

MT. TRUMBULL ECOSYSTEM RESTORATION PROJECT

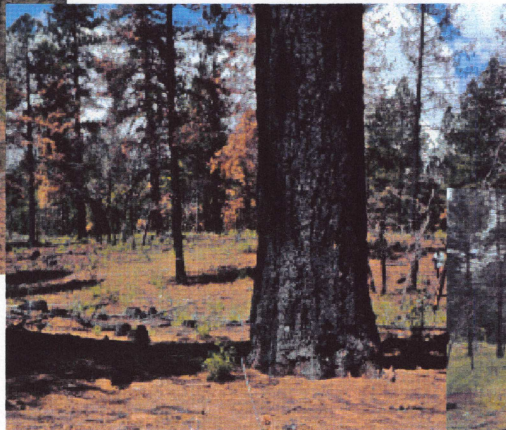
Annual Report for the Year

1995

October 1, 1997 to September 30, 1998



1997



1998



Photos taken from a permanent photopoint in 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 burned in prescription in October 1996. A year and a half after the burn, grasses and wildflowers have begun to come in. Researchers are following successional changes in the herbaceous community.

Submitted to:
Bureau of Land Management
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Prepared by:
Ecological Restoration Program
Northern Arizona University
College of Ecosystem Science and Management
School of Forestry
W. Wallace Covington, Principal Investigator

Compiled by Amy Waltz
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EXECUTIVE SUMMARY

The Mt. Trumbull Resource Conservation Area is typical of most ponderosa pine forests in the southwest. Fire exclusion, grazing and logging have caused contemporary forests to become dense with stressed trees, at the expense of the once diverse grass and wildflower community. Instead of the low intensity ground fires that burned every 3-5 years prior to Euro-American settlement, current fuel loads threaten to support stand-replacing crown fires. These unnatural conditions are not sustainable; active restoration is needed to reset the ecosystem on its natural trajectory.

The project to restore Mt. Trumbull forest to conditions similar to those prior to Euro-American settlement continues at Mt. Trumbull. This multi-disciplinary project is jointly sponsored by the Arizona Strip District Bureau of Land Management, Northern Arizona University and the Arizona Game and Fish Department.

Current forests are being thinned to emulate pre Euro-American settlement tree densities, resulting in open forest stands dominated by large, old trees. Once the landscape is returned to presettlement-like structure, low intensity fire can be reintroduced to the site. The understory will then have a chance to return, resulting in a diversity of wildflowers and grasses.

Researchers continued to examine current forest and vegetation conditions, as well as current arthropod, mammal, and avian populations at the Mt. Trumbull Ecosystem Restoration Project site in 1998. Vegetative monitoring work has been completed on the

experimental block design established in 1997. In addition, the arthropod, mammal and avian studies completed the pre-treatment phase of monitoring. Vegetation was re-monitored in the 46 acres thinned and burned in 1996. Further remeasurements will take place as more units are treated.

New projects initiated included studies of small mammal life history traits, hanta virus infection rates in small rodents, and a preliminary soil analysis of the five experimental blocks. After further restoration treatments, the arthropod, avian and mammal populations will be remeasured to assess their responses to ecosystem restoration. This large, integrative study is possible only through the cooperation of land managing agencies and the university and agency researchers, and will result in an intensive, comprehensive study of ecosystem restoration on a landscape scale.



Flowers bloom in a newly restored unit at Mt. Trumbull. This unit was burned in October 1996, and after a wet 1997-1998 winter, flower and grass density increased.

INTRODUCTION

This document is the third 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.

Featured in this report is the forest and herbaceous post-treatment data available from the first unit treated at Mt. Trumbull. Analyses and discussion of post-treatment data start on page 3 of this report. Post-treatment monitoring provides more information that can be applied to treatments currently occurring in the project (adaptive management). In particular, 13 acres of this unit was reseeded, and 33 acres was not reseeded. Comparisons through time allow researchers to assess the successfulness of reseeding, and the importance of its future implementation in the Mt. Trumbull project.

This report will summarize Northern Arizona University's progress in the 1998 fiscal year on the project, including the 1998 research field season. It does not duplicate data presented in other Bureau of Land Management 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) or the Changes in Ponderosa Pine Forests of the Mt. Logan wilderness (May 1998).

As in the 1997 annual report, research projects are organized into three groups in this report. The first group includes the landscape level research projects, including the monitoring plot project designed to evaluate the effects of the restoration on the Mt. Trumbull ecosystem. This section will include the remeasurement data from the 46 acres treated in 1996. Other 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 research looking at ponderosa pine community stability. The third group is the arthropod and mammal response, projects examining 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 1998 field season is still being analyzed, this document serves primarily to present a summary of work accomplished. Detailed analysis of the 1998 collected data will be included in subsequent annual reports.

RESEARCH PROJECTS

1. LANDSCAPE ANALYSIS AND ECOSYSTEM PATTERNS:

Initial Treatment Area: Post-Treatment Ecosystem Monitoring

Long-term monitoring is essential to assess current conditions, reconstruct presettlement ecosystem structure, and evaluate the effects of restoration treatments. Forty-six acres of the Mt. Trumbull landscape were treated in 1996 (unit 96-1), allowing researchers to remeasure the 3 ecosystem monitoring plots that fell within the unit. Identical variables were measured before and after treatment. 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 and permanent photo points. These data are analyzed below to assess short-term changes. 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 160 treatment plots will be treated, and those plots remeasured. In addition, 55 plots are in areas initially determined to act as controls for various studies; another 34 plots are located in wilderness areas. In addition to the initial post-treatment assessment, control and treatment plots will continue to be monitored on periodic increments over time, to measure the effects of restoration on ecosystem structure and function over time.

Herbaceous:

The treatment has increased herbaceous species richness 4-fold, and increased ground cover by plants from less than 1% in 1996 to more than 40% ground cover in 1998. Herbaceous transects were measured in 1997 and again in 1998, to capture rapid responses. The 96-1 unit is divided into a 13-acre parcel and a 33-acre parcel. The 13-acre parcel was reseeded twice with native seed, while the 33-acre parcel was left to naturally revegetate. We have compiled two separate species lists, one for each parcel, which are listed in Appendix A.

One of the three plots remeasured fell within the reseeded 13-acre unit, the other two plots are in the 33-acre section, which was not reseeded. Below is a table listing the 1998 frequency of plants found on each of these plots, from the most frequent to the least. Because these plots were treated differently, we examined their percent frequency separately. Plot 1384 was reseeded, plots 1385 and 1435 were not. Non-native plants are marked with an asterisk.

The reseeded plot has the highest frequency of non-native plants, possibly because this plot is placed in an area that received the highest fire intensity in the unit. Many non-natives are successful because of their ability to colonize areas of heavy disturbance. The frequency of non-native plants varied from 22.3% on plot 1384 to 4.5% on plot 1385. Overall, we have seen a rise in the frequency of non-natives, from 16% of the plants on a plot to 25% of observed plants on a plot.

Of the 14 species reseeded, on plot 1384 only three were encountered, *Penstemon barbatus*, *Sitanion hystrix* and *Koeleria macrantha*. There also was a species of *Agropyron*, that could not be identified; it may be *smithii* which was seeded. Because the reseeded species were all native to Mt. Trumbull, we cannot confirm if these plants resulted directly from the seeding effort, or from natural seed stock. Of these three species on plot 1384, only one species, *Sitanion hystrix*, appeared on the two plots in the unseeded area. Conversely, some species appeared on the plots in the 33-acre parcel that did not occur in the reseeded

parcel: *Lupinus argenteus*, *Senecio multilobatus*, *Senecio eremophilus*, *Penstemon pachyphyllus*, *Chamaesyce serpyllifolia* and *Phlox gracilis*.

Table 1. Most frequent species, by plot.

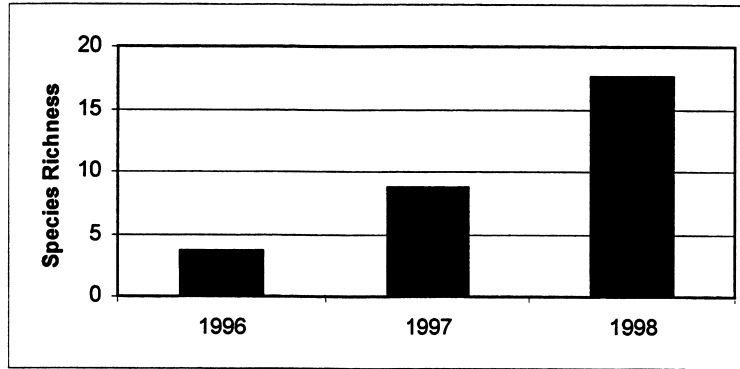
* Non-native. Note: *Chenopodium album* var. *berlandieri* has not been determined as native or exotic (Utah Flora.).

Plot 1384 (reseeded)		Plot 1385		Plot 1435	
Species	Freq.	Species	Freq.	Species	Freq.
<i>Chenopodium album</i> *	21.1*	<i>Lupinus argenteus</i>	24.4	<i>Gayophytum diffusum</i>	11.1
<i>Gayophytum diffusum</i>	2.7	<i>Sitanion hystrix</i>	6.3	<i>Lupinus argenteus</i>	7.2
<i>Chenopodium leptophyllum</i>	2.1	<i>Polygonum douglasii</i>	4.8	<i>Artemisia tridentata</i>	6.9
<i>Penstemon barbatus</i>	2.1	<i>Artemisia tridentata</i>	2.7	<i>Polygonum douglasii</i>	4.8
<i>Hackelia</i> sp.	0.9	<i>Gayophytum diffusum</i>	2.7	<i>Verbascum thapsus</i> *	4.8*
<i>Verbascum thapsus</i> *	0.9*	<i>Senecio multilobatus</i>	2.7	<i>Bromus tectorum</i> *	3.3*
<i>Corydalis aurea</i>	0.9	<i>Penstemon pachyphyllus</i>	2.4	<i>Senecio multilobatus</i>	2.7
<i>Eriogonum</i> sp.	0.9	<i>Collinsia parviflora</i>	2.1	<i>Senecio eremophilus</i>	2.7
<i>Argemone munita</i>	0.6	<i>Chenopodium album</i> *	2.1*	<i>Sitanion hystrix</i>	2.1
<i>Sitanion hystrix</i>	0.6	<i>Bromus tectorum</i> *	1.5*	<i>Chenopodium album</i> *	2.1*
<i>Polygonum douglasii</i>	0.6	<i>Verbascum thapsus</i> *	0.9*	<i>Euphorbia lurida</i>	1.8
<i>Agropyron</i> sp.	0.3	<i>Phlox gracilis</i>	0.6	<i>Conyza canadensis</i>	1.5
<i>Nicotiana attenuata</i>	0.3	<i>Arabis fendleri</i>	0.3	<i>Chenopodium leptophyllum</i>	1.5
<i>Koeleria macrantha</i>	0.3	<i>Festuca arizonica</i>	0.3	<i>Collinsia parviflora</i>	0.9
<i>Conyza canadensis</i>	0.3	<i>Chamaesyce serpyllifolia</i>	0.3	<i>Phlox gracilis</i>	0.3
<i>Bromus</i> sp.	0.3	<i>Senecