent of the area in openings no less than 0.25 acre and no more than 2 acres in size, with a minimum dimension of 100 feet.

4. Slash criteria: Cut down all damaged trees. Harvest created slash will be treated in the burn split by the re-introduction of fire. Harvest created slash will not be treated in the unburned split, unless site preparation (handpiling slash and burning handpiles) is required for planting.

5. Tree layer objectives:

a. Maintain as many Layer 1a pine for a 50-year period as possible by providing adequate survival space for each, without reducing the number of these or Layer 1b pine trees by more than 10 percent. Remove all Layer 1 fir and cedar and Layer 2 through Layer 4 trees within twice the dripline or 33 feet (whichever is greater) of any Layer 1a and 1b pine trees, except retain one replacement tree for each Layer 1a pine that meets leave tree criteria. Priority for this replacement tree is pine Layers 1b, 2, and 3.

b. Reduce the probability of insect-caused mortality for Layer 1a and Layer 1b pine trees. Mark any "High and Very High Risk" Layer 1a and Layer 1b trees (using Salmon and Bongberg [1942] Risk Rating) that have < 25 percent Live Crown Ratio and are within 20 feet of any other Layer 1a or lb trees that are NOT "High and Very High Risk."

If all Layer 1a and 1b trees within 20 feet of each other are "High and/or Very High Risk," do NOT exceed 10 percent removal in any single aggregation of these trees. Remove only the worst of the worst. Do NOT designate trees for removal > 36 inch dbh. Retain remaining "High and/or Very High Risk" trees for development of future snags.

Evaluate snag status in 10 years and develop snag objectives for the remaining 40 years of the study.

c. Reduce the probability of insect caused mortality for Layer 1 fir trees and increase the proportion of pine snags created during the next decade.

Remove any white fir that meets any one of the following criteria (outlined in the Eagle Lake Ranger District white fir salvage marking guidelines):

- Pitch streamers visible on three-fourths of the bole circumference.
- Bark beetle frass visible on three-fourths of the bole circumference.
- The top 10 percent or more of the crown has begun to fade (from green to yellow or brown).

d. Encourage Layer 2 and 3 trees to assume Layer 1 tree characteristics between 50 and 100 years from now. Using leave tree criteria, thin from below to create adequate growing space for 20 years. Adequate growing space is an area that provides a minimum of 10 ft and a maximum of 15 ft between crowns of Layer 2 trees and approximately 15 ft between boles of Layer 3 trees.

6. Regeneration and thinning strategy:

- If opening percentage (15 percent) or opening size (2 acres) is exceeded, evaluate for planting.
- If less than 15 percent of each treatment area is in openings less than 2 acres in size, do nothing.
- If more than 15 percent of each treatment area is in openings, or if more than 10 percent is in openings greater than 2 acres in size and with a minimum dimension of 100 ft, and if commercial forest land (capable of growing 20 ft^3/acre/year), plant excess to meet opening criteria.
- If more than 15 percent of each burned split or 5 percent of each unburned split requires planting, proceed with the following:
  - Prepare site for planting by handpiling slash and burning handpiles, and scalping organic matter.

- Plant 90 percent 1-0 containerized ponderosa pine, 10 percent 1-0 containerized Jeffrey pine at the rate of 300 trees per acre or 12 x 12 ft spacing.
- Evaluate for precommercial thinning at 20 years.
- Thin if space between crowns is less than 5 ft. Create a minimum space between crowns of 5 ft and maximum space between crowns of 10 ft.
- Evaluate for commercial thinning at 40 and 60 years.
- Thin if space between crowns is less than 10 ft. Create a minimum space between crowns of 10 ft and a maximum space between crowns of 15 ft.
- If original planted opening was greater than 2 acres, thin to 60 by 60 ft spacing and underplant with 90 percent 1-0 containerized ponderosa pine, 10 percent 1-0 containerized Jeffrey pine at the rate of 300 trees per acre, or 12 x 12 ft spacing.

"Special Case": In the "Clearcut Method-of-Cutting plot" in unit 42 (plot plus associated buffer totaling 30 acres), the following prescription applies:

- Maintain 10 to 15 percent (3 to 4 acres) of the area in dense clumps of Layer 4 trees. Maximum dense clump size is 2 acres.
- Thin 10 to 15 percent (3 to 4 acres) of the area in Layer 2 trees to maximize growth of remaining trees for 20 years (use previously described thinning guidelines). Maximum size for these patches is 2 acres.
- Create two openings, 1.5 to 2 acres each, on commercial forest land, to be planted. Priority locations for these openings are areas of Layer 4, then Layer 3 trees. Plant with 90 percent 1-0 containerized ponderosa pine, 10 percent 1-0 containerized Jeffrey pine at the rate of 300 trees per acre or 12 x 12 ft spacing.
- In the remaining 60 to 70 percent of the area (18-20 acres), thin from below to an average spacing of 60 ft. Use leave tree criteria, giving preference to Layer 1a, 1b, 2, 3, then 4.
- Prepare site for planting by hand piling slash, burning handpiles, and locally scalping organic matter.
- Underplant with 90 percent 1-0 containerized ponderosa pine, 10 percent 1-0 containerized Jeffrey pine at the rate of 300 trees per acre or 12 x 12 ft spacing.
- Evaluate for precommercial thinning at 20 years. Thin if space between crowns is less than 5 ft. Create a minimum space between crowns of 5 ft and a maximum space between crowns of 10 ft.
- At 30 years, initiate the development of a third layer in about 50 percent of this area (9 to 10 acres). Thin from below to 40 by 40 ft spacing.
- Handpile and burn slash.
- Prepare site for planting by scalping the organic matter.
- Underplant with 90 percent 1-0 containerized ponderosa pine, 10 percent 1-0 containerized Jeffrey pine at the rate of 300 trees per acre or 12 x 12 ft spacing.

- Evaluate the remaining area for commercial thinning at 40 years. Thin if space between crowns is less than 10 ft. Create a minimum space between crowns of 10 ft and a maximum space between crowns of 15 ft.

B. Low Structural Diversity: The objectives are to simplify the forest tree structure, maximize tree growth for a 20 year period, and strive toward continuous forest cover, while meeting snag, slash, and opening criteria.

Remove all Layer 1, 1a and 1b trees, except those needed for recruitment to meet snag criteria. Thin all remaining tree layers from below, including doghair clumps. Utilize the desirable leave tree characteristics and spacing guidelines when selecting trees to be left. Maximize the removal and utilization of biomass.

1. Snag criteria: Leave or create an average of 1.5 snags per acre.

- Favor snags > 23 inches dbh.
- Favor pine, cedar, then fir snags.
- Favor hard snags over soft snags.
- Remove excess snags that are feasible to remove.

If snag criteria cannot be met over 20-acre parcels, designate recruitment trees:

- Favor trees > 23 inches dbh.
- Favor pine, cedar, then fir snags.
- Favor low value trees (i.e., cull).
- Wait 5 years after harvest activities before creating snags from these recruitment trees.

2. Slash criteria: Utilize (biomass/chips) tops and limbs resulting from thinning Layers 2 to 4 trees. Maintain existing down logs. Cut down all damaged trees. Handpile (in unburned split only) and burn slash where needed to prepare the site for planting (see opening criteria).

We estimate 10 percent of unburned split will require site preparation and planting.

3. Opening criteria: Minimize the number and size of openings by sacrificing spacing where necessary. An opening is at least 2 acres with a minimum dimension of 100 ft and contains no more than 50 trees per acre. If openings are created, especially after fire re-introduction, fall, limb, buck, and handpile the remaining trees. Burn the handpiles. We estimate that 30 percent of the burn split, and 15 percent of the unburned split will be openings.

4. Regeneration and thinning strategy:

- Prepare the openings for planting by scalping organic matter.
- Plant 90 percent 1-0 containerized ponderosa pine and 10 percent 1-0 Jeffrey pine at the rate of 300 trees per acre or 12 x 12 ft spacing. Most openings will occur in the burn split where the number of Layer 1 trees removed exceeds 15 trees per acre, because there are few Layer 2 to 4 trees in these areas, and the large limbs and crowns of the Layer 1 trees will damage the smaller trees when they are felled.

- Evaluate for precommercial thinning at 20 years. Thin if space between crowns is less than 5 ft. Create a minimum space between crowns of 5 ft and a maximum space between crowns of 10 ft.
- Evaluate for commercial thinning at 40 and 60 years. Thin if space between crowns is less than 10 ft.

IV. Harvest Treatment Prescription and Implementation Guidelines

Definitions apply to both the high and low structural diversity treatments:

A. Tree Definitions:

- Layer 1a (pine)—These trees are old, have very platey yellow / cinnamon bark color, flattened tops, and are usually taller than 80 ft.
- Layer 1b (pine)—These trees are younger than Layer 1a trees, their platey bark is beginning to form, and their crowns are more full and not so flat on top as 1a trees.
- Layer 1 (fir and cedar)—These trees are older than 175 years, and are taller than 80 ft.
- Layer 2—The crowns of these trees are full, pointed, and the live crown ratio is usually greater than 50 percent. The trees range in height from 40 to 100 ft, and the pine bark is without characteristic plates.
- Layer 3—These trees have less live crown ratio than Layer 2, and they range in height from 20 to 60 ft.
- Layer 4—These trees are less than 20 ft tall, and they are usually found in dense clumps.

B. Desirable Leave Tree Characteristics:

- Greater than 40 percent live crown ratio.
- Greater than 4 inches leader growth.
- Free of insects, disease, and mechanical damage.
- Species preference: pine, cedar, fir.

C. Spacing Guidelines:

- Layer 1b pine, Layer 1 fir and cedar, and all Layer 2 trees: Usually, leave no less than 10 ft and no more than 15 ft between crowns.
- Layers 3 and 4 trees: Leave about 15 ft between tree boles.

D. Soils Standards: Motorized equipment will not be operated off the designated skid trails when the soil moisture is sufficient to permit a sample from the wettest part of the 3 to 10 inch soil depth zone to be molded by hand compression. If the compressed soil will hold its shape (not shatter) when tossed up and down in the hand, it is too wet. Also, all skidding operations will cease on designated skid trails when the potential for puddling exists. Soil moisture sufficient to restrict operations is likely before June 15 and after late September to October, depending on amount of spring precipitation and when fall rains wet the soil. Equipment exerting more than 6.5 psi will not be permitted to operate off the designated skid trails at any time.

Appendix B

Memorandum of Understanding

between
PACIFIC SOUTHWEST RESEARCH STATION
FOREST SERVICE, UNITED STATES DEPARTMENT OF AGRICULTURE
and
LASSEN NATIONAL FOREST
FOREST SERVICE, UNITED STATES DEPARTMENT OF AGRICULTURE
for

The design, development, and implementation of interdisciplinary research, to provide information regarding the effects of different management strategies on biodiversity and sustainable productivity.

This MEMORANDUM, made and entered into the 30th day of October, 1992, by and between the Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, hereinafter referred to as the Station, and the Lassen National Forest, Pacific Southwest Region, Forest Service, U.S. Department of Agriculture, hereinafter referred to as the Lassen Forest,

WITNESSETH:

WHEREAS, the Station is responsible for and conducts a program of forest research of use and value to land managers and dependent industries; and is active in the development and dissemination of scientific information and technology; and

WHEREAS, the Lassen Forest is responsible for the management of National Forest Lands under its jurisdiction according to the policies and regulations of the Forest Service, as specified in Federal Law; and

WHEREAS, the Station's Forest and Wildland Research emphasis area includes responsibilities for investigations of the impacts of both human induced and natural disturbances on biodiversity and long-term productivity; and

WHEREAS, both parties have the common objective of promoting and facilitating implementation of ecosystem research and management; and

WHEREAS, it is to the distinct advantage of both parties to create and expand the cooperative partnership described in this Memorandum.

NOW, THEREFORE, in consideration of the above premises, the parties hereto agree as follows:

I. Purpose

The purpose of this memorandum is to establish the basis for a partnership of people, organizations, and agencies with the common goal to implement the intent and spirit of fully integrated forest ecosystem research and management. In order to achieve this goal, it will be necessary to focus interest, activities, and resources on the difficult and complex problem of understanding the consequences of disturbances on forest attributes and processes. The primary objective of this partnership will be to develop and implement a large-scale, long-term interdisciplinary research project that will provide information necessary to evaluate ecosystem management activities at a scale, both spatially and temporally, heretofore not attempted.

II. Definition of the Problem and Background

The Forest Service is in a time of transition to a new conceptual basis for forest land management, as is all public and private forestry.

There are many reasons for the Forest Service to make this change. High on the list of reasons are the findings from recent research, which show the need to understand and manage the wildlands for the ecological components and their interactions.

The elements of this change in approach are outlined in the Forest Service's commitment to ecosystem management, which is reflected in the Forest Service Chief's June 4, 1992 memo and the Forest and Wildland Ecosystem Research emphasis area in the Station's Strategic Plan.

However the approach is described, it is clear that forest management will now be judged on the degree to which the individual project will contribute to the effects of other projects regarding biological diversity (including wildlife, plant, and genetic) and sustained productivity at both stand and landscape levels.

Understanding ecosystem interactions and processes and projecting consequences of disturbances is an extraordinary task. The task requires an integration of data, science, practice, management experience, and art to a degree—and on spatial and temporal scales—not before attempted. Integrated information to correctly evaluate these consequences currently does not exist.

In order to implement research at spatial scales large enough to have a high probability of detecting response differences of the many variables (especially wildlife), a large land base is needed. This land base must include contiguous areas of forest attributes associated with old-growth conditions, especially large old trees. Although much of the Blacks Mountain Experimental Forest, located on the Lassen Forest, has these attributes, the area is inadequate for this large-scale research project.

III. It Is Agreed by the Parties That:

1. Initial partners to this cooperation are the Station and the Lassen Forest. Additional partners will be sought, or welcomed, as appropriate to further the combined objectives. Potential partners include, but are not limited to: universities with particular skills and interests in the subject area, additional National Forests, private industry, and State organizations.

2. A steering committee will be formed for the purpose of maintaining oversight and providing coordination of efforts. One or more representative(s) of each participating organization will serve on the steering committee. This committee will meet at least annually to evaluate progress of the work, resolve difficulties, identify new areas of cooperation and create a yearly work plan.

The committee will initially be composed of the Station Director, Lassen Forest Supervisor, representatives of the Redding Silviculture Lab and the Eagle Lake District Ranger. Additional members will be added, as deemed necessary by the committee.

Chairmanship of the committee will alternate, on an annual basis, between the Station Director and the Lassen Forest Supervisor, unless otherwise determined by the committee.

Attachments to this Memorandum or separate Supplements to this Memorandum will be developed by the steering committee for the allocation of resources, activities, laboratories, buildings, office space, other facilities, and programs considered by the agreeing parties to have mutual interest and benefit, and these agreements will be an integral part of this Memorandum (see Attachment A).

3. The Lassen Forest agrees the Station will have administrative control of two separate forest areas, outside Blacks Mountain Experimental Forest. This agreement shall be binding for a period of ten years, at which time this agreement will be evaluated for extension.

4. All parties to this Memorandum, including those who later join this partnership by adding their signatures to this Memorandum, agree to actively contribute to the development and promotion of the capacity to understand forest ecosystems at both stand and landscape scales over time. The interests, responsibilities, and contributions of each partner will be coordinated and guided by a steering committee created under this Memorandum; and on the ground coordination will be ensured through the submission of a Notice of Intention and Progress Reports.

5. No member of, or delegate to, Congress or Resident Commissioner shall be admitted to any share or part of this Agreement, or to any benefit that may arise therefore; but this provision shall not be construed to extend to this Agreement if made with a corporation for its general benefit.

6. Nothing herein shall be considered as obligating the Forest Service to expend or as involving the United States in any contract or other obligation for the future payment of money in excess of appropriations authorized by law and administratively allocated for this work.

7. This Memorandum may be amended at any time by written consent of the parties hereto. Unless so terminated by written agreement of the parties, this Memorandum will remain in force until September 30, 2002.

IN WITNESS WHEREOF, the parties hereto have executed this Memorandum of Understanding as of the date first written above.

PACIFIC SOUTHWEST RESEARCH STATION
FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

By **/s/ Philip S. Aune**
Name (for) BARBARA C. WEBER
Title: Station Director

LASSEN NATIONAL FOREST
PACIFIC SOUTHWEST REGION
FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

By **/s/ Leonard Atencio**
Name LEONARD ATENCIO
Title: Forest Supervisor

Memorandum of Understanding

Attachment A

The Station will:

a. Develop the Treatment Descriptions
b. Develop the Silvicultural Prescriptions
c. Develop the Marking Guidelines
d. Draft a Project Initiation Letter and News Release for Public Involvement
e. Draft a Memorandum of Understanding, to include
    Tentative Schedule
    Protection Needs (fire, fuelwood)
    Land Allocation Commitment for Satellite Plots
    Discussion regarding activities adjacent to Satellite Plots
    Grazing Scheme
    Fencing/Maintenance
f. Participate in Public Involvement Meetings
g. Cooperate in the Analysis of Public Comments
h. Participate in Development of SAI Plan
I. Participate in Development of Special “C” provisions
j. Assist in Sale Administration
k. Responsible Official for PSW (Bill Oliver) will co-sign the FONSI/DN.

The Eagle Lake Ranger District will:

a. Implement the NEPA Process
    Conduct/Oversee Field Surveys for Environmental Reports
    Develop Environmental Resource Reports
    Conduct Public Involvement
    Analyze Public Comments
    Draft Environmental Document
    Sign the Decision Notice
b. Prepare the Timber Sales
    Designate Timber
    Prepare Maps
c. Develop the Appraisal and Contract
    Prepare the Special “C” Clauses
    Prepare the SAI Plan
d. Administer the Timber Sale Contract
e. Develop and Administer the Post Harvest Activities Contracts
f. Cooperate on Prescribed Fire
    Develop Burn Plans
    Assist during Implementation
g. Initiate cooperative agreements with Allotment Permittee
    Facilitate implementation of grazing treatment
h. Responsible for Protection and Law Enforcement
I. Responsible Official for L.F. (Robert Andrews) will co-sign the FONSI/DN

Timeframes (Critical Path)

Collect Baseline Data Wildlife, Vegetation	Summer 1992 ≥ 1994
Field Identify Plot Boundaries	Summer 1992

Locate/Monument Permanent Plot Centers	Summer 1992 ≥ 1994
Begin NEPA field work	Summer 1993
Archeological Survey	
Wildlife	
Owl Survey	
Browse Species and Use	
Goshawk Survey	
Sensitive Plant Survey	
Silvicultural Prescriptions (Treatment Descriptions)	
Develop Marking Guidelines	Winter 1992
Develop cooperative grazing plan	Summer 1993
Begin Public Involvement	Spring > 1993
Write NEPA Reports	Winter 1993
ARR	
BE	
CEA (Owl, Watershed)	
Fuels Plan	
Transportation Plan	
Develop Sale Area Improvement Plan	Spring 1994
Prepare Environmental Analysis	Spring 1994
Prepare Timber Sales	Summer 1994
Develop and get Approval of Special "C" Provisions	Fall 1994
Develop Appraisal and Contract	Fall 1994
Sell	Winter 1994
Treatment Implementation	
First Replication (4 plots) - Harvest	Summer 1996
Conduct Post Harvest Activities	Summer 1997
Conduct Prescribed Fire	Fall 1997
Install Grazing Fences	Summer 1997
Collect Response Data	Summer 1998
Second Replication - Harvest	Summer 1997
Conduct Post Harvest Activities	Summer 1998
Conduct Prescribed Fire	Fall 1999

Install Grazing Fences	Summer > 1998
Collect Response Data	Summer 2000
Third Replication - Harvest	Summer 1998
Conduct Post Harvest Activities	Summer 1999
Conduct Prescribed Fire	Fall 2000
Install Grazing Fences	Summer > 1999
Collect Response Data	Summer 2001

Supplement 1
to the
Memorandum of Understanding
between
PACIFIC SOUTHWEST RESEARCH STATION
FOREST SERVICE, UNITED STATES DEPARTMENT OF AGRICULTURE
and
LASSEN NATIONAL FOREST
FOREST SERVICE, UNITED STATES DEPARTMENT OF AGRICULTURE

WHEREAS, the parties hereto have executed a Memorandum of Understanding, effective October 30, 1992, authorizing and providing for cooperation in the design, development, and implementation of interdisciplinary research, to provide information regarding the effects of different management strategies on biodiversity and sustainable productivity; and

WHEREAS, the Memorandum provides that a Supplement be issued to describe the conditions of resource allocation of mutual benefit and interest to both parties, and

WHEREAS, the Lassen National Forest has received $99,000 for the Blacks Mountain Research Project in Fiscal Year 1993,

NOW THEREFORE, in consideration of the above premises, the parties hereto agree as follows:

I. The Station Shall:

Coordinate the establishment of a ground based reference system in the treatment plots and RNAs. The Station will cover all except $53,000 of the cost of establishing this reference system.

Coordinate the development and completion of a soil inventory of the treatment plots.

II. The Lassen National Forest Shall:

Contribute $53,000 toward the installation of the ground based reference system.

Contribute $10,000 toward the completion of the soil survey.

Fund and complete all NEPA field work in FY93, as agreed in Attachment A of the MOU.

I. It Is Mutually Agreed That:

The cost of the ground based reference system will be borne by both the Station and the Lassen National Forest, as stated above

IN WITNESS WHEREOF, the parties hereto have executed this Supplement 1, as of the last date written below.

PACIFIC SOUTHWEST RESEARCH STATION	LASSEN NATIONAL FOREST
FOREST SERVICE	PACIFIC SOUTHWEST REGION
U.S. DEPARTMENT OF AGRICULTURE	FOREST SERVICE
	U.S. DEPARTMENT OF AGRICULTURE
By **/s/ Philip S. Aune**	By **/s/ Leonard Atencio**
Name (for) BARBARA C. WEBER	Name LEONARD ATENCIO
Title: Station Director	Title: Forest Supervisor

Date____________________________

Appendix C—Tree Harvesting Operations

The Blacks Ecological Research Project Timber Sale (Contract No. 58-058668) consisted of 2,904 acres contained within 12 cutting units. Six of the cutting units were harvested to establish a high structural diversity stand, while the remaining six cutting units were harvested to establish a low structural diversity stand. The 12 units were harvested over a 3-year period, with one block (two high structural and two low structural) cut each year (Timber Sale Contract, CT6.316 Progress of Logging). The total volume of the sale was 33,310 mbf (thousand board feet), in which 12,757 mbf were sawlogs (trees with a dbh greater than or equal to 10 inches), 1,567 mbf were cull logs (dead trees with a dbh greater than or equal to 10 inches), and 132,032 green tons (18,986 mbf) of miscellaneous convertible products (MCP). MCP are trees processed into chips that can be burned as a fuel source during the production of electricity. MCP is also referred to as "biomass." MCP consists of trees with a dbh greater than or equal to 3 inches but less than 10 inches, their limbs and tops, plus the limbs and tops of trees with a dbh of 10 inches or greater but less than 16 inches (CT2.21 Utilization and Removal of Included Products). MCP and small sawlogs (dbh greater than or equal to 10 inches but less than 16 inches) were cut and skidded before cutting and removing the large sawlogs (dbh greater than or equal to 16 inches) by using mechanized harvesting equipment (CT6.42 Tractor Skidding Requirements).

Miscellaneous Convertible Products (MCP)—Harvesting of the first replication began on May 13, 1996. Skid road and landing locations were agreed upon before any operations started in an area. Skid roads were required to be spaced no closer than 150 feet from one another to minimize ground disturbance (CT6.42 Tractor Skidding Requirements). MCP was harvested with 3 Hydro-Ax 221 shears fitted with 28L tires to bring the ground pressure of the equipment down to the 6.5 psi required by CT6.42 to operate off designated skid roads. Trees cut by the shears were packed by the shears to or adjacent to the designated skid roads and piled into doodles (bundles of small trees). Trees with a dbh from 3 inches to 10 inches were thinned according to operator selection based on criteria stated in CT2.366 (Designation of Included Timber). A 10- to15-foot crown spacing was the desired distance between trees left after thinning. Doodles were skidded with both a D5 Caterpillar fitted with 32-inch wide tracks to meet the low ground pressure requirements and a Caterpillar 528 rubber tire skidder that did not meet the low ground pressure requirements. The D5 Caterpillar would skid the doodles that were piled off of the skid roads onto the skid roads where the Caterpillar 528, which was confined to operating only on designated skid roads, would then skid the doodles to the established landing. A Trelan 21 L chipper was used to chip the doodles. Production of 275 tons per day was achieved. This is about 11 to 12 van loads per day. Any refuse left on the landing after chipping was spread on the skid roads associated with that landing.

Small Sawlogs—The small sawlog (10- to 16-inches dbh) component of the stand was harvested after all the small biomass trees (3- to 10-inches dbh) were thinned and removed. Trees as large as 16 inches dbh were required to be skidded as whole trees (CT6.414). A Hydro-Ax 711E shear equipped with a circular sawhead was used to harvest the small sawlogs (*fig. 11*). The Hydro-Ax 711E shear and a Caterpillar 518 rubber tired skidder were fitted with 30.5L tires to meet the low ground pressure requirements (CT6.42) to allow operation off the designated skid roads. These equipment delivered the trees to the designated skid roads. A Timberjack 38A rubber tire skidder delivered the trees to the landing. The Timberjack skidder was confined to operating only on the designated skid roads because it did not meet the low ground pressure requirements. A CTR log processer delimbed the trees and cut them into log lengths at the landing. Limbs and tops were piled and stored. After the small log operation was completed on a landing, the Trelan 21L chipper returned to the landing to chip the limbs and tops. Processed logs were loaded on trucks with the use of a shovel loader. Shovel loaders were used to minimize the landing size needed for the operation. Production of 40 mbf per day was achieved during this phase of the operation.

Large Sawlogs and Cull Logs—The large sawtimber and cull logs (dbh equal to or greater than 16 inches) followed the operations for the harvest of MCP (small trees 3- to 10-inches dbh) and small sawlogs (10- to 16-inches dbh) as required by the contract (CT6.42). The operator was required to cut the large trees in two or more operations to prevent undue damage to the residual stand (CT6.42). Also, the trees were felled in specified directions for the same reason (CT6.411 Directional Felling). Six fallers were usually employed to fall the large timber. Fallers were required to limb and buck trees before they were skidded (CT6.41 Felling and Bucking, CT6.414 Limbing). Three 528 Caterpillar rubber tire skidders were used to remove the logs from the stand. All skidding equipment was confined to the designated skid roads for this phase of the harvest operations. Logs had to be end-lined to the skid roads before they could be skidded (CT6.42 Tractor Skidding Requirements). Logs were once again loaded onto trucks with the use of a shovel loader. Production of 150 mbf per day was achieved during this phase of the operation.

Post-Harvest Operations—Slash left on the landing after all phases of the harvest operations were completed was machine piled and later burned (CT6.7 Slash Treatment). All skid roads were crossed-ditched after use for erosion control (BT6.64). Landings were scarified to a 6-inch depth after use was completed (CT6.603 Soil Scarification). During all phases of the harvest operation, the stump surface of all cut trees 4 inches or larger in stump diameter were treated with a borate compound for the prevention of annosus root disease (CT6.415 Treatment of Stumps). Slash in the stand from the large sawlogs and damaged small trees marked by the Sale Administrator were required to be lopped to an 18-inch depth (CT6.7 Slash Treatment).

Productivity and Cost of Harvesting and Resulting Damage to Residual Trees—A harvesting study was conducted on the High Pine Block I that included two high diversity and two low diversity units in stands with a high proportion of pine. The study objectives were to quantify production rates and costs for the stump-to-mill activities for both the high and low structural diversity treatments, and to determine the damage to residual trees in each harvesting stage and activity associated with the two treatments (Hartsough 1998).

The low diversity treatment generated considerable revenue (about $2,600 per acre with the assumed product values) because of the large volume of larger sawlogs removed. The high diversity treatment resulted in a net loss per acre, because of the small volume of sawlogs, higher costs and lower values because of the small size of the sawlog trees, and the negative net value of the biomass. Productivity relationships were derived from time-motion study data so that incremental costs by diameter class could be estimated. The stump-to-mill cost for the smallest trees harvested—at more that $60 per bone dry ton (BDT)—far exceeded the assumed delivered value of $20 per BDT. Leaving these 4-inch dbh trees unharvested would reduce the net loss per acre by almost half, but would result in about 3 BDT per acre of additional material on site.

The study of harvesting damage found that 17 percent of the sampled leave trees suffered damage in the high structural diversity treatment. In the low structural diversity treatment 23 percent of the leave trees suffered damage.

Undamaged leave trees averaged 85 and 73 trees per acre for the high and low diversity treatments, respectively. Leave tree size had the biggest impact on damage; higher percentages of smaller trees were damaged than were larger trees. Felling damage frequency increased with the level of removals as well. Relationships were developed to estimate the probabilities of damage for a given size of tree during each harvesting stage and activity. These can be applied to a leave tree stand table to estimate roughly how many trees will survive undamaged, or to estimate how many trees must be initially selected as leave trees so that a desired number will remain undamaged after all harvesting activities. For example, with the assumed average conditions for the high diversity treatment, about 120 initial leave trees would result in 100 final leave trees per acre without major damage. The low diversity treatment is much rougher on leave trees because more volume is removed and the leave trees are smaller. The damage relationships indicate that about 180 initial leave trees are needed to give a final stand density of 100 undamaged trees per acre.

Appendix D—Plant and Animal Species

Plant Species, Blacks Mountain Experimental Forest, 1994 to present.

Species Code[1]	*Vernacular Name*	*Scientific Name*
ABCO	White fir	*Abies concolor*
ACMI	Common yarrow	*Achillea millefolium*
ACOC	Needlegrass	*Achnatherum occidentalis*
AGGL	Agoseris	*Agoseris glauca*
AGHE	Woodland agoseris	*Agoseris heterophylla*
AGRE	Spearleaf mountain dandelion	*Agoseris retrorsa*
AGUR	Nettle-leaved horsemint	*Agastache urticifolia*
ALCA	Sierra onion	*Allium campanulatum*
AMAL	Pacific serviceberry	*Amelanchier alnifolia (A. utahensis?)*
ANDI	Low pussytoes	*Antennaria dimorpha*
ANGE	Pearly everlasting	*Antennaria geyeri*
ANLU	Silvery-brown pussytoes	*Antennaria luzuloides*
ANRO	Rosy everlasting	*Antennaria rosea*
APAN	Bitter dogbane	*Apocynum androsaemifolium*
ARDI	Spreading rock cress	*Arabis divaricarpa*
ARLA	Arnica	*Arnica latifolia*
ARPA	Greenleaf manzanita	*Arctostaphylos patula*
ARSE	Sandwort	*Arenaria serphyllifolia*
ARTR	Basin big sagebrush	*Artemisia tridentata*
ASIN	Susanville milkvetch	*Astragalus inversus*
ASOC	Aster	*Aster occidentalis*
ASPU	Pursh’s locoweed	*Astragalus purshii*
ASWH	Locoweed	*Astragalus whitneyi*
BALS	Balsamroot	*Balsamorhiza* sp.
BASA	Arrowleaf balsamroot	*Balsamorhiza sagittata*
BERE	Oregon-grape	*Berberis repens*
BRIN	Smooth brome	*Bromus inermis*
BRMA	Mountain brome	*Bromus marginatus*
BRRA	Field mustard	*Brassica rapa*
BRTE	Cheat grass	*Bromus tectorum*
CAAP	Applegate’s paintbrush	*Castilleja applegatei*
CAFI	Short-grass sedge	*Carex filifolia* var. *erostrata*
CANE	Sedge	*Carex nebrascensis*
CARO	Ross’ sedge	*Carex rossii*
CASE	Bush chinquapin	*Castanopsis sempervirens*
CASP	Sedge	*Carex* sp.
CELE	Curlleaf mountain mahogany	*Cercocarpus ledifolius*
CEN	Star-thistle	*Centaurea* sp. (exotic)
CEPR	Squaw carpet	*Ceanothus prostratus*
CEVE	Snowbrush	*Ceanothus velutinus*
CHSP	Rabbitbrush	*Chrysothamnus* sp.
CHUM	Prince’s pine	*Chimaphila umbellata*
CHVI	Yellow rabbitbrush	*Chrysothamnus viscidiflorus*
CIAN	Anderson thistle	*Cirsium andersonii*
CIVU	Bull thistle	*Cirsium vulgare* (exotic)
CLPE	Miner’s lettuce	*Clatonia perfoliata*
CLRH	Forest clarkia	*Clarkia rhomboidea*
COAR	Bindweed	*Convolvulus arvensis*
COCO	California hazel	*Corylus cornuta* var. *californica*
COGR	Grand collomia	*Collomia grandiflora*

