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MT. TRUMBULL ECOSYSTEM RESTORATION PROJECT

Annual Report for the Year
October 1, 1996 to September 30, 1997



April 1997 scene of the first unit at Mt. Trumbull to be treated with a restoration prescription (96-1). Trees were thinned to restore presettlement forest structure, and the unit was prescribed burned in October, 1996.

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EXECUTIVE SUMMARY

Forest ecosystems in the Southwest are threatened by uncontrollable wildfires and insect outbreaks. Because of changes initiated by grazing, logging, and fire suppression, southwestern forests have become dense with stressed, slow growing trees. Forest floor fuel loadings have climbed to catastrophic levels, while the diverse herbaceous plant communities and the animals dependent upon them are being choked out of the ecosystem.

At Mt. Trumbull, a ponderosa pine and Gambel oak forest located on the Arizona Strip, researchers, land managers and wildlife managers are heading up a project to restore this forest to its pre Euro-American settlement conditions: open forest stands dominated by large, old trees above a diverse understory of native grasses and wildflowers, maintained by frequent, low-intensity fires. The Mt. Trumbull ecosystem restoration is a multidisciplinary project jointly sponsored by the Arizona Strip District Bureau of Land Management, Northern Arizona University and the Arizona Game and Fish Department.

The frequent fire regime (low intensity fires every 3-7 years) was interrupted upon Euro-American settlement by overgrazing of fine herbaceous fuels that carried the fire and later by active fire suppression. With no fires to thin the tree regeneration, dense stands of trees developed. By reducing tree densities of these young, "post-settlement" trees through mechanized thinning, researchers can recreate the structure of the presettlement forest across 4800 acres of the Mt. Trumbull landscape and then can safely reintroduce fire to resume its natural role. Putting fire back on the land reintstates an important ecological process that has been missing from this ecosystem for over 100 years.

Researchers have completed data collection on current forest density and age structure, herbaceous diversity and density, fuel loadings, as well as dendrochronological data to reconstruct what these forests looked like before fire exclusion. The project is now in the process of applying this knowledge to the landscape to reconstruct forest characteristics prior to disruption of the fire regime. Following the initial restoration treatments, researchers will continue to collect data to monitor post-restoration forest characteristics. These re-measurements allow researchers to monitor the results of initial activities and use this information to refine and improve subsequent prescriptions. Managing land with this iterative process of refining treatments by monitoring exemplifies adaptive ecosystem management.

In addition to vegetation characteristics, researchers are studying the effect of ponderosa pine restoration on arthropods, small mammals, birds and game animals dependent on this ecosystem. In 1997, data were collected on butterflies, Kaibab squirrels, lizards, snakes, bats and birds to determine current population characteristics. As the treatment continues, monitoring of these populations will continue to assess their response to restoration. This large, integrative study is possible only through the cooperation of land managing agencies and university researchers, and will result in an intense, comprehensive study of ecosystem restoration on a landscape scale.



A remnant of the open, old-growth ponderosa pine forest which once covered the Mt. Trumbull area. Researchers hope to restore these open stands to 4800 acres of the ponderosa pine forest at Mt. Trumbull.

INTRODUCTION

This document is the second annual report on the status of the southwestern ecological restoration project at Mt. Trumbull, Arizona. The Mt. Trumbull ecosystem restoration project is a multidisciplinary project jointly sponsored by the Arizona Strip District Bureau of Land Management, Northern Arizona University, and the Arizona Game and Fish Department. The project goal is adaptive ecosystem restoration of southwestern ponderosa pine ecosystems to their pre Euro-American settlement conditions: open forest stands dominated by large, old trees above a rich, diverse understory of native grasses and wildflowers, maintained by frequent, low-intensity fires.

This report will summarize Northern Arizona University's progress in the 1997 fiscal year on the project, including the 1997 research field season. It does not duplicate data presented in other interior reports. It does not duplicate data presented in other interior reports. For definitions of terms and research design, please refer to the 1996 Mt. Trumbull Ecosystem Restoration Project Annual Report. For preliminary analyses of data on ecosystem structure and composition, please refer to the Mt. Trumbull Ecosystem Restoration Project Progress Report (April 1997).

Research projects are organized into three groups in this report. These groups are not meant to be distinct from each other; data from all groups provide information and support for research projects in other groups. The first group is the landscape level research projects, including the monitoring plot project designed to evaluate the effects of the restoration on the Mt. Trumbull ecosystem. Projects following this heading are large-scale, and should help elucidate and determine ecosystem patterns. The second group is the vegetation response studies. This group includes projects studying specific vegetational responses to the restoration treatment, such as the herbaceous (grasses and flowers) response, the Gambel oak response, as well as projects looking at ponderosa pine community stability. The third group is the arthropod and mammal response. This group of projects examines taxonomic groups at higher trophic levels, including butterflies (arthropods), mammals and birds. By focussing on several specific groups within the ecosystem, we develop a better understanding of ecosystem structure and function. These studies developed by NAU researchers, when combined with the studies developed by BLM researchers, and the studies developed by Arizona Game and Fish researchers, provide the most intensive study of ecosystem functioning in an ecological restoration context to date.

Detailed sections on the ecosystem monitoring plot progress, the fire history studies, the passerine bird studies, and other ongoing and initial research projects follow. Because most of the data collected in the 1997 field season is still being analyzed, this document serves primarily to present a summary of work accomplished. Detailed analysis of the 1996 collected data is available in the April 1997 Mt. Trumbull Progress Report. Further results of data analysis will be included in subsequent annual reports.

1. LANDSCAPE ANALYSIS AND ECOSYSTEM PATTERNS:

Ecosystem Monitoring Plots

Long-term monitoring is essential to assess current conditions, reconstruct presettlement ecosystem structure, and evaluate the effects of restoration treatments. The 1997 field season resulted in the completion of the **pre-treatment** plot placement and data collection across the Mt. Trumbull landscape. A total of 216 permanent ecosystem monitoring plots are in place across approximately 4,800 acres of ponderosa pine/ Gambel oak forest. The plots are located on a 300-meter (984-ft) grid (e.g., there is 1 plot per 9 ha, or 22 acres), and are 0.1 hectare (0.25 acre) in size. Complete descriptions of plot methodology can be found in the 1996 Mt. Trumbull Annual Report. Briefly, variables measured on these plots provide data on tree density, tree regeneration, tree age structure, herbaceous density, herbaceous diversity, fuel loadings, canopy cover percentages and permanent photo points. Additional data collected on presettlement remnants (snags, dead and down trees, stumps and stump holes) allow us to reconstruct presettlement forest conditions.

Analyzed preliminary data is available for the 168 plots placed in 1996 (Mt. Trumbull Ecosystem Restoration Project Progress Report, April 1997). Data collected in 1997 will be processed and analyzed fall/ winter 1997 - 1998.

These permanently marked plots will be revisited after the restoration treatment of thinning and fire has been introduced onto the landscape. Identical variables will be remeasured at this time to monitor the effects of the restoration.

Status: Completed plot placement and pre-treatment assessment.

Year 3: Plots will be revisited as treated, see below.

Completion: Multi-year.

Post-Treatment Ecosystem Monitoring Plots

Forty-six acres of the Mt. Trumbull landscape were treated in 1996, allowing researchers to remeasure the 3 ecosystem monitoring plots that fell in the 46 acre unit. Identical variables were measured post-treatment as were measured pre-treatment. These data will be analyzed to assess changes in tree density (part of treatment), herbaceous density and diversity, fuel loadings and canopy cover due to the treatment. This information in turn will determine the progress towards the goal of restoring presettlement forest structure and function. Changes in the treatment procedure suggested by these data will be incorporated into the ongoing treatments at Mt. Trumbull.

Areas of the Mt. Trumbull landscape currently being treated will be remeasured when treatment is complete. Over the next 4-5 years, all units containing the 216 plots will be treated, and those plots remeasured. In addition to the initial post-treatment assessment, plots will continue to be monitored on periodic increments over time, to measure the effects of restoration on ecosystem structure and function over time.

Status: 3 plots remeasured.

Year 3: Plots in units treated in 1997 will be remeasured.

Completion: Multi-year.

Experimental Block Study

Experimental blocks for controlled testing of the effects of ecosystem restoration manipulations are an important complement of the landscape-scale sampling at Mt Trumbull. The experimental blocks have been established at a series of five controlled study sites. Each **block** consists of a nominal 80-acre area divided into two similar **units**. Treatments—(1) ecosystem restoration and (2) control—have been randomly assigned to each unit. Basic measurements at each experimental block include contemporary and presettlement (pre-1870) forest structure (species composition, size distribution, age distribution), current understory composition and density, canopy closure, fuel loading, and photographs. All measurements will be taken on permanently marked plots. In addition, the grid of permanent ecosystem monitoring plots and fire history studies will cross the experimental blocks. Analysis will be based on comparison of presettlement, contemporary, and post-treatment ecosystem characteristics using analysis of variance in a blocked experimental design. In addition to the basic measurements at all experimental blocks, collaboration with other researchers will be encouraged to investigate other ecological responses.

Considerations in plot selection include:

- *Five nominal 40-acre pairs (minimum experimental unit size = 20 acres)*
- *Simultaneous treatment (prepare as a package for environmental assessment and treatment contracts)*
- *Random assignment of treatments*
- *Relatively homogeneous within blocks*
- *Relatively diverse between blocks to represent a variety of ecosystem conditions at Mt Trumbull (range of forest types, soils, topography, elevation, and geographic distribution)*

All areas of the Mt Trumbull project were represented except the landscape-scale paired control and treatment area reserved for the passerine bird and other large-scale wildlife studies. Descriptions of the individual experimental blocks follow.

Experimental Block 1:

- *NW corner of S9T34NR8W, ELEV 6680'*
- *Lava/cinder soils*
- *Many living presettlement trees*
- *Potential for shrub studies, especially Amelanchier, Ribes, Artemisia*

Experimental Block 2:

- *NW corner of S8T34NR8W, ELEV 6880'*
- *PIPO/QUGA forest on basalt soils*
- *Typical of the early restoration units (located between 96-2 and 96-3)*

Experimental Block 3:

- *NW corner of S18T34NR8W, ELEV 7240-7600'*
- *PIPO/QUGA/RONE forest at highest treated elevation*
- *Large unit (≈ 100 acres)—could reserve a portion for other treatment testing (e.g., wilderness treatments)*

Experimental Block 4:

- *NE corner of SW corner of S1T34NR9W, ELEV 7000'*
- *Dense pole/sapling stand with very few living presettlement trees, close to old sawmill site*

Experimental Block 5:

- *N half of SW corner of S1T34NR9W, ELEV 6800'*
- *Substantial PIED/JUOS (PJ) component, also QUGA, relatively low/dry site*
- *Few living presettlement pines but some very large diameter trees*

Status: Five blocks in place, ecosystem monitoring plots completed within blocks.

Year 3: Placement of 40 smaller monitoring plots per experimental block, collection of pre-treatment data, and then a restoration prescription will be applied to the treatment halves of the blocks.

Completion: Multi-year.

Fire History

Frequent, low-intensity fire regimes are characteristic of ponderosa pine throughout its range, but specific knowledge of the characteristics of presettlement fire patterns at Mt Trumbull is important to guide the re-introduction of fire and to permit future evaluation of the restored fire disturbance regime. Fire history reconstruction based on dendrochronological measurement of fire-scarred trees, stumps, and logs is being undertaken at Mt Trumbull to estimate the frequency and seasonality of presettlement fire as well as determining the date of fire exclusion and developing a record of any postsettlement fires. A key feature of the project is the landscape scale of sampling across the entire ponderosa pine forest, allowing us to explore questions of fire size, intensity, and variability within the ecosystem, issues which have exceeded the scope of many previous studies.

Preliminary fire history results were presented in the 1996 annual report. The 1996 samples have been dated and a database has been prepared, but further analysis is continuing with the complete data set to explore the landscape-scale fire regime. The scale of sampling for 1997 was ambitious, but we were able to carry it out. We completed the sampling of the entire area proposed for treatment at Mt Trumbull, in addition to the wilderness areas and forested surrounding regions. The 1997 samples are currently being prepared for analysis.

Status: Approximately 4000 acres sampled.

Year 3: Analysis and publication of fire history.

Completion: 1998.

Dendroclimatic Reconstruction

Climate history over the past several hundred years is recorded in the varying widths of tree rings. Climate has an important influence both on vegetation (species composition, establishment, growth, and mortality) and on the patterns of disturbances such as fire. Increment cores collected in 1996 from old ponderosa pine trees were crossdated and measured to develop a long tree-ring width chronology for the Mt. Trumbull area. Currently, a third dendrochronologist is checking the chronologies to improve correlations. This chronology will be correlated with weather data to create a model that will reconstruct past climatic trends and will be compared with tree age data and fire history results to search for past climate-plant-disturbance connections and to suggest potential future changes.

Status: Sampling and initial analysis complete.

Year 3: Climatic reconstruction

Completion: 1998.

High Intensity Fire Study

Severe, stand-replacing fires are becoming increasingly common in ponderosa pine forests due to the high tree densities and heavy fuels accumulated over a century or more of fire exclusion. What kind of ecosystem structures and habitats appear following high-intensity fire? Can these fires recreate conditions similar to presettlement forest patterns, or do different plants and novel vegetation structures emerge? To answer these questions, this study focuses on measuring ecosystem structure (trees, shrubs, grasses, forbs, dead biomass) in sites burned with high-intensity fire, reconstructing pre-burn conditions where possible, and comparing present and forecast conditions over the burned area. Two severe wildfires at Mt Trumbull were sampled in 1996, the Lava fire (approximately 20 acres) and the Logan fire (approximately 150 acres). Further sampling is currently extending to the landscape-scale fires elsewhere in northern Arizona in recent years (e.g., Bear Jaw, Horseshoe, Hochderffer). In addition, a complementary study of a high-intensity 1996 wildfire at the Michilía study site in Durango, Mexico, was initiated. This study will follow permanent plots over several years in a forest which burned with high intensity following approximately 60 years of fire exclusion. Measurements were taken in 1996 (one month after the fire) and 1997 (one year after the fire). The Mexican results will be compared with the effects of high-intensity fire at Mt Trumbull and other southwestern sites.

Status: Mt Trumbull fires sampled, other sites in progress.

Year 3: Analysis of data and continued sampling of larger fires elsewhere in northern Arizona.

Completion: 1999.

Wilderness Restoration Study

In 1997, we completed the field data collection on 34 plots within the Mount Logan Wilderness Area. The data collected on each plot included the composition of herbaceous material, the fuel loading, tree density, tree volume and tree age distribution, as described in the ecosystem monitoring plot protocol. Additionally, fire scar samples were collected within the wilderness area. In the laboratory, we are entering the plot information, mounting and dating the core samples, and dating the fire scars. This information will be used to determine current forest conditions in the wilderness and the reference conditions at the time of Euro-American settlement.

Concurrent with completing this information in the laboratory, Marcy DeMillion and Marty Lee are working on a social survey on wilderness restoration with an emphasis on local populations. This survey will determine the level of knowledge and support the local populations have for the restoration project, determine what kinds of treatments may be acceptable in wilderness, and investigate how local populations feel about the visual and aesthetic aspects of restoration.

Status: Mt. Logan wilderness sampling completed.

Year 3: Analysis of data.

Completion: Multi-year.

Corresponding Studies in the northern Mexico

Long-needled pine ecosystems in northern Mexico, closely related to the pine-oak forests of the Southwest, have been less severely impacted by fire exclusion than US ecosystems. Although rapid change is occurring in Mexican forests, a few unharvested areas with continuing frequent fire regimes remain. We are documenting natural ecosystem structures and fire disturbance regimes in northern Mexico to develop points of comparison with presettlement conditions in the Southwest. Such studies address questions which are difficult to answer because of ubiquitous fire exclusion in the US, such as the persistence of snags and downed biomass under frequent fire regimes, the intensity and effects of 'low-intensity' fire in a frequently-burned ecosystem, and the universal character of forest changes following fire exclusion (increased tree density, increased fuels, etc.). In addition to directly supporting the southwestern ecological restoration research, these studies broaden our overall understanding of ecological structure and process, and will serve as a valuable resource for conservationists in Mexico.

In 1996 we sampled pine-oak and mixed conifer forests over an elevational gradient at La Michilía Biosphere Reserve, in the Sierra Madre Occidental of Durango, Mexico. In 1997, we returned to Michilía to sample additional sites, including a high-elevation forest at the Reserve core which has not been subject to fire exclusion. This free-burning forest, with structural and environmental characteristics similar to those of the southwestern US, will form an important resource for comparison to US ecosystems. We also re-measured permanent plots on a wildfire—control study which we initiated in 1996 following a high-intensity fire. Data from this site will be contrasted with the high-intensity fire studies in northern Arizona. Finally, we sampled our northernmost site to date in Mexico: a forest in southwestern Chihuahua. This ecosystem has been heavily harvested and is relatively dense with small trees, like many southwestern US forests. However, occasional fires of moderate to high intensity have occurred at the Chihuahua site, consuming evidence of past forest conditions, such as dead trees, old stumps, and scars of past fires. The loss of reference information at the Chihuahua site would present greater difficulties for ecological restoration, and may foreshadow similar losses in the US as increasingly severe modern fires erase the evidence of past ecosystem structure and function. We are currently analyzing data from the 1997 work. Fire history results from La Michilía were presented at the Ecological Society of America annual meeting in August, 1997.

Status: Sampling completed at La Michilía Biosphere Reserve, Durango, Mexico, and Guachochi, Chihuahua, sites.

Year 3: Data analysis and sampling at Durango and Chihuahua sites.

Completion: Multi-year.

Modeling Forest Structural Change

The success of management is largely based upon the ability to predict the consequences of alternative actions. Assessing the future cumulative impacts of ecosystem management practices, involving highly complex and variable interactions, is challenging. We are applying an ecological process simulation model, FIRESUM, to forecast the effects of alternative forest structural conditions, understory and fuel characteristics, and fire occurrence. FIRESUM was designed to integrate fire behavior and effects modeling together with ecological process modeling (Keane et al. 1990). The model has been calibrated to southwestern ponderosa pine forests and will be initialized with data from the permanent monitoring plots at Mt. Trumbull. Comparisons among past and present ecosystem structures, as well as potential future alternatives, will be made.

Status: Model calibration and data sets developed from monitoring plot data.

Year 3: Simulate ecosystem changes.

Completion: Multi-year

2. VEGETATION RESPONSE:

Herbaceous Response to Ecosystem Restoration

Studies of the species in the soil seed bank, and of the effects of restoration on the seed bank, are important for determining the species that will emerge following ecological restoration treatments at Mt. Trumbull. There are numerous aspects of the seed bank currently under study at NAU, including the current baseline soil seed bank at Mt. Trumbull, location of seeds in the seed bank (litter or soil), effects of fire on the seed bank, and whether perennial grasses and herbs utilize the soil seed bank as a mechanism for seedling survival. To obtain a baseline of the species in the current soil seed bank at Mt. Trumbull, soil samples were collected in September, 1997 from five vegetation types within three of the experimental units. These samples will be cold treated and placed in the NAU greenhouse to document seedling emergence. Samples can then be collected in the future from the experimental units to document changes in the seed bank over time and with ecological restoration treatments.

Fire suppression in the ponderosa pine forest has resulted in heavy accumulations of litter. This litter accumulation may serve as a trap for seeds, so that they do not reach the more insulating soil layer. Soil samples were collected from both the soil and litter in September, 1997 in five vegetation types in the experimental blocks at Mt. Trumbull to examine whether seeds accumulate in the litter and whether these seeds can remain viable. These samples will also be cold treated and placed in the NAU greenhouse.

Fire may have both beneficial and detrimental impacts on the soil seed bank. Soil samples were collected in April, 1997 from unburned, lightly burned, and severely burned patches within the 33-acre subunit of the 96-1 treatment unit at Mt. Trumbull. Samples were placed in the NAU greenhouse for several months. Germination from these samples was compared to samples taken in a control (untreated) area to determine where recruitment of plants from the seed bank occurs in a restored area. Preliminary results indicate that a large number of seeds survive in the soil seed bank in unburned and lightly burned patches within the landscape mosaic. The survival of these seeds has implications for seeding and recruitment, as well as for exotic species control. A future study will involve the collection of samples taken immediately prior to and after a prescribed burn so that the effects of fire on the seed bank can be documented.

Finally, further research is needed to determine if perennial grasses and forbs utilize the soil seed bank for seed storage. The majority of species that store seeds in the soil seed bank are early successional annuals. In order to restore areas to historic species composition and frequency, seeding of species that have been extirpated from an area may be required, especially if these species are not found in the soil seed bank.

Status: Field work completed; seed bank samples collected September 1997 will be germinated in greenhouse this winter.

Year 3: Final analysis and report

Completion: 1999.

Presettlement Ponderosa Pine Community Persistence and Stability

Forests have changed from open park-like stands of older trees to overall denser stands of young small-diameter trees. Concurrent changes in the forest understory are likely. However, neither presettlement composition of understory herbaceous and shrub plant communities, nor persistence of old-growth ponderosa pine clumps in the Southwest is known. Moreover, undisturbed reference sites no longer exist due to fire suppression policies, grazing and logging. In order to restore these forests to their natural range of variability, it will be necessary to determine presettlement reference conditions for communities. This research examines long-term vegetation stability and pre-Euro-American settlement (presettlement) understory reference conditions for a ponderosa pine/bunchgrass community in northern Arizona.

Soil characteristics such as texture, organic carbon, total nitrogen, C:N ratios, lipid content, and phytolith accumulation and morphology can be used to differentiate soils that formed under persistent grasslands versus soils that formed under forest vegetation. For example, soils beneath persistent grassland vegetation typically have more organic carbon content at depth, lower C: N ratios, and more phytoliths by mass than soils beneath forest vegetation (e.g., Fisher et al. 1995).

Plant remnants can "fossilize" in the soil and through identification of these remnants, researchers can determine plant communities through time. For example, phytoliths are particles of hydrated silica formed in the cells of living plants, and upon death and decay of the plant, the highly stable silica remains in the depositional environment. We used modern plants to establish a phytolith reference collection and then develop a classification system for the species from the study sites. Because a single plant species may produce many different phytolith shapes, and some species produce the same shapes, a multivariate classification procedure will be used to determine the degree of correspondence between the soil phytolith assemblages and the present-day plant community. This modern classification system and phytolith assemblage data will then be used to interpret phytolith assemblages found deeper in the soil that represent presettlement reference conditions. Phytolith analysis has played an increasingly important role in environmental reconstructions and the interpretation of past vegetative communities (e.g., Schwandes and Collins 1994).

The results from this project will be a critical component of ecological restoration research in ponderosa pine, particularly in answering questions regarding community pattern and stability, and understory herbaceous reference conditions.

References:

Fisher, R.F., C.N. Boum, and W.F. Fisher. 1995. Opal phytoliths as an indicator of the floristics of prehistoric grasslands. Geoderma 68:243-255.

Schwandes, L.P., and M.E. Collins. 1994. Distribution and significance of freshwater sponge spicules in selected Florida soils. Trans. Am. Microsc. Soc. 113: 242-257.

Status: Modern plants collected and phytolith collection established. Soils sampled for reference conditions analyses. Soil characteristics measured and analyzed.

Year 3: Continued soil analysis for phytolith remnants.

Completion: 1998.

*Effect of Thinning and Sprouting on Gambel Oak (*Quercus gambelii*)*

As a result of EuroAmerican settlement, populations of old growth (those trees greater than 200 years old) Gambel oak have crashed while younger age classes have irrupted. Because of the ecological and sociological importance of Gambel oak, land managers are now addressing the question of how

large Gambel oak can be restored to the southwestern ponderosa pine type. The purpose of this research is to provide answers to some key questions regarding ecological restoration of Gambel oak by discovering ways in which the growth rate of existing large Gambel oak can be increased, and the growth rate of replacement pole-sized oak can be enhanced, to restore the large trees characteristic of these ecosystems.

Mount Trumbull is one of two northern Arizona field sites selected for this study, because it is currently the site of a large scale ecosystem restoration project. We are using retrospective ecological analysis and dendroecological techniques to determine the effect of thinning and sprouting on Gambel oak. By returning to oak clumps years after a thinning event, it is possible to analyze the differences between growth rates in oak clumps that were thinned and those that were not. Likewise, Gambel oak trees growing in isolation were analyzed relative to oak trees surrounded by numerous sprouts. Two interrelated questions regarding the ecological restoration of Gambel oak addressed in this research are: 1) What is the effect of thinning within oak clumps on the growth of residual oaks? 2) What is the effect of sprouting on the growth rate of oak clumps?

Preliminary results from Mount Trumbull indicate that there is no effect of thinning within an oak clump or of sprouting on the growth rate of mature Gambel oak. Similar results were obtained from the second study site on the Kaibab National Forest, for the effect of sprouting. However, different results were obtained at the two sites regarding the effect of thinning on residual oak in a clump. This difference in the effect of thinning may be attributed to the different way in which the thinning was conducted.

At Mount Trumbull, oak thinning was primarily the result of fuelwood collection over the years. It is common for dead standing oak to be preferred for fuelwood collection, so many of the thinned oak trees at Mount Trumbull may have been dead before removal. In contrast, much of the oak thinning sampled on the Kaibab was the result of a systematic thinning from below that the Forest Service conducted about 15 years ago. In this case, live Gambel oaks were removed with the intention of increasing mass production in the larger surrounding oak. At the Kaibab site there is a distinct trend for mature oak trees that remain in clumps that were thinned of pole- and large-sized oak to show an increase in ring width index after thinning and growth is more pronounced as the time since thinning increases.

The results of this study provide evidence for recommending that thinning from below of live Gambel oak within mature oak clumps will increase the growth of residual mature oaks in that clump. A positive by-product of this type of thinning will be to increase new sprouts at apparently little or no cost to the residual tree, providing palatable browse for elk and deer. Therefore, thinning Gambel oak from below in the northern Arizona area will contribute to maintaining and invigorating old-growth Gambel oak in the landscape. This growth release could probably be enhanced by also thinning ponderosa pine surrounding oak clumps and/or implementing prescribed burning to eliminate pine and oak poles and saplings that are competing with the mature oak trees. Further efforts toward ecological restoration of old-growth Gambel oak will focus on the effects of prescribed burning and ponderosa pine thinning on the surrounding Gambel oak.

Status: Oak samples from Mt. Trumbull have been processed and analyzed. Field work on Kaibab National Forest will continue through fall 1997.

Year 3: Examine effects of fire on oak clump survivorship, analysis of data collected in 1997.

Completion: Multi-year.

Butterfly Response to Ecosystem Restoration

Butterflies are an excellent group to examine changes in habitat. Because the butterfly larval stage (caterpillar) is typically host specific, butterfly diversity can be a good indicator of host-plant species diversity. Different species of butterflies feed on a variety of plants, including trees, shrubs, grasses and forbs, providing host-plant diversity information on different guilds of plant species.

The restoration of ponderosa pine forest habitat to its presettlement structure reduces current tree density, opening the canopy. Theoretically, this should increase herbaceous diversity and abundance. The butterfly community may respond to both the abiotic changes (e.g., warmer soil temperatures with an open canopy) and the biotic changes (e.g., increased nectar resources, increased host-plant abundance and fitness).

To address the question of changes in butterfly diversity with ponderosa pine restoration treatment, a long-term experiment was developed in the experimental block units. Permanent transects were placed in the control and treatment units of the experimental blocks. These transects range in length from 450 meters to 900 meters, dependent on the block size. Transects were walked at a timed pace once every two weeks through the summer of 1997. Observed butterflies were recorded if known. If not known, butterflies were pursued, caught and collected. Time pursuing and collecting butterflies was not recorded as surveying time. This pre-treatment data will be used to assess the similarity between control and treatment parts of the experimental blocks, as well as to establish the pre-treatment diversity and abundances of the butterfly community.

In addition, areas across the Mt. Trumbull landscape representing different habitat types were sampled to get an estimate of total butterfly diversity. For example, open meadows not in the experimental blocks were sampled, to see if there were species present that were not represented in the experimental blocks. Besides open meadows, oak groves, oak/ locust groves, and pinyon juniper woodlands were sampled. If changes in diversity and abundance are seen with restoration treatment, researchers will be able to infer if these changes result from species already found at Mt. Trumbull, or if new species are immigrating into or emigrating out of the Mt. Trumbull ecosystem.

Preliminary data shows a lower species diversity and abundance at Mt. Trumbull than expected (compared to observations near Flagstaff, AZ). Two factors may affect this pattern. First, the drought of 1996 would be expected to adversely affect insect populations that mature on 1996 vegetation, overwinter, and then emerge in 1997. Low vegetation quality in 1996 due to the drought would directly affect emergence rates in 1997. Secondly, Mt. Trumbull is an isolated island of ponderosa pine forest, approximately 80 miles from the nearest large contiguous stand of ponderosa pine (the Kaibab Plateau). This creates an island biogeography effect, where the biodiversity and species richness of a habitat type is dependent on the size of the habitat and distance from similar habitat. Further data collection in 1998 should illuminate the magnitude of both of these effects. In addition, other isolated islands of ponderosa pine will be sampled, to test for the island biogeography affect.

Status: Permanent butterfly transects established, species list compiled.

Year 3: Analysis of abundance data. Continued pre-treatment sampling of butterfly transects, sampling of additional sites, initiation of larval response study.

Completion: Multi-year.

Passerine Bird Study

This study is an initial effort to monitor the response of passerine birds to the first large-scale effort to restore old-growth ponderosa pine conditions at Mt. Trumbull. Careful documentation of wildlife response to the first large-scale experiment may suggest desirable changes to future experimental treatments, and will help direct future land manager's recommendations. Accordingly, we quantified bird distribution, abundance, and (for selected species) reproductive parameters on 2 areas (approximately 300 to 400 ha each) of ponderosa pine forest.

During the field season of 1997, we continued our monitoring of bird diversity, bird abundance, fledging success and nest site selection. In addition, we collected vegetation measurements on our census points, and on points centered on nest trees.

As a result, this effort provides a 2-year picture of abundance, diversity, reproduction, and nest site selection by birds in Mt. Trumbull's pine-oak forest. We found substantial year-to-year changes in abundance and species diversity. We documented strong selection for nest sites at the level of the nest tree, as well as at the level of a 20x20-m plot. Selection for larger trees and snags emerged as important trends in the species studied; individual species differed in their selection for other habitat attributes. These habitat selection patterns will help managers anticipate, and to interpret the mechanisms that underlie bird responses to the restoration treatment.

Status: Data collected and analyzed for years 1&2.

Year 3: Currently not funded for year 3.

Completion: Dec. 1997, as per Heritage Grant contract (see attached report). Currently waiting funding to continue data collection through treatment and post-treatment years.

Sciurid Habitat Associations and Responses to Restoration Treatments

Little is known about the habitat associations of Kaibab squirrels (*Sciurus aberti kaibabensis*), rock squirrels (*Spermophilus variegatus*), and cliff chipmunks (*Eutamias dorsalis*) in dry, low-elevation ponderosa pine (*Pinus ponderosa*) forests. Essentially nothing is known about the responses of these species to restoration treatments which seek to restore presettlement-like conditions.

During the summer of 1997, work was began on a study to document the relative abundance of Kaibab squirrels, rock squirrels, and cliff chipmunks in five distinct units within the area to be treated as part of the Mt. Trumbull Restoration Project. These three species constitute the only three Sciurids (members of the squirrel family) known to occur in the Mt. Trumbull area. The five units chosen were designated as experimental blocks (EB units) one through five. They represent five distinct vegetation types common in the Mt. Trumbull area. Characteristics of these habitat types are summarized in the experimental block section above.

Track stations were used to measure the relative abundance of each species within the experimental blocks. A total of 234 track stations were placed within 5 meters of rebar stakes that permanently mark the center of circular vegetation plots. Plot centers were located 60 meters apart on a systematic grid, with 120 - 200 meter buffers between control and treatment halves of each experimental block. Tracking was conducted August 12-16, 1997. Collection of vegetation data using fixed area circular plots was begun in the EB-1 unit in August 1997. Vegetation data collection will be completed during the 1998 field season, and tracking will be repeated in May and August of 1998.

Due to the low frequency of Kaibab squirrel tracks in track stations, relative abundance of this species was also measured using a feeding index. This method uses 1-m^2 plots arranged systematically over

the unit in which fungi digs, cone cores, peeled twigs, and terminal clusters of pine twigs are counted. A total of 796 such plots were examined. This method also gives an indication of the level of use of various food resources by squirrels in the area surveyed. The feeding index was conducted on July 31 and August 1, 1997. The feeding index will be conducted again in May and August of 1998.

Results from the 1997 field season indicate higher relative populations of rock squirrels and cliff chipmunks in unit EB-1. This may be related to the large number of den sites available in the lava rock. Differences in vegetation are also apparent in this unit. Kaibab squirrels were most abundant in units EB-1 and EB-3--areas with the largest trees and most open understories. Kaibab squirrel use of fungi and pine cones as food sources appeared to be higher in unit EB-3 than the other units. Thorough analysis of results will not be possible until data collection is completed next year.

Preliminary efforts were made to observe feeding behavior of each species in each of the units. Knowing what food resources are used by each species in each habitat type will provide helpful information for identifying possible explanations for habitat associations. Preliminary observations in 1997 yielded an unexpected observance of a rock squirrel feeding on an immature female cone about 50 feet up in a mature ponderosa pine, as well as a number of other observations of all species foraging. It is anticipated that visual observations of foraging by these diurnal rodents will be standardized and expanded in scope during the 1998 field season. It is also anticipated that additional habitat parameters pertinent to Sciurids (such as number of interlocking canopies and size of rock substrate) will be added to the information collected on circular vegetation plots.

Habitat data and Sciurid abundance will be compared at both the unit and plot level in order to look at both intermediate-scale and small-scale habitat associations. These associations will also be compared with foraging observations in an attempt to help develop hypotheses explaining differences in abundance of each species in the respective habitat types.

It is anticipated that measurements of Sciurid abundance, and observations of foraging behavior, made in years following restoration treatments in 1999 will give early indications of how restoration treatments impact Sciurids in five representative types of dry, low-elevation ponderosa pine forests at Mt. Trumbull.

Status: First year data collection complete.

Year 3: Finish data collection and analysis.

Completion: 1999.

OUTREACH

Providing information to other land managers and the general public is an important part of this joint restoration project. Environmental groups, land managers, the general public, and service organizations have continued to express a large amount of interest in the Mt. Trumbull project. Presentations have ranged from slide shows to on site tours, and have been greeted with great enthusiasm. As more data is analyzed and more findings become apparent, NAU and the Arizona Strip District will continue to provide that information. In the past year, presentations on the Mt. Trumbull Ecosystem Restoration Project have been made to the following groups.

Society of American Foresters	Alberquerque, NM	November, 1996
BIA Tri-Area Fire Conference	Gallup, NM	February, 1997
Grand Canyon Trust, Conservation Spotlight Series	St. George, UT	March, 1997
Wildlands Council Meeting	Flagstaff, AZ	March, 1997
Sunrise Rotary Club	Phoenix, AZ	April, 1997
USDI-OIG Audit	St. George, UT	April, 1997
USDA Extension Service tour	Mt. Trumbull, AZ	April, 1997
BLM National Conference	St. George, UT	May, 1997
Senator Kyl staff	Mt. Trumbull, AZ	June, 1997
Arizona Daily Sun newspaper	Mt. Trumbull, AZ	June, 1997
National Guard Bureau	Camp Navajo, AZ	June, 1997
Gila River Spotted Owl WT	Flagstaff, AZ	July, 1997
North and South Rim fire and interpretive staff, GCNP	North Rim, GCNP	July, 1997
Tusayan Ranger District	Tusayan, AZ	July, 1997
Ecological Society of America	Albuquerque, NM	August, 1997
Arizona Ponderosa Pine Workshop	Flagstaff, AZ	August, 1997
Grand Canyon National Park Staff	Flagstaff, AZ	August, 1997

LOOKING FORWARD

Many of the projects summarized here are multi-year projects. It is only by monitoring these different aspects of ecosystems over time that we can better understand ecosystem process and function. As the treatment phase moves across the landscape, the post-treatment evaluation will follow. Remeasurement of ecosystem monitoring plots following treatment will provide information on the immediate effects of treatment (i.e., reduced tree density, reduced fuel, increased herbaceous production). Results that suggest that restoration practices could be improved will be immediately incorporated into prescriptions on the current treatment units (adaptive ecosystem management). For example, the burning prescription was modified after we observed excessive fire intensity in a portion of the 96-1 treatment unit. Tracking these monitoring plots over the next decades will provide important information on successional changes in the ecosystem from the time of restoration.

The response of plants, arthropods, mammals and birds will also be tracked on a decadal scale. While responses may occur within a year or two of treatment, these initial responses may be due to temporary effects associated with the initial treatment, (i.e., increased slash, initial abiotic changes with the opening of the canopy, etc.). Therefore, initial effects, although important, may not represent long-term patterns developing from ecosystem restoration.

The next few years will be very exciting at Mt. Trumbull as we observe these initial responses to

ecosystem restoration. Although landscapes and ecosystems vary greatly, the conceptual and operational information learned from this first large-scale ecosystem restoration project will be applied to other large-scale restoration projects started across the southwest.

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FINAL REPORT -- Heritage Grant I96008
BIRD ABUNDANCE AND DIVERSITY PRIOR TO RESTORATION TREATMENTS FOR OLD-GROWTH PONDEROSA PINE

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INTRODUCTION

Many federal land management agencies and congressional leaders of both political parties have embraced the idea that ponderosa pine forests should be restored to the structural and functional conditions that prevailed prior to the current era of dominant Euro-American influence. In particular, there is a strong impetus to restore the forest structure suggested by Covington and Moore (1992, 1994), i.e., a density of about 13 to 56 trees per acre, basal areas of about 63 square feet per acre, and stands dominated by large yellow pines with few snags or downed logs. It is quite likely that federal agencies will implement these changes over large areas during the next decade. However, we do not know how wildlife will respond to these treatments. Careful documentation of wildlife response to the first large-scale experiment may suggest desirable changes to future experimental treatments, and will help direct future AGF recommendations.

All too often wildlife abundance, reproduction, or other parameters are measured only *after* a manipulation, and data are analyzed under the assumption that, prior to treatment, the treated area did not differ from the "control" site. But in this design, treatment effects are hopelessly confounded with site effects (Hurlbert 1984). The remedy is to collect pre-treatment data at both control and treatment sites; this creates a Before-After-Control-Impact Pairs design (BACIP design: Stewart-Oaten and Murdoch 1986).

This study is an initial effort to monitor the response of passerine birds to the first large-scale effort to restore old-growth ponderosa pine conditions, namely the effort on the Bureau of Land Management's (BLM) Mount Trumbull Resource Conservation Area (MTRCA). Accordingly we quantified bird distribution, abundance, and (for selected species) reproductive parameters on 2 areas (approximately 300 to 400 ha each) of ponderosa pine forest in the BLM's. In the near future, 1 of these 2 areas will be thinned and burned in an attempt to restore Old Growth conditions to the ponderosa pine forest. This study presents the first 2 years of "Before" data for a BACIP design to quantify avian response to these treatments. We anticipate collecting a third year of pre-treatment data (although not on this Heritage Grant), and collecting the same type of observations for 3 years after treatment.

STUDY AREA

The Mount Trumbull Resource Conservation Area (MTRCA) lies on the Arizona Strip about 50 miles southwest of Fredonia, Arizona. The surrounding regional landscape is desert, with the ponderosa pine forest restricted to about 5000 acres, mostly above 6500 feet in elevation on the slopes of Mt Trumbull and Mt Logan. Gambel oak, juniper, pinyon, and locust occur commonly throughout much of the ponderosa pine forest.

METHODS

Layout and Number of Sampling Points

In our original proposal, we had planned to divide the area into ponderosa pine, pine-oak, and pine-juniper strata. However, after working at the site we found oaks so widespread that most the area qualifies as pine-oak. We further decided not to sample in areas with greater than 30% basal area in pinyon or juniper. Thus we had only one stratum.

Researchers under the direction of Dr. Covington mapped a square grid of sample points, spaced 300-m apart, across the MTRCA. Our crews located these points on the ground, marking each point with rebar and a bright plastic rebar cap. We identified 48 points in areas scheduled for treatment starting in 1998 ("Treatment Area") and another 46 points in a 400-ha area currently not scheduled for treatments ("Control Area").

We used these 94 points in 2 ways. First they were the center points of 75-m radius plots on which we censused birds. Second, these were center points of 20x20-m plots on which we measured vegetation and physical characteristics of the habitat. These vegetation surveys became our measure of "available habitat" that we contrasted to those habitats chosen for nesting by birds in focal species.

Note: At the time we selected these areas, treatments in these areas were to begin in 1998; in fact, treatments may not begin until the year 2000 or later.

Vegetation measurements

We measured vegetation on 20x20 m square plots. On each plot we tallied the number of trees by species in each of 6 size classes corresponding to the US Forest Service's Vegetation Structural Stages (VSS), namely 0-1", 1-5", 5-12", 12-18", 18-24", and >24" dbh. We tallied snags separately from live trees. We measured canopy closure and ground cover (including herbaceous vegetation and shrubs) by point intercept at each of 49 points. We tallied all logs on the plot. We used the dwarf mistletoe rating system developed by Hawksworth to index mistletoe infections in 10 ponderosa pines on each plot. (Note: To our surprise, we found no dwarf mistletoe in ponderosa pine in any plot; true mistletoe occurred frequently in junipers). We counted the number of oak clumps on each plot and measured the aerial extent of oak clumps. For 4 randomly-selected large (>15" dbh) ponderosa pines on each plot, we measured the distance to the nearest neighboring large ponderosa pine. We also recorded aspect, percent slope, and whether or not the plot was within 20 m of a drainage.

We established and measured vegetation on plots centered on nest trees and intersection points on the 300-m grid (available habitat). The available habitat plots share a plot center with the 20x50-m rectangular plots established by Dr. Covington, and originally we had intended to use the vegetation data collected by Dr. Covington's crews at these sites. However, we felt that smaller plots, such as a 20x20-m square, would better reflect the scale on which birds select nest sites, and would thus be appropriate for nest plots. To avoid problems in comparing 20x20-m nest plots to 20x50-m plots measuring available habitat, we used a single plot size for all plot types. Also, unlike Dr. Covington's crews (who we using the plots to reconstruct pre-settlement conditions), we did *not* offset our available habitat plots to avoid roads, old landings, or rock outcrops.

Bird diversity and abundance

We indexed presence and abundance of passerine birds by 8-minute point counts on circular fixed radius plots (Ralph et al. 1993), tallying all birds heard or seen within 75-m of the point. We also recorded whether the bird was detected 0-50 m, or 50-75 m, from the point. We did not sample when noise from wind or other sources (airplanes, cicadas) exceeded 3 on the Beaufort noise scale. Our sampling protocol will be attached to the final report. Crews trained during May 1-30 of each year, and carried out the surveys during May 28-July 10 of each year. During our initial 1996 effort, we visited each point 4 times (May 29-June 2, June 12-14 , June 27-29, and July 10-12). Because the fourth visit added little additional information (Quarterly Report Jul-Sep 1996), we visited each point 3 times in 1997 (May 31-June 2, June 13-16, and June 28-30), dropping the mid-July visit (which had the fewest detections). Because both total detections and numbers of species detected decreased after 8:30 and again after 9:00 during 1996 (Quarterly Report Jul-Sep 1996), we completed all point counts by 8:30 AM in 1997.

We estimated abundance of each species in each year as the maximum number of birds detected during the 3 June visits, excluding known juveniles, birds of unknown species, and birds that flew through the plot without using it. Our use of the maximum of the 3 counts assumes that the birds we detected used the plot throughout the breeding season, but that our ability to detect them fluctuated.

We used the SPSS SamplePower software to estimate the power of our sampling effort to detect changes in species richness (number of species), overall avian abundance, and abundance of individual species between the pre- and post-treatment periods. These analyses will allow adjustments to the study design for increased power or efficiency. For instance, the analysis can indicate whether we should increase (or possibly could reduce) the number of years of observations or number of census plots.

Our overall study design consists of 40 census plots each in the Control and Treatment

Areas (3 visits per year, and other details as described above), and 2 or 3 years of observation in each of the pre- and post-treatment time periods, with restoration influences to be evaluated by an ANOVA of the null hypothesis that diversity and abundance will change between the pre- and post-treatment Periods in similar amounts in the Treatment and Control Areas. Note that although we sampled 46 points (Control Area) and 48 points (Treatment Area) in 1996-1997, the precise boundaries of the treatment units have not been set, and we have not fully analyzed our data on the vegetation of the plots. Doubtless some "treatment" plots will not be treated, some "control" plots will lie too close to the treated edge, and some plots will be dropped because, for instance, there is too much juniper. We believe that it is realistic to assume that 40 plots per Area will remain in the final analysis.

In these analyses we chose an alpha level of 0.05 and an acceptable level of power of 80%, both conventional values. Selecting the smallest difference that one wishes to detect is a more subjective process. We started the analyses hoping to be able to detect a change of 20% in species richness and total bird abundance; we reasoned that smaller changes in total numbers would be of questionable ecological significance. We wish to be able to detect a 30% change in numbers of an individual species, but also evaluated power to detect changes of 50%; again we reasoned that subtler changes would not only be expensive to detect but their ecological significance would be more difficult to interpret.

Fledging Success

Reproduction is a better index of habitat quality than species presence or density (Van Horne 1983, Vickery et al. 1992). Therefore, in addition to documenting changes in species occurrence, we monitored reproduction for a suite of 7 focal species that would be expected to respond to the treatments. To do so, we established six Nest Search Grids (3 on the Control Area and 3 on the Treatment Area). Each Grid is about 36-ha (600x600m in most cases, one plot is rectangular to stay in the ponderosa pine type) and is marked on the ground with a numbered wooden stake every 50 meters. The stakes allow us to reference the location of each nest for revisiting, and eliminates the need to put out additional flagging or other marks which could attract predators to nests. We monitored each nest every 2-7 days until the nest failed or until the young birds apparently left the nest. We followed the protocols of Martin and Geupel (1992) to maximize our success and minimize our impact on the birds. We considered a nest successful if it survived to within 3 days of the earliest fledging date expected on the basis of inferred dates of egg-laying or hatching.

Focal Species for Monitoring Reproduction and Nest Site Selection	Reason for including this species
Mountain chickadee	branch and foliage gleaner in pine and oak
Northern flicker	important primary excavator; feeds on ants
Pygmy nuthatch	bark and branch gleaner in pines; primary excavator in pines
Solitary vireo	most susceptible to cowbirds; nests in small oaks
Western bluebird	cavity nester; ground feeder
Western tanager	foliage gleaner (especially pines); nests in pine canopy
White-breasted nuthatch	secondary cavity nester in oaks (primarily) and pines

Mayfield (1961) pointed out that the number of successful nests will always give a biased estimate of true reproductive success because nests found later in the season have a greater likelihood of fledging young. To remedy this problem, Mayfield suggested closely monitoring nests through all phases of the nesting season (building, incubation, egg-laying, nestling, and fledging) and calculating probability of nest survival per day of exposure for each phase. Because we discovered relatively few nests in the earlier phases, we were unable to apply this method. Instead, for each species, we are using the number of successful nests to estimate the *relative* nest success on the

Treatment Area compared to the Control Area. After treatment we will test to see if this ratio has changed, using an analytic technique such as a Chi-squared analysis.

Our efforts searching for and monitoring nests are carefully balanced between the Control and Treatment Areas. To insure this balance, each observer was assigned a pair of Nest Search Grids (1 each on Control and Treatment Areas) to monitor for the duration of each field season. After an observer expended a day's effort on a Nest Search Grid in the Treatment Area, he or she spent the same number of hours and used the same start and finish times on a paired Nest Search Grid on the Control Area the following day. This balancing of effort is crucial to our approach. By carefully balancing our effort, we can state whether the proportion of total nests on the Treatment Area changed with treatment. The *proportion* should be free of bias, even though the true reproductive success on an Area is unknown.

We also conducted statistical power analyses for our effort to detect whether restoration treatments influence fledging success of these species. In these analyses, we used Chi-square analysis of the null hypothesis that the proportion of total successful nests (for each species) that occur in the Treatment Area will not change between the pre-treatment and post-treatment Periods. Anticipating the difficulty of detecting changes in ratios, we conducted analyses with alpha (risk of type I error) of 0.05 and 0.10. We calculated how many successful nests we must find (per species, in each of the pre- and post-treatment Periods) to conclude that a change of 10, 20, or 30 percentage points would be statistically significant.

Nest Site Selection

Although not required by the contract, we collected data on nest site selection by 7 focal species. Because we were already searching for nests of these species to determine fledging success, and because we were already collecting data on habitat available to the birds, we recognized an opportunity to gain this additional data at little cost. The extra measurements required for this effort involved only 30 minutes per nest to measure vegetation. These data add significantly to our understanding of the ecology of these species, and will help managers interpret any responses observed during the post-treatment period.

We measured vegetation characteristics on 20x20-m plots centered on 128 nests of 7 focal species using the procedures outlined above. We compared these characteristics to that on 89 plots (also 20x20-m) representing habitat available to the birds. In addition, we studied nest site selection at a finer scale, namely the nest tree, comparing nest trees to trees available in different species, size classes, and tree class (snag versus live).

RESULTS AND DISCUSSION

Bird diversity and abundance

Table 1 summarizes bird abundance for 1996 and 1997. The 12 most abundant species across the 2 years were white-breasted nuthatch (#1), Grace's warbler, mountain chickadee, pygmy nuthatch, western tanager, yellow-rumped warbler, solitary vireo, spotted towhee, western bluebird, Steller jay, dark-eyed junco, and gray flycatcher (#12). Seven plots on the treatment area were relocated between 1996 and 1997 in order to avoid having plots dominated by pinyon or juniper. As a result, although we censused 94 points each year, only 87 plots were sampled in both 1996 and 1997. Census plots tended to have similar number of species and total abundance across the 2 years (correlation coefficients: +0.49 for richness and +0.52 for abundance, $n = 87$, $P < 0.0005$ for each). The species list at each point also tended to be similar, but not identical, across years.

Average species diversity on a census plot decreased from 9.0 species per point in 1996 to 7.5 species in 1997 (paired t-test, $n = 87$, $P < 0.0005$), and average abundance per plot decreased from 11.4 to 9.2 birds detected ($P < 0.0005$). There were significant decreases between 1996 and 1997 in numbers of 8 species (Clark nutcracker, mourning dove, pygmy nuthatch, solitary vireo, spotted towhee, Virginia warbler, white-breasted nuthatch, and western tanager), while 3 species (black-

throated gray warbler, common raven, and Steller jay) increased (t-tests, $P < 0.07$; we chose a relatively high alpha because our effort has relatively low power to detect changes between individual years). The decrease in Clark nutcrackers may reflect the irruptive nature of this species. The decreases in many of the other birds may reflect extremely dry conditions in the 1996 breeding season, and heavy snows during spring migration in 1997. The marked year-to-year variation in the absence of treatment underscores the value of collecting data for several years both before and after treatment.

Brown-headed cowbirds were extremely rare during 1996 and 1997 (Table 1). These nest parasites may increase in the more open post-treatment landscape, especially if grazing animals maintain a low stubble height.

We are satisfied with our statistical ability to detect meaningful changes in species richness (number of species) and total avian abundance. With 1 year of observation in each of the pre- and post-treatment Periods, we would have about 60% power to detect a 20% change in richness or total bird numbers, this increased to about 71% power with 2 years of observations in each period (Figure 1). Because Years are nested within Period, we could not directly estimate how much power will increase with a 3rd year of observation in each Period. Based on the 11% increase in power due to adding the 2nd year, and the law of diminishing returns, we expect that power will increase to about 80% with a 3rd year of observation.

Our sampling scheme is not expected to detect (i.e. confer statistical significance upon) that changes of 30% in the abundance of individual species. Our analyses indicated that >100 census plots in each Area would be needed to detect changes as small as 30%. Examining the maps, we conclude that a maximum of 84 independent points an fit into the Control Area (with a 75-m plot radius and bird home range diameters of about 100m, plot centers must be at least 200m apart). Because some of these plots would doubtless be deleted eventually (see *Methods*), we would probably have at most 80 plots, far short of the 100 needed to detect changes of 30% in the abundance of an individual species.

We have satisfactory power to detect changes of 50% in the abundance for the most abundant species, but with only 2 years of data we cannot do so for less abundant species (Figure 2). As with total avian abundance, power to detect a 50% change in individual species increased substantially as number of years of observation increased from 1 to 2 years (Figure 3). Given the delay in implementing treatments on Mt Trumbull, we have the opportunity to collect a 3rd year of pre-treatment data, and we feel it is important to do so. The 3rd year of observation will substantially increase our ability to detect smaller changes, and to detect changes for a greater fraction of the individual species.

Fledging Success

We discovered a total of 142 nests of the 7 focal species during 1996-1997, including 28 nests that failed and 3 successful nests that did not fall in either the Control or Treatment Area. We measured vegetation at all 142 nests, but only 111 nests are useful for analysis of fledging success (Table 2). In terms of the overall study design, the null hypothesis, for each species, is that the proportion of successful nests falling in the Treatment Area will not change between the pre- and post-treatment periods. The restoration treatments will be judged to have a significant influence on fledging success of a species if that proportion is significantly different in the post-treatment period.

Our power analysis suggests that, in each of the pre- and post-treatment Periods, we would have to find 300 successful nests to have 80% power to detect a shift of 10 percentage points in the proportion of successful nests that lie in the Treatment Area at an alpha of 0.10. We would need 135 nests to detect a shift of 15%, again with alpha of 0.10. We conclude, given the number of nests we were able to find during 1996-1997 (Table 2), that our effort will not find changes of 10% to 20% statistically significant (Figure 4).

Our effort can reliably detect larger changes in nest success. For instance, we need only 30 successful nests to detect a shift of 30% at an alpha of 0.10, and 39 nests at an alpha of 0.05 (Figure

4). In light of the cost associated with nest-searching, we favor accepting an alpha of 0.10 so that 30 (instead of 39) successful nests will be sufficient. Assuming we can carry out a 3rd field season in 1998, we should easily obtain 30 successful nests each for white-breasted nuthatch, western bluebird, western tanager (Table 2), and we may approach this level for the other species. To do so, we plan to expand each nest grid by 50% (from 36 ha to 54 ha) before the 1998 field season; the geometry of the study area prohibits further expansion. Even with the enlarged nest search grids, we may need 2 more field seasons (1998 and 1999) to reach the 30-nest threshold for some species.

Nest Site Selection

Although not required by the contract, we collected data on nest site selection by 7 focal species.

At the level of the individual tree chosen as a nest site, most cavity nesters showed a strong preference for snags, using snags in greater proportion than expected based on available trees (Table 3). However, except for the northern flicker, all cavity nesters used live trees for 42% (mountain chickadee, pygmy nuthatch) to 80% (white-breasted nuthatch) of their nests. The 2 cup-nesters (solitary vireo, western tanager) nested exclusively in live trees, with tanagers nesting almost exclusively in ponderosa pine (Table 3). Although the solitary vireo nested in a broad range of tree sizes, the other 6 bird species showed a strong preference for nesting in the largest trees; this was true for both pines and oaks, live and snag (Table 4).

At the level of the 20x20-m plot, species differed in their habitat preferences (Tables 5-11). Solitary vireos and white-breasted nuthatches selected habitats with more oak (Table 5, 6), perhaps reflecting their tendency to nest in oak trees. On the other hand, northern flickers, pygmy nuthatches, and western tanagers showed an aversion to oaks, especially small-diameter oaks (Tables 8, 9, 10). Despite the preference for large nest trees, few species showed any tendency to respond to the spacing of large trees. The only 2 species that did (white-breasted nuthatch, mountain chickadees) seemed to prefer a wider than average spacing among large (>15" dbh) trees (Tables 5, 10). Solitary vireos, white-breasted nuthatch, western bluebirds, and western tanagers seemed to prefer gentler slopes (Table 5, 6, 7, 8). White-breasted nuthatches and western bluebirds both tended to pick nest locations with high canopy closure (Tables 6, 7).

These findings may help interpret bird responses to the restoration treatments. For instance if western bluebirds were to decline with treatment, despite creation of what will certainly be more favorable foraging conditions, it may be due to their aversion to nesting in more open sites. We will also learn a great deal more about a species' habitat selection patterns by repeating these measurements after treatment. Perhaps many birds that are indifferent to (for example) canopy closure or spacing of large trees in the dense pre-treatment landscape will manifest selection with respect to these habitat features in the more open post-treatment landscape.

CONCLUSIONS

Although we succeeded in completing all tasks specified in this contract, the data presented herein comprise a baseline survey that will be of value primarily for comparison with similar data to be collected after treatment. Because it is crucial that future data be collected using compatible, if not identical, procedures, our protocols (i.e., instructions to field crews on how to carry out measurements) and original data forms will be appended to the final report.

To increase statistical power of this effort, we strongly recommend collecting additional pre-treatment data at Mt Trumbull during 1998, and perhaps 1999. Delays in implementing the restoration treatments at Mt Trumbull will certainly allow for additional data collection. Funding for these seasons has been included in the 3-year (1997-1999) that AGFD undertaken with funding from BLM (this project includes studies of deer, squirrels, and reptiles, as well as continuation of these avian studies). We have prepared this report promptly so that we can focus our field efforts wisely in 1998. With a productive 1998 season, we believe that we will need only a pared-back 1999 season, freeing up dollars from the BLM-AGFD project budget to achieve other objectives in 1999.

Even in the absence of post-treatment data, this effort provides a 2-year picture of abundance, diversity, reproduction, and nest site selection by birds in Mt. Trumbull's pine-oak forest. We found substantial year-to-year changes in abundance and species diversity. We documented strong selection for nest sites at the level of the nest tree, as well as at the level of a 20x20-m plot. Selection for larger trees and snags emerged as important trends in the species studied; individual species differed in their selection for other habitat attributes. These habitat selection patterns will help managers anticipate, and to interpret the mechanisms that underlie, bird responses to the restoration treatments.

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Table 1. Abundances of birds during June 1996 and June 1997. We indexed abundance as the maximum number of birds detected within a 75-m radius during 3 visits each year, excluding birds flying through the plot. Species with a mean of "0" were present on the study area, but not detected during our censuses. Means and standard deviation reflect all 94 census plots, but significance level (*P*) is of a paired t-test (2-tailed) using n= 87 census points visited in both years.

Species	Year	Mean Abundance	Standard Deviation	P
Acorn woodpecker	1996	0.02	0.21	1.00
	1997	0.03	0.22	
American crow	1996	0.01	0.10	1.00
	1997	0.01	0.10	
American kestrel	1996	0.00	0.00	a
	1997	0.00	0.00	
American robin	1996	0.07	0.26	0.48
	1997	0.04	0.20	
Ash-throated flycatcher	1996	0.03	0.18	0.41
	1997	0.05	0.22	
Black-chinned hummingbird	1996	0.05	0.34	0.13
	1997	0.00	0.00	
Bewick wren	1996	0.00	0.00	a
	1997	0.00	0.00	
Blue-gray gnatcatcher	1996	0.01	0.10	1.00
	1997	0.02	0.14	
Brown-headed cowbird	1996	0.01	0.10	0.32
	1997	0.00	0.00	
Black-headed grosbeak	1996	0.26	0.48	0.52
	1997	0.28	0.56	
Brown creeper	1996	0.06	0.29	0.96
	1997	0.01	0.10	
Black-throated gray warbler	1996	0.10	0.33	**0.005**
	1997	0.26	0.65	
Broad-tailed hummingbird	1996	0.06	0.25	0.53
	1997	0.07	0.26	
Band-tailed pigeon	1996	0.02	0.15	0.42
	1997	0.04	0.20	
Bushtit	1996	0.03	0.23	0.18
	1997	0.00	0.00	
Cassin finch	1996	0.00	0.00	0.16
	1997	0.02	0.14	
Chipping sparrow	1996	0.41	0.65	0.086
	1997	0.35	0.57	
Clark nutcracker	1996	0.05	0.27	**0.058**
	1997	0.00	0.00	
Cordilleran flycatcher	1996	0.01	0.10	1.00
	1997	0.01	0.10	
Common raven	1996	0.03	0.18	**0.060**
	1997	0.13	0.43	

Dark-eyed junco	1996	0.37	0.57	0.87
	1997	0.45	0.59	
Dusky flycatcher	1996	0.12	0.32	0.29
	1997	0.07	0.26	
Flammulated owl	1996	0.00	0.00	0.32
	1997	0.01	0.10	
Gray flycatcher	1996	0.35	0.50	0.07
	1997	0.46	0.57	
Grace's warbler	1996	0.94	0.79	0.28
	1997	0.86	0.79	
Green-tailed towhee	1996	0.01	0.10	0.32
	1997	0.00	0.00	
Hairy woodpecker	1996	0.38	0.55	0.11
	1997	0.24	0.45	
Hermit thrush	1996	0.07	0.26	0.76
	1997	0.07	0.34	
House wren	1996	0.03	0.18	0.08
	1997	0.00	0.00	
Lesser goldfinch	1996	0.00	0.00	0.08
	1997	0.03	0.17	
Mountain chickadee	1996	0.95	0.82	0.30
	1997	0.85	0.82	
Mourning dove	1996	0.15	0.39	**0.012**
	1997	0.03	0.17	
Northern flicker	1996	0.22	0.49	0.87
	1997	0.22	0.52	
Northern goshawk	1996	0.00	0.00	0.32
	1997	0.01	0.10	
Olive-sided flycatcher	1996	0.00	0.00	0.32
	1997	0.01	0.10	
Pinyon jay	1996	0.00	0.00	a
	1997	0.00	0.00	
Plain titmouse	1996	0.01	0.10	0.42
	1997	0.03	0.22	
Pygmy nuthatch	1996	1.32	0.96	**<0.0005**
	1997	0.21	0.43	
Red-breasted nuthatch	1996	0.03	0.18	0.32
	1997	0.01	0.10	
Red crossbill	1996	0.17	0.65	0.61
	1997	0.15	0.47	
Red-tailed hawk	1996	0.01	0.10	0.32
	1997	0.00	0.00	
Scrub jay	1996	0.00	0.00	0.32
	1997	0.01	0.10	
Solitary vireo	1996	0.59	0.68	**0.056**
	1997	0.43	0.57	
Spotted towhee	1996	0.47	0.65	**0.048**
	1997	0.38	0.68	
Steller jay	1996	0.33	0.56	**0.047**
	1997	0.55	0.83	

Townsend solitaire	1996	0.13	0.34	0.20
	1997	0.20	0.42	
Turkey vulture	1996	0.01	0.10	0.32
	1997	0.00	0.00	
Violet green swallow	1996	0.24	0.60	0.15
	1997	0.15	0.47	
Virginia warbler	1996	0.21	0.48	**0.032**
	1997	0.09	0.31	
Warbling vireo	1996	0.11	0.34	0.49
	1997	0.15	0.41	
Western bluebird	1996	0.35	0.62	0.45
	1997	0.49	0.70	
Western tanager	1996	0.78	0.67	**0.058**
	1997	0.63	0.62	
Western wood peewee	1996	0.12	0.32	0.11
	1997	0.04	0.20	
White-breasted nuthatch	1996	1.05	0.71	**0.033**
	1997	0.89	0.74	
White-throated swift	1996	0.04	0.25	0.18
	1997	0.00	0.00	
Wild turkey	1996	0.02	0.15	0.57
	1997	0.01	0.10	
Williamson sapsucker	1996	0.01	0.10	0.32
(bred on site in 1996)	1997	0.00	0.00	
Yellow rumped warbler	1996	0.54	0.67	0.91
	1997	0.56	0.63	

[a] t-test cannot be performed because the standard deviation was 0.

Table 2. Number of nests that fledged young during 1996-1997 on the Control and Treatment Areas at the Mt. Trumbull study site.

Species	Number of Nests Fledging Young			Approx. Ratio
	Treatment Area	Control Area	Total	(Treatment to Total)
Mountain chickadee	4	7	11	0.40
Northern flicker	5	4	9	0.55
Pygmy nuthatch	7	3	10	0.70
Solitary vireo	8	5	13	0.60
White-breasted nuthatch	11	9	20	0.55
Western bluebird	17	7	24	0.70
Western tanager	14	10	24	0.60
Total	66	45	111	

Table 3. Percentage of trees by species and tree class (live or snag) available on MTRCA, in comparison to trees selected for nests by 7 focal species. Available tree distribution tallied on 89 plots (20x20-m each).

Tree category	Available	Mountain chickadee	Northern flicker	Pygmy nuthatch	Solitary vireo	White-breasted nuthatch	Western bluebird	Western tanager
Live ponderosa pine	58%	42%	0%	42%	34%	25%	35%	97%
Live Gambel oak	17%	0%	0%	0%	59%	42%	27%	3%
Live pinyon or juniper	17%	0%	0%	0%	7%	13%	4%	0%
Ponderosa pine snag	1%	42%	50%	50%	0%	8%	27%	0%
Gambel oak snag	6%	17%	50%	8%	0%	13%	8%	0%
Pinyon or juniper snag	1%	0%	0%	0%	0%	0%	0%	0%
Total	3422 trees	12 nests	8 nests	12 nests	29 nests	24 nests	26 nests	30 nests

Table 4. Percentage of trees, by size class within tree category, available on MTRCA, in comparison to trees selected for nests by 7 focal species.

Tree category	Size class	Available	Mountain chickadee	Northern flicker	Pygmy nuthatch	Solitary vireo	White-breasted nuthatch	Western bluebird	Western tanager
Live ponderosa pine	0-1"	9%	0%	0%	0%	0%	0%	0%	0%
	1-5"	36%	0%	0%	0%	30%	0%	0%	0%
	5-12"	40%	0%	0%	0%	20%	0%	0%	14%
	12-18"	12%	20%	25%	0%	30%	0%	0%	31%
	18-24"	2%	0%	25%	40%	20%	16%	0%	28%
	>24"	1%	80%	50%	60%	0%	84%	100%	28%
	total	1991 trees	5 nests	4 nests	5 nests	10 nests	6 nests	9 nests	29 nests
Ponderosa pine snags	0-1"	20%	0%	0%	0%		0%	0%	
	1-5"	57%	0%	0%	0%		0%	0%	
	5-12"	16%	40%	0%	33%		33%	0%	
	12-18"	6%	20%	25%	17%		0%	43%	
	18-24"	0%	0%	0%	33%		33%	43%	
	>24"	2%	40%	75%	17%		33%	14%	
	total	51 snags	5 nests	4 nests	6 nests	none	3 nests	7 nests	none
Live Gambel oak	0-1"	43%				13%	0%	0%	0%
	1-5"	24%				7%	0%	0%	0%
	5-12"	33%				73%	90%	86%	100%
	12-18"	0.5%				7%	10%	14%	0%
	18-24"	0%				0%	0%	0%	0%
	>24"	0.2%				0%	0%	0%	0%
	total	565 trees	none	none	none	15 nests	10 nests	7 nests	1 nest
Gambel oak snags	0-1"	1%	0%		0%		0%	0%	
	1-5"	75%	0%		0%		0%	0%	
	5-12"	22%	100%		100%		50%	50%	
	12-18"	1%	0%		0%		50%	50%	
	18-24"	0.5%	0%		0%		0%	0%	
	>24"	0%	0%		0%		0%	0%	
	total	204 snags	2 nests	none	1 nest	none	2 nests	2 nests	none

Table 5. Vegetation and physical characteristics on 27 0.04-ha plots in which **solitary vireos** nested during June 1996 or June 1997, and 89 random plots, in ponderosa pine forests at the Mount Trumbull study area. Except as noted, all tests were 2-tailed t-tests of the null hypothesis that the mean difference is zero.

	Used Plots		Available Plots		P
Characteristic	Mean	SD	Mean	SD	
Aspect (% of plots)					0.08[a]
316-45°	22	42	38	49	
46-135°	37	49	28	45	
136-225°	11	32	19	40	
226-315°	22	42	11	33	
Flat	7	27	3	18	
% ground cover					0.18[b]
Rock	3.9	5.5	5.1	6.8	
Bare ground, including roads	14.6	10.8	13.2	12.0	
Litter	67.1	23.0	75	17	
Shrub	10.0	14.4	4.1	6.9	
Grass or forb	4.3	6.4	2.3	4.5	
% slope	5.9	5.8	10.6	9.4	**0.003**
% Canopy Closure	48.7	15.8	46	13	0.38
Logs	2.4	2.5	1.6	1.7	0.19
Total trees (excluding locust)	27.7		35.2	27.4	0.23
Ponderosa pines:					
0-12.7 cm dbh	8.0	11.2	10.1	15.4	0.73
12.7-30.5 cm dbh	6.4	7.3	8.9	9.8	0.11
>30.5 cm dbh	3.3	2.9	3.4	2.7	0.72
Oaks:					
0-12.7 cm dbh	3.3	8.3	4.2	9.8	0.76
12.7-30.5 cm dbh	4.7	6.6	2.1	4.4	**0.006**
>30.5 cm dbh	0.22	0.4	0.04	0.21	**0.04**
Pinyon or Junipers:					
0-12.7 cm dbh	1.4	3.2	4.9	8.0	**0.005**
12.7-30.5 cm dbh	0.4	1.1	1.5	2.7	**0.008**
>30.5 cm dbh	0.04	0.2	0.2	0.6	0.13
Locust stems	11.6	35.2	2.7	12.7	0.25
Total snags	2.6	2.6	3.2	5.2	0.63
Ponderosa pine snags					
0-12.7 cm dbh	0.22	0.51	0.44	1.89	0.56
12.7-30.5 cm dbh	0.04	0.19	0.09	0.38	0.77
>30.5 cm dbh	0.07	0.27	0.04	0.21	0.52
Oak snags					
0-12.7 cm dbh	1.0	1.5	1.8	3.9	0.63
12.7-30.5 cm dbh	0.78	1.15	0.51	1.23	0.10
>30.5 cm dbh	0.07	0.27	0.04	0.24	0.40
Area occupied by oak clumps	39.5	70.0	23.7	44.9	0.17
Number of oak clumps	1.30	1.23	1.24	1.58	0.51
Mean large tree spacing (m)	7.9	4.4	5.2	2.8	0.33
(n plots with trees > 15")	(16)		(56)		

[a] chi-square analysis.

[b] compositional analysis using MANOVA of log-ratio-transformed percents.

Table 6. Vegetation and physical characteristics on 24 0.04-ha plots in which **white-breasted nuthatches** nested during June 1996 or June 1997, and 89 random plots, in ponderosa pine forests at the Mount Trumbull study area. Except as noted, all tests were 2-tailed t-tests of the null hypothesis that the mean difference is zero.

	Used Plots		Available Plots		P
Characteristic	Mean	SD	Mean	SD	
Aspect (% of plots)					**0. 0207**[a]
316-45°	17	38	38	49	
46-135°	54	51	28	45	
136-225°	13	34	19	40	
226-315°	8	28	11	33	
Flat	8	28	3	18	
% ground cover					0.057[b]
Rock	2.0	3.6	5.1	6.8	
Bare ground, including roads	8.6	7.2	13.2	12.0	
Litter	83.9	9.7	75	17	
Shrub	2.9	4.0	4.1	6.9	
Grass or forb	2.4	4.8	2.3	4.5	
% slope	7.2	5.9	10.6	9.4	**0. 035**
% Canopy Closure	53	9	46	13	**0. 003**
Logs	2.1	1.8	1.6	1.7	0. 120
Total trees (excluding locust)	34.0	12.6	35.2	27.4	0. 479
Ponderosa pines:					
0-12.7 cm dbh	6.8	11.3	10.1	15.4	0. 515
12.7-30.5 cm dbh	9.5	7.5	8.9	9.8	0. 417
>30.5 cm dbh	4.0	2.6	3.4	2.7	0. 219
Oaks:					
0-12.7 cm dbh	1.8	2.7	4.2	9.8	0. 439
12.7-30.5 cm dbh	4.2	5.7	2.1	4.4	0. 110
>30.5 cm dbh	0.75	1.0	0.04	0.21	0. 002
Pinyon or Junipers:					
0-12.7 cm dbh	4.2	6.8	4.9	8.0	0. 867
12.7-30.5 cm dbh	2.1	3.5	1.5	2.7	0. 508
>30.5 cm dbh	0.7	1.5	0.2	0.6	0. 056
Locust stems	0.6	3.1	2.7	12.7	0. 085
Total snags	4.3	6.1	3.2	5.2	0. 335
Ponderosa pine snags					
0-12.7 cm dbh	0.37	0.71	0.44	1.89	0. 652
12.7-30.5 cm dbh	0.08	0.28	0.09	0.38	0. 908
>30.5 cm dbh	0.08	0.28	0.04	0.21	0. 461
Oak snags					
0-12.7 cm dbh	1.8	4.0	1.8	3.9	0. 894
12.7-30.5 cm dbh	1.21	2.17	0.51	1.23	0. 121
>30.5 cm dbh	0.25	0.61	0.04	0.24	0. 086
Area occupied by oak clumps	27.4	43.0	23.7	44.9	0. 716
Number of oak clumps	1.04	0.95	1.24	1.58	0. 993
Mean large tree spacing (m)	8.1	4.5	5.2	2.8	**0. 010**
(n plots with trees > 15")	(22)		(56)		

[a] chi-square analysis.

[b] compositional analysis using MANOVA of log-ratio-transformed percents.

Table 7. Vegetation and physical characteristics on 26 0.04-ha plots in which **western bluebirds** nested during June 1996 or June 1997, and 89 random plots, in ponderosa pine forests at the Mount Trumbull study area. Except as noted, all tests were 2-tailed t-tests of the null hypothesis that the mean difference is zero.

	Used Plots		Available Plots		P
Characteristic	Mean	SD	Mean	SD	
Aspect (% of plots)					0.30[a]
316-45°	31	47	38	49	
46-135°	46	51	28	45	
136-225°	12	33	19	40	
226-315°	12	33	11	33	
Flat	0	0	3	18	
% ground cover					0.23[b]
Rock	3.3	3.8	5.1	6.8	
Bare ground, including roads	7.3	7.4	13.2	12.0	
Litter	86.2	8.8	75	17	
Shrub	2.1	2.1	4.1	6.9	
Grass or forb	1.2	2.9	2.3	4.5	
% slope	7.7	4.2	10.6	9.4	**0. 031**
% Canopy Closure	53	8.8	46	13	**0. 002**
Logs	2.1	1.82	1.6	1.7	0. 151
Total trees (excluding locust)	33.6	22.3	35.2	27.4	0. 977
Ponderosa pines:					
0-12.7 cm dbh	14.5	18.8	10.1	15.4	0. 148
12.7-30.5 cm dbh	8.0	4.6	8.9	9.8	0. 571
>30.5 cm dbh	4.4	2.5	3.4	2.7	0. 043
Oaks:					
0-12.7 cm dbh	2.2	6.63	4.2	9.8	0. 210
12.7-30.5 cm dbh	1.3	2.26	2.1	4.4	0. 600
>30.5 cm dbh	0.0	0.0	0.04	0.21	0. 054
Pinyon or Junipers:					
0-12.7 cm dbh	1.8	3.72	4.9	8.0	0. 025
12.7-30.5 cm dbh	1.2	2.64	1.5	2.7	0. 797
>30.5 cm dbh	0.2	0.49	0.2	0.6	0. 570
Locust stems	0.2	0.78	2.7	12.7	0. 009
Total snags	1.9	3.45	3.2	5.2	0. 275
Ponderosa pine snags					
0-12.7 cm dbh	0.04	0.20	0.44	1.89	**0. 010**
12.7-30.5 cm dbh	0.04	0.20	0.09	0.38	0. 543
>30.5 cm dbh	0.15	0.46	0.04	0.21	0. 272
Oak snags					
0-12.7 cm dbh	0.85	2.13	1.8	3.9	0. 120
12.7-30.5 cm dbh	0.58	1.55	0.51	1.23	0. 857
>30.5 cm dbh	0.04	0.20	0.04	0.24	0. 785
Area occupied by oak clumps	12.9	28.8	23.7	44.9	0. 253
Number of oak clumps	0.65	1.0	1.24	1.58	0. 076
Mean large tree spacing (m)	6.5	4.5	5.2	2.8	0. 232
(n plots with trees > 15")	(24)		(56)		

[a] chi-square analysis.

[b] compositional analysis using MANOVA of log-ratio-transformed percents.

Table 8. Vegetation and physical characteristics on 31 0.04-ha plots in which **western tanagers** nested during June 1996 or June 1997, and 89 random plots, in ponderosa pine forests at the Mount Trumbull study area. Except as noted, all tests were 2-tailed t-tests of the null hypothesis that the mean difference is zero.

	Used Plots		Available Plots		P
Characteristic	Mean	SD	Mean	SD	
Aspect (% of plots)					**0. 0052[a]**
316-45°	23	43	38	49	
46-135°	42	50	28	45	
136-225°	16	37	19	40	
226-315°	6	25	11	33	
Flat	13	34	3	18	
% ground cover					0. 007[b]
Rock	2.0	4.6	5.1	6.8	
Bare ground, including roads	9.5	7.8	13.2	12.0	
Litter	76.3	17.9	75	17	
Shrub	5.6	7.1	4.1	6.9	
Grass or forb	6.6	11.3	2.3	4.5	
% slope	6.2	6.1	10.6	9.4	0. 004
% Canopy Closure	46	12	46	13	0. 982
Logs	2.4	2.4	1.6	1.7	0. 114
Total trees (excluding locust)	21.1	15.4	35.2	27.4	0. 002
Ponderosa pines:					
0-12.7 cm dbh	5.3	8.0	10.1	15.4	0. 095
12.7-30.5 cm dbh	7.0	7.8	8.9	9.8	0. 266
>30.5 cm dbh	4.9	3.2	3.4	2.7	0. 010
Oaks:					
0-12.7 cm dbh	1.4	4.3	4.2	9.8	0. 014
12.7-30.5 cm dbh	1.0	2.5	2.1	4.4	0. 101
>30.5 cm dbh	0.03	0.2	0.04	0.21	0. 763
Pinyon or Junipers:					
0-12.7 cm dbh	1.1	1.9	4.9	8.0	0. 001
12.7-30.5 cm dbh	0.2	0.7	1.5	2.7	0. 000
>30.5 cm dbh	0.03	0.2	0.2	0.6	0. 090
Locust stems	8.2	32.2	2.7	12.7	0. 462
Total snags	1.0	1.9	3.2	5.2	0. 001
Ponderosa pine snags					
0-12.7 cm dbh	0.32	0.98	0.44	1.89	0. 847
12.7-30.5 cm dbh	0.06	0.36	0.09	0.38	0. 611
>30.5 cm dbh	0.03	0.18	0.04	0.21	0. 763
Oak snags					
0-12.7 cm dbh	0.35	1.05	1.8	3.9	0. 002
12.7-30.5 cm dbh	0.16	0.58	0.51	1.23	0. 061
>30.5 cm dbh	0.03	0.18	0.04	0.24	0. 893
Area occupied by oak clumps	14.9	34.5	23.7	44.9	0. 323
Number of oak clumps	0.52	0.7	1.24	1.58	0. 013
Mean large tree spacing (m)	5.6	4.0	5.2	2.8	0. 668
(n plots with trees > 15")	(28)		(56)		

[a] chi-square analysis.

[b] compositional analysis using MANOVA of log-ratio-transformed percents.

Table 9. Vegetation and physical characteristics on 8 0.04-ha plots in which **northern flickers** nested during June 1996 or June 1997, and 89 random plots, in ponderosa pine forests at the Mount Trumbull study area. Except as noted, all tests were 2-tailed t-tests of the null hypothesis that the mean difference is zero.

	Used Plots		Available Plots		P
Characteristic	Mean	SD	Mean	SD	
Aspect (% of plots)					0.48[a]
316-45°	50	53	38	49	
46-135°	25	46	28	45	
136-225°	0	0	19	40	
226-315°	25	46	11	33	
Flat	0	0	3	18	
% ground cover					0.89[b]
Rock	4.5	4.4	5.1	6.8	
Bare ground, including roads	10.6	11.1	13.2	12.0	
Litter	77	21	75	17	
Shrub	5.4	9.0	4.1	6.9	
Grass or forb	2.3	4.8	2.3	4.5	
% slope	9.4	6.4	10.6	9.4	0.73
% Canopy Closure	52	17	46	13	0.26
Logs	3.0	2.4	1.6	1.7	**0.032**
Total trees (excluding locust)	43.6	33.4	35.2	27.4	0.44
Ponderosa pines:					
0-12.7 cm dbh	28.8	28.5	10.1	15.4	**0.005**
12.7-30.5 cm dbh	10	7	8.9	9.8	0.56
>30.5 cm dbh	3.4	1.4	3.4	2.7	0.59
Oaks:					
0-12.7 cm dbh	0.3	0.7	4.2	9.8	**0.001**
12.7-30.5 cm dbh	0.0	0.0	2.1	4.4	**<0.0005**
>30.5 cm dbh	0.0	0.0	0.04	0.21	0.55
Pinyon or Junipers:					
0-12.7 cm dbh	0.6	1.2	4.9	8.0	**0.005**
12.7-30.5 cm dbh	0.6	0.9	1.5	2.7	0.53
>30.5 cm dbh	0.0	0.0	0.2	0.6	0.37
Locust stems	0.1	0.4	2.7	12.7	0.43
Total snags	1.5	2.7	3.2	5.2	0.36
Ponderosa pine snags					
0-12.7 cm dbh	0.13	0.35	0.44	1.89	0.61
12.7-30.5 cm dbh	0.13	0.35	0.09	0.38	0.65
>30.5 cm dbh	0.50	0.76	0.04	0.21	0.12
Oak snags					
0-12.7 cm dbh	0.75	2.12	1.8	3.9	0.30
12.7-30.5 cm dbh	0.0	0.0	0.51	1.23	**<0.0005**
>30.5 cm dbh	0.0	0.0	0.04	0.24	0.88
Area occupied by oak clumps	1.9	5.3	23.7	44.9	**<0.0005**
Number of oak clumps	0.13	0.35	1.24	1.58	**0.001**
Mean large tree spacing (m)	6.8	6.8	5.2	2.8	0.54
(n plots with trees > 15")	( )		(56)		

[a] chi-square analysis; in this case results are suspect due to very small sample size.

[b] compositional analysis using MANOVA of log-ratio-transformed percents.

Table 10. Vegetation and physical characteristics on 12 0.04-ha plots in which **mountain chickadees** nested during June 1996 or June 1997, and 89 random plots, in ponderosa pine forests at the Mount Trumbull study area. Except as noted, all tests were 2-tailed t-tests of the null hypothesis that the mean difference is zero.

	Used Plots		Available Plots		**P**
Characteristic	Mean	SD	Mean	SD	
Aspect (% of plots)					0.26[a]
316-45°	42	51	38	49	
46-135°	8	29	28	45	
136-225°	42	51	19	40	
226-315°	8	29	11	33	
Flat	0	0	3	18	
% ground cover					**0.006[b]**
Rock	3.7	4.5	5.1	6.8	
Bare ground, including roads	6.3	8.1	13.2	12.0	(0.002)
Litter	78	26	75	17	
Shrub	2.7	4.9	4.1	6.9	
Grass or forb	9.5	20.8	2.3	4.5	
% slope	8.6	6.6	10.6	9.4	0.48
% Canopy Closure	52	12	46	13	0.11
Logs	2.8	2.1	1.6	1.7	0.057
Total trees (excluding locust)	47.0	35.9	35.2	27.4	0.21
Ponderosa pines:					
0-12.7 cm dbh	22.0	25.4	10.1	15.4	0.20
12.7-30.5 cm dbh	13.5	13.7	8.9	9.8	0.31
>30.5 cm dbh	3.1	2.5	3.4	2.7	0.99
Oaks:					
0-12.7 cm dbh	2.7	4.7	4.2	9.8	0.87
12.7-30.5 cm dbh	2.9	3.4	2.1	4.4	0.26
>30.5 cm dbh	0.0	0.0	0.04	0.21	0.46
Pinyon or Junipers:					
0-12.7 cm dbh	2.5	3.8	4.9	8.0	0.43
12.7-30.5 cm dbh	0.3	0.8	1.5	2.7	**0.022**
>30.5 cm dbh	0.0	0.0	0.2	0.6	**0.004**
Locust stems	0.3	0.7	2.7	12.7	0.54
Total snags	3.9	5.1	3.2	5.2	0.40
Ponderosa pine snags					
0-12.7 cm dbh	2.17	5.17	0.44	1.89	0.22
12.7-30.5 cm dbh	0.25	0.62	0.09	0.38	0.39
>30.5 cm dbh	0.17	0.39	0.04	0.21	0.31
Oak snags					
0-12.7 cm dbh	0.58	1.16	1.8	3.9	0.28
12.7-30.5 cm dbh	0.58	1.44	0.51	1.23	0.82
>30.5 cm dbh	0.0	0.0	0.04	0.24	0.61
Area occupied by oak clumps	16.8	23.1	23.7	44.9	0.60
Number of oak clumps	0.67	0.98	1.24	1.58	0.25
Mean large tree spacing (m)	8.5	5.4	5.2	2.8	0.06
(n plots with trees > 15")	(12)		(56)		

[a] chi-square analysis; in this case results are suspect due to very small sample size.

[b] compositional analysis using MANOVA of log-ratio-transformed percents.

Table 11. Vegetation and physical characteristics on 11 0.04-ha plots in which **pygmy nuthatches** nested during June 1996 or June 1997, and 89 random plots, in ponderosa pine forests at the Mount Trumbull study area. Except as noted, all tests were 2-tailed t-tests of the null hypothesis that the mean difference is zero.

	Used Plots		Available Plots		P
Characteristic	Mean	SD	Mean	SD	
Aspect (% of plots)					0.25[a]
316-45°	27	47	38	49	
46-135°	45	52	28	45	
136-225°	0	0	19	40	
226-315°	18	40	11	33	
Flat	9	30	3	18	
% ground cover					0.88[b]
Rock	5	7	5.1	6.8	
Bare ground, including roads	13	17	13.2	12.0	
Litter	77	18	75	17	
Shrub	3	3	4.1	6.9	
Grass or forb	2	5	2.3	4.5	
% slope	9.4	8.4	10.6	9.4	0.67
% Canopy Closure	50	16	46	13	0.36
Logs	3.2	2.4	1.6	1.7	**0.033**
Total trees (excluding locust)	35.5	21.7	35.2	27.4	0.80
Ponderosa pines:					
0-12.7 cm dbh	15.4	15.0	10.1	15.4	0.13
12.7-30.5 cm dbh	8.9	5.7	8.9	9.8	0.67
>30.5 cm dbh	4.5	2.8	3.4	2.7	0.25
Oaks:					
0-12.7 cm dbh	0.5	0.8	4.2	9.8	**0.014**
12.7-30.5 cm dbh	0.8	2.1	2.1	4.4	0.15
>30.5 cm dbh	0	0	0.04	0.21	0.48
Pinyon or Junipers:					
0-12.7 cm dbh	4.1	6.0	4.9	8.0	0.99
12.7-30.5 cm dbh	0.9	1.9	1.5	2.7	0.42
>30.5 cm dbh	0.36	0.67	0.2	0.6	0.28
Locust stems	0.09	0.30	2.7	12.7	0.32
Total snags	2.2	3.0	3.2	5.2	0.83
Ponderosa pine snags					
0-12.7 cm dbh	0.18	0.40	0.44	1.89	0.77
12.7-30.5 cm dbh	0.09	0.30	0.09	0.38	0.87
>30.5 cm dbh	0.45	0.52	0.04	0.21	**0.03**
Oak snags					
0-12.7 cm dbh	1.3	2.9	1.8	3.9	0.49
12.7-30.5 cm dbh	0	0	0.51	1.23	**<0.0005**
>30.5 cm dbh	0	0	0.04	0.24	0.62
Area occupied by oak clumps	7.8	17.9	23.7	44.9	0.25
Number of oak clumps	0.55	0.69	1.24	1.58	0.23
Mean large tree spacing (m)	6.2	5.1	5.2	2.8	0.58
(n plots with trees > 15")	(9)		(56)		

[a] chi-square analysis; in this case results are suspect due to very small sample size.

[b] compositional analysis using MANOVA of log-ratio-transformed percents.

APPENDIX B: 1997 PLANT LIST, MT. TRUMBULL, AZ

Family	Species	Common Name	Nat/Exotic	Location
Amaranthaeceae	Amaranthus albus (= graecizans)+	prostrate pigweed	exotic	
Anacardiaceae	Rhus glabra+	smooth sumac	native	Lava burn
	Rhus trilobata+	skunkbush sumac	native	
Apiaceae	Cymopterus purpureus@	purple springparsley	native	
Asclepiadaceae	Asclepias asperula var. asperula	antelope horns	native	
	Asclepias subverticillata+	whorled milkweed	native	
Asteraceae	Agoseris glauca+	pale mountain dandelion	native	
	Artemisia carruthii+	Carruth's sagewort	native	
	Artemisia tridentata	big sagebrush	native	
	Aster foliaceus (prob. var. parryi)+	Parry's aster	native	
	Brickellia grandiflora+	tasselflower brickellbush	native	Lava flows
	Chaenactis douglasii	Douglas' dustymaiden	native	
	Conyza canadensis**	horseweed	exotic?	
	Erigeron bellidiastrum@	western daisy fleabane	native	
	Erigeron divergens	spreading fleabane	native	
	Erigeron flagellaris+	trailing fleabane	native	
	Gutierrezia sarothrae+	broom snakeweed	exotic	
	Hymenopappus filifolius	fineleaf hymenopappus	native	
	Hymenoxys acaulis+	ncn	native	crest of Mt. Logan
	Hymenoxys cooperi	Cooper's hymenoxys	native	
	Machaeranthera canescens+	hoary aster	native	
	Senecio eremophilus (= macdougallii)+	Macdougall's groundsel	native	
	Senecio multilobatus	lobeleaf groundsel	native	
	Taraxacum officinale+	common dandelion	exotic	
	Townsendia ambigua (incana, scapigera)@	hoary townsendia	native	
	Tragopogon dubius+	yellow salsify	exotic	
	Verbesina encelioides+	golden crownbeard	native	
	Viguiera multiflora+	showy goldeneye	native	
Berberidaceae	Berberis fremontii	Fremont's mahonia	native	
	Berberis repens+	Oregon-grape	native	
Boraginaceae	Cryptantha cinerea var. cinerea (= C. jamesii)+	James' catseye	native	
	Lappula occidentalis (= L. redowskii)+	desert stickseed	exotic	
	Mertensia sp.*+	oblongleaf bluebells	native	
Brassicaceae	Arabis holboellii var. fendleri (=A. fendleri var. fend.)+	Fendler's rockcress	native	

Family	Species	Common Name	Nat/Exotic	Location
	Descurainia californica*	Sierran tansymustard		
	Descurainia pinnata+	western tansymustard		
	Lepidium densiflorum+	common pepperweed		
	Streptanthus cordatus+	twistflower	native	near trail on Mount Trumbull
Capparaceae	Cleome lutea+	yellow spiderflower	native	
	Cleome serrulata+	Rocky Mtn. bee plant	native	
Caprifoliaceae	Sambucus nigra ssp. cerulea (= S. glauca)	blue elder	native	
	Symphoricarpos oreophilis+	whortleleaf snowberry	native	
Caryophyllaceae	Arenaria fendleri var. glabrescens (= v. aculeata)+	ncn	native	
	Silene scouleri+	Scouler's campion	native	Top of Mt. Logan
	Stellaria longipes+	longstalk starwort	exotic?	
Chenopodiaceae	Chenopodium album var. berlandieri+	lambsquarters	exotic	
	Chenopodium graveolens	lambsquarters	native	
Convulvulaceae	Convulvulus arvensis+	field bindweed	exotic	
Cyperaceae	Carex occidentalis+	common sedge	native	
	Carex sp. *	sedge	native	Old Folk's Home
Ericaceae	Arctostaphylos platyphylla@ (=A. patula var. platy.)	greenleaf manzanita	native	
	Arctostaphylos pungens	pointleaf manzanita	native	
Euphorbiaceae	Euphorbia lurida	San Francisco mountain spurge	native	
	Euphorbia montana@			
	Euphorbia serpyllifolia+	thymeleaf sandmat		
Fabaceae	Astragalus argophyllus+	silverleaf milkvetch	native	
	Dalea candida var. oligophylla +	western prairie-clover	native	
	Dalea polygonoides@	sixweeks prairieclover	native	
	Lotus humistratus@	foothill deervetch	native	
	Lotus utahensis	Utah trefoil	native	
	Lotus wrightii	Wright's trefoil	native	
	Lupinus argenteus	silver lupine	native	
	Lupinus greenei@ (= L. formosus var. robustus)	summer lupine	native	
	Lupinus kingii+	King's lupine	native	
	Medicago sativa+	alfalfa	exotic	
	Melilotus oficinalis+	yellow sweet-clover	exotic	
	Petalostemon searlsiae@ (= Dalea searlsiae)	Searl's prairieclover	native	
	Phaseolus angustissima	Arizona lima bean	native	Logan burn
	Psoralidium tenuiflorum (Psoralea tenuiflora)+	slimflower scurfpea	native	
	Robinia neomexicana	New Mexican locust	native	

Family	Species	Common Name	Nat/Exotic	Location
	Vicia americana+	American vetch	native	
Fagaceae	Quercus gambelii (Cottam - Q. utahensis)	gambel oak	native	
	Quercus turbinella+	turbinella oak	native	
Fumiariaceae	Corydalis aurea	golden corydalis	native	crest of Mt. Trumbull, 96-1
Garryaceae	Garrya flavescens	ashy silktassel	native	
Gentianaceae	Swertia albomarginata	white-margined swertia	native	along Cty. Rd. 5
	Swertia radiata+	deers' ears	native	
Geraniaceae	Erodium cicutarium	redstem stork's bill	exotic?	
	Geranium caespitosum+	pineywoods geranium	native	
	Geranium richardsonii+	Richardson's geranium	native	
Hydrophyllaceae	Nama dichotomum**+	wishbone fiddleleaf	native	
	Phacelia corrugata@ (= crenulata var. corrugata)	cleftleaf wild heiotrope	native	
	Phacelia magellanica+	varileaf phacelia	native	
	Phacelia sp. #	phacelia		Lava fire
Lamiaceae	Leonurus cardiaca+	common motherwort	exotic	
	Marrubium vulgare+	horehound	exotic	
	Moldavica parviflora+	smallflower dragonhead		
	Monardella odoratissima+	Pacific monardella	native	Lava flows
	Nepeta cataria *	catnip	exotic	
Liliaceae	Allium bisceptrum+	twincrest onion	native	
	Calochortus nuttallii@	sego lily	native	
	Fritillaria atropurpurea *	spotted missionbells	native	
Linaceae	Linum aristatum *	bristle flax	native	
	Linum lewisii	prairie flax	native	
Loasaceae	Mentzelia pumila+	dwarf mentzelia	native	
Malvaceae	Sphaeralcea sp.*	globemallow	native	
	Sphaeralcea subrhomboidea (munroana)@	Munro's globemallow	native	
Monotropaceae	Pterospora andromedea+	pinedrops	native	
Nyctaginaceae	Mirabilis decipiens+	broadleaf four o'clock	native	
	Mirabilis linearis	narrowleaf umbrellawort	native	
	Mirabilis oxybaphoides+	smooth spreading four o'clock	native	
Onagraceae	Camissonia chamaenerioides**+	long-capsuled primrose	native	
	Oenothera cespitosa+	tufted eveningprimrose	native	
	Oenothera coronopifolia+	crownleaf eveningprimrose	native	
Orobanchaceae	Orobanche fasciculata@ (= Cottam's Thalesia f.)	clustered broomrape	native	
	Orobanche sp. *	broomrape		

Family	Species	Common Name	Nat/Exotic	Location
Papaveraceae	Argemone munita	flatbud pricklypoppy	native	
Pinaceae	Pinus ponderosa	ponderosa pine	native	
Poaceae	Agropyron cristatum+	crested wheatgrass	exotic	
	Agropyron elongatum (=Elymus elongatus)+	tall wheatgrass	exotic	
	Agropyron intermedium var. intermedium (E. intermedium)+	intermediate wheatgrass	exotic	
	Agropyron intermedium var. trichophorum (E. trichophorum)+	intermediate wheatgrass	exotic	
	Agropyron trachycaulum var. trachycaulum (E. trachycaulum)+	slender wheatgrass		
	Aristida fendleriana@	Fendler three-awn	native	
	Aristida purpurea var. longiseta+	purple three-awn	native	
	Bouteloua curtipendula+	side-oats grama	native	
	Bouteloua gracilis+	blue grama	native	
	Bromus ciliatus+	fringed brome		
	Bromus inermis+	smooth brome	exotic	
	Bromus tectorum+	cheatgrass	exotic	
	Eragrostis mexicana@	Mexican lovegrass		
	Festuca arizonica+	Arizona fescue	native	Logan burn
	Koeleria macrantha (= K. nitida, K. cristata)	Junegrass	native	
	Muhlenbergia minutissima+	annual muhly	native	
	Muhlenbergia wrightii+	spike muhly	native	
	Munroa squarrosa+	ncn	native	Logan burn
	Oryzopsis micrantha+	ncn	native	
	Poa fendleriana	muttongrass	native	
	Poa pratensis+	Kentucky bluegrass	exotic	
	Schizachyrium scoparium+	little bluestem	native	Lava flows
	Secale cereale+	rye	exotic	
	Sitanion hystrix	squirreltail	native	
	Sporobolus cryptandrus+	sand dropseed		
Polemoniaceae	Gilia arizonica@ (= Ipomopsis arizonica)	Arizona skyrocket	native	
	Gilia sinuata (inconspicua)@	rosy gilia	native	
	Ipomopsis aggregata	skyrocket gilia	native	
	Ipomopsis multiflora+	manyflowered gilia	native	
	Phlox longifolia (= var. stansburiana)	longleaf phlox	native	
Polygonaceae	Eriogonum corymbosum var. corymbosum+	crispleaf buckwheat	native	
	Eriogonum deflexum+	flatcrown buckwheat	native	
	Eriogonum pharnaceoides var. cervinum	wirestem buckwheat	native	
	Eriogonum racemosum+	redroot buckwheat	native	

Family	Species	Common Name	Nat/Exotic	Location
	Eriogonum umbellatum+	sulphur wildbuckwheat	native	
	Polygonum convolvulus+	black bindweed	exotic	
	Polygonum sawatchense+	Douglas' knotweed	native	
Polypodiaceae	Cheilanthes feei@	slender lipfern	native	
	Cystopteris fragilis	brittle bladderfern	native	
	Woodsia scopulina@	Rocky Mountain woodsia	native	
Portulaceae	Portulaca oleracea+	purslane (little hogweed)	exotic	
Ranunculaceae	Delphinium menziesii@	Menzies' larkspur	native	
	Delphinium nuttallianum var. nuttallianum	Nelson's larkspur	native	
	Ranunculus oreogenes	mountain buttercup	native	crest of Mt. Logan
	Thalictrum fendleri	Fendler's meadowrue	native	
Rhamnaceae	Ceanothus fendleri+	Fendler's ceanothus	native	
	Ceanothus martinii+	Martin's ceanothus	native	
Rosaceae	Amelanchier alnifolia+	Saskatoon serviceberry	native	
	Antennaria sp. *+	Pussytoes	native	
	Fallugia paradoxa	Apache plume	native	
	Petrophyton caespitosum@ (Cottam - Petrophytum)	mat rockspirea	native	
	Prunus emarginata@	bitter cherry	native	
	Purshia stansburiana (= Cowania st, P. mexicana)	Stansbury cliffrose	native	
	Purshia tridentata+	antelope bitterbush	native	
	Rosa woodsii var. ultramontana (= arizonica)+	Arizona wildrose	native	
Rubiaceae	Galium bifolium	twinleaf bedstraw	native	
	Kelloggia galioides+	milk kelloggia	native	
Rutaceae	Ptelea trifoliata ssp. pallida+	common hoptree	native	
Santalaceae	Comandra pallida	bastard toadflax	native?	
Saxifragaceae	Heuchera rubescens+	pink alumroot	native	
	Ribes cereum	wax currant	native	
Scrophulariaceae	Castilleja integra+	wholeleaf indian paintbrush	native	
	Castilleja linariifolia+	Wyoming indian paintbrush	native	
	Collinsia parviflora+	blue-eyed mary	native	
	Mimulus rubellus **	red monkeyflower	native	
	Pedicularis centranthera+	dwarf lousewort	native	
	Penstemon barbatus+	beardlip penstemon	native	
	Penstemon eatonii@	Eaton's penstemon	native	
	Penstemon linarioides ssp. sileri (= var. sileri)	toadflax penstemon	native	
	Penstemon linarioides var. unknown (or ssp.) *	toadflax penstemon	native	west of Logan burn

Family	Species	Common Name	Nat/Exotic	Location
	Penstemon ophianthus@ (= P. jamesii ssp. oph.)	coiled anther penstemon	native	
	Penstemon pachyphyllus	thick-leaf penstemon	native	
	Penstemon palmeri+	Palmer penstemon	native	
	Penstemon rostriflorus (= bridgesii)	Bridge penstemon	native	
	Penstemon thompsoniae #	Thompson penstemon	native	behind cabin in Logan burn
	Penstemon utahensis *	Utah penstemon	native	Mt. Trumbull below Nixon Springs tank
	Verbascum thapsus+	common mullein	exotic	
Solanaceae	Datura wrightii (=meteloides)+	sacred datura	native	Logan burn
	Nicotiana attenuata+	coyote tobacco	native	
	Physalis hederaefolia+	ivy-leaved ground cherry	native	
	Physalis hederifolia var. palmeri+	Palmer's groundcherry	native	
	Solanum jamesii+	wild potato	native	
	Solanum triflorum+	cutleaf nightshade	native	
Unknown Family	Colpis glauca@			
Unknown Family	Glabra dichotomum@			
Verbenaceae	Verbena bracteata**	bigbract verbena	native	
	Verbena gooddingii	southwestern mock vervain	native	
Violaceae	Viola canadensis	Canadian white violet	native	
Viscaceae	Phoradendron juniperinum	juniper mistletoe	native	

Last updated 3/19/97

* - Not enough plant material for positive ID
** - Emerged in seed bank study, not found on-site
- Not enough plant material to collect
@ - Collected by Cottam & others -
not collected in 1996 by NAU (Check for name changes)
+ - Collected or IDd in 1996 by NAU; not found on the lists
that we have as previously collected in immediate vicinity of MT