COMP	Composite family (including Asters, etc.)	
COPA	Maiden blue-eyed Mary	*Collinsia parviflora*
COTI	Tinctureplant	*Collinsia tinctoria*
CRAT	Slender hawksbeard	*Crepis atribarba*
CROC	Western hawksbeard	*Crepis occidentalis*
CRSP	Crypthantha	*Crypthantha* sp.
ELEL	Squirrel tail	*Elymus elymoides*
EPHA	Glandular willowherb	*Epilobium halleanum*
EPMI	Slender annual fireweed	*Epilobium minutum*
ERBL	Goldenbush	*Ericameria bloomeri*
ERIG	Fleabane daisy	*Erigeron bloomerii* var. *bloomeri*
ERLA	Common woollysunflower	*Eriophyllum lanatum*
ERNU	Naked buckwheat	*Eriogonum nudum*
ERUM	Sulfur buckwheat	*Eriogonum umbellatum*
FEID	Idaho fescue	*Festuca idahoensis*
FRAT	Spotted mountain bell	*Fritillaria atropurpurea*
FRPU	Yellow fritillary	*Fritillaria pudica*
GANU	Nuttall’s groundsmoke	*Gayophytum nuttallii*
GASP	Gayophytum	*Gayophytum* sp.
GECI	Prairie smoke	*Geum ciliatum*
GETR	Old man’s whiskers	*Geum triflorum*
GRAS	unidentified grass	
HIAL	Whiteflower hawkweed	*Hieracium albiflorum*
HYCA	Wollen-breeches	*Hydrophyllum capitatum*
IPAG	Scarlet gilia	*Ipomopsis aggregata*
KEGA	Kelloggia	*Kelloggia galioides*
KOMA	Junegrass	*Koeleria macrantha*
LAGL	White layia	*Layia glandulosa*
LICA	Stoneseed	*Lithospermum californicum*
LIDE	Incense-cedar	*Libocedrus decurrens*
LIHA	Harkenss linanthus	*Linanthus harknessii*
LOPU	Spanish clover	*Lotus purshianus*
LOSP	Lomatium	*Lomatium* sp.
LUAR	Spurred lupine	*Lupinus argenteus*
LUBR	Brewer’s lupine	*Lupinus breweri*
LULE	Lupine	*Lupinus leucophyllus*
LUSP	Lupine	*Lupinus* sp.
MEDI	Nodding microseris	*Microseris nutans*
MINU	Brittle sandwart	*Minuartia nuttallii*
MITO	Monkey flower	*Mimulus torreyi*
MOOD	Coyote mint	*Monardella odaritissima*
MOPE	Miner’s lettuce	*Montia perfoliata*
MOSS	moss	
NESP	Meadow nemophila	*Nemophila spatulata*
OSCH	Mountain sweetcicely	*Osmorhiza chilensis*
PABR	Western peony	*Paeonia brownii*
PEDE	Indian warrior	*Pedicularis densiflora*
PEGR	Slender penstemon	*Penstemon gracilentus*
PELA	Gay penstemon	*Penstemon laetus*
PENS	Penstemon sp.	*Penstemon* sp.
PESE	Pine lousewort	*Pedicularis semibarbata*
PESP	Showy penstemon	*Penstemon speciosus*
PHCO	Phlox	*Phlox condensata*
PHDI	Spreading phlox	*Phlox diffusa*
PHGR	Phlox	*Phlox gracilis*

PHLI	Phacelia	*Phacelia linearis*
PHMU	Changeable phacelia	*Phacelia mutabilis*
PODO	Knotweed	*Polygonum douglasii*
PIJE	Jeffrey pine	*Pinus jeffreyi*
PIPO	Ponderosa pine	*Pinus ponderosa*
PLNO	Popcornflower	*Plagiobothrys nothofulvus*
PODR	Drummond's cinquefoil	*Potentilla drummondii*
POGR	Cinquefoil	*Potentilla gracilis*
POMI	Cinquefoil	*Potentillia millefolia*
POPO	Knotweed	*Polygonum polygaloides*
POPR	Kentucky bluegrass	*Poa pratensis*
POSE	Bluegrass	*Poa secunda*
POSP	Bluegrass	*Poa* sp.
PREM	Bitter cherry	*Prunus emarginata*
PRSU	Sierra plum	*Prunus subcordata*
PRVI	Chokecherry	*Prunus virginiana*
PTAN	Pinedrops	*Pterospora andromedea*
PUTR	Antelope bitterbrush	*Purshia tridentata*
PYHI	Pyrrocoma	*Pyrrocoma hirta*
PYMI	Lesser wintergreen	*Pyrola minor*
PYPI	White-veined wintergreen	*Pyrola picta*
RICE	Wax current	*Ribes cereum*
RIRO	Sierra gooseberry	*Ribes roezlii*
ROWO	Interior rose	*Rosa woodsii*
RUAC	Sheep sorrell	*Rumex acetosella*
SCCA	California skullcap	*Scuetelloria californica*
SEAR	California butterweed	*Senecio aronicoides*
SEIN	Tower butterweed	*Senecio integerrimus*
SEOR	Spike-moss	*Selaginella oregana*
SIHY	Squirreltail	*Sitanion hystrix*
SOCA	Meadow goldenrod	*Solidago canadensis* ssp. *elongata*
SOOL	Common sow thistle	*Sonchus oleraceus*
STLA	Stephen's lettuce	*Stephanomeria lactucina*
STOC	Needlegrass	*Stipa occidentalis*
SYMO	Creeping snowberry	*Symphoricarpos mollis*
TRLO	Summer clover	*Trifolium longipes*
UNK	unknown	
VIPU	Mountain violet	*Viola purpurea*
WYMO	Mountain mule ears	*Wyethia mollis*
XXXX	Nothing	
ZIVE	Death camas	*Zigadenus venenosus*

[1]Hickman (1993)

Terrestrial Vertebrates, Blacks Mountain Experimental Forest, 1988-1995.[1]

Order	***Vernacular name***	***Scientific name***
	Class: Amphibia (Amphibians)	
Salientia (Frogs and toads)		
	Great Basin spadefoot	*Scaphiopus intermontanus*
	Western toad	*Bufo boreas*
	Pacific treefrog	*Hyla (Pseudacris) regilla*
	Class: Reptilia (Reptiles)	
Squamata (Lizards and Snakes)		
	Western fence lizard	*Sceloporus occidentalis*
	Sagebrush lizard	*Sceloporus graciosus*
	Western terrestrial garter snake	*Thamnophis (Nerodia) elegans*
	Class: Avies (Birds)	
Anseriformes (Ducks, and relatives)		
	Mallard	*Anas platyrhynchos*
Falconiformes (Vultures, hawks, and falcons)		
	Sharp-shinned hawk	*Accipiter striatus*
	Cooper's hawk	*Accipiter cooperi*
	Northern goshawk	*Accipiter gentilis*
	Red-tailed hawk	*Buteo jamaicensis*
Galliformes (Pheasants, and relatives)		
	Mountain quail	*Oreortyx pictus*
Columbiformes (Pigeons and doves)		
	Band-tailed pigeon	*Columba fasciata*
	Mourning dove	*Zenaida macroura*
Strigiformes (Owls)		
	Northern pygmy-owl	*Glaucidium gnoma*
	Spotted owl	*Strix occidentalis*
Caprimulgiformes (Goatsuckers and relatives)		
	Common nighthawk	*Chordeiles minor*
Apodiformes (Swifts and hummingbirds)		
	Calliope hummingbird	*Stellula calliope*

Piciformes
(Woodpeckers and relatives)

Red-naped sapsucker	*Sphyrapicus nuchalis*
Red-breasted sapsucker	*Sphyrapicus ruber*
Williamson's sapsucker	*Sphyrapicus thyroideus*
Downy woodpecker	*Picoides pubescens*
Hairy woodpecker	*Picoides villosus*
White-headed woodpecker	*Picoides albolarvatus*
Black-backed woodpecker	*Picoides arcticus*
Northern flicker	*Colaptes auratus*
Pileated woodpecker	*Dryocopus pileatus*

Passeriformes
(Perching birds)

Olive-sided flycatcher	*Contopus borealis*
Western wood-pewee	*Contopus sordidulus*
Hammond's flycatcher	*Empidonax hammondii*
Dusky flycatcher	*Empidonax oberholseri*
Gray flycatcher	*Empidonax wrightii*
Pacific-slope flycatcher	*Empidonax difficilis*
Horned lark	*Eremophila alpestris*
Barn swallow	*Hirundo rustica*
Steller's jay	*Cyanocitta stelleri*
Common raven	*Corvus corax*
Mountain chickadee	*Parus gambeli*
Red-breasted nuthatch	*Sitta canadensis*
White-breasted nuthatch	*Sitta carolinensis*
Pygmy nuthatch	*Sitta pygmaea*
Brown creeper	*Certhia americana*
Bewick's wren	*Thryomanes bewickii*
Golden-crowned kinglet	*Regulus satrapa*
Ruby-crowned kinglet	*Regulus calendula*
Mountain bluebird	*Sialia currucoides*
Townsend's solitaire	*Myadestes townsendi*
Hermit thrush	*Catharus guttatus*
American robin	*Turdus migratorius*
Varied thrush	*Ixoreus naevius*
Solitary vireo	*Vireo solitarius*
Warbling vireo	*Vireo gilvus*
Orange-crowned warbler	*Vermivora celata*
Yellow-rumped warbler	*Dendroica coronata*
Black-throated Gray warbler	*Dendroica nigrescens*
Townsend's warbler	*Dendroica townsendi*
Hermit warbler	*Dendroica occidentalis*
MacGillivray's warbler	*Oporornis tolmiei*
Wilson's warbler	*Wilsonia pusilla*
Western tanager	*Piranga ludoviciana*
Black-headed grosbeak	*Pheucticus melanocephalus*
Lazuli bunting	*Passerina amoena*
Green-tailed towhee	*Pipilo chlorurus*
Rufous-sided towhee	*Pipilo erythrophthalmus*
Chipping sparrow	*Spizella passerina*
Fox sparrow	*Passerella iliaca*
Golden-crowned sparrow	*Zonotrichia atricapilla*
White-crowned sparrow	*Zonotrichia leucophrys*
Dark-eyed junco	*Junco hyemalis*

Red-winged blackbird	*Agelaius phoeniceus*
Brewer's blackbird	*Euphagus cyanocephalus*
Brown-headed cowbird	*Molothrus ater*
Northern oriole	*Icterus galbula*
Purple finch	*Carpodacus purpureus*
Cassin's finch	*Carpodacus cassinii*
Red crossbill	*Loxia curvirostra*
Pine siskin	*Carduelis pinus*
Lesser goldfinch	*Carduelis psaltria*
Evening grosbeak	*Coccothraustes vespertinus*

Class: Mammalia (Mammals)

Insectivora
(Insectivores)

Trowbridge's shrew	*Sorex trowbridgii*
Broad-footed mole	*Scapanus latimanus*

Lagomorpha
(Rabbits, hares, and pikas)

Nuttall's (mountain) cottontail	*Sylvilagus nuttallii*
Snowshoe hare	*Lepus americanus*
Black-tailed (hare) jackrabbit	*Lepus californicus*

Rodentia
(Squirrels, rats, mice, and relatives)

Yellow-pine chipmunk	*Tamias amoenus*
Townsend's chipmunk (shadow)	*Tamias townsendii*
Lodgepole chipmunk	*Tamias speciosus*
Belding's ground squirrel	*Spermophilus beldingi*
California ground squirrel	*Spermophilus beecheyi*
Golden-mantled ground squirrel	*Spermophilus lateralis*
Western gray squirrel	*Sciurus griseus*
Douglas' squirrel	*Tamiasciurus douglasii*
Northern flying squirrel	*Glaucomys sabrinus*
Mountain pocket gopher	*Thomomys monticola*
Great Basin pocket mouse	*Perognathus parvus*
Dark kangaroo mouse	*Microdipodops megacephalus*

Cricetidae
(Native mice, rats, and voles)

Deer mouse	*Peromyscus maniculatus*
Dusky-footed woodrat	*Neotoma fuscipes*
Bushy-tailed woodrat	*Neotoma cinerea*
Western Red-backed vole	*Clethrionomys californicus*
Montane vole	*Microtus montanus*
Long-tailed vole	*Microtus longicaudus*

Carnivora
(Carnivores)

Coyote	*Canis latrans*
Black bear	*Ursus americanus*
Badger	*Taxidea taxus*
Bobcat	*Felis rufus*

Artiodactyla (Even-toed ungulates)	
Wapiti or elk	*Cervus elaphus*
Mule deer	*Odocoileus hemionus*
Pronghorn	*Antilocapra americana*

[1]Laudenslayer and others (1991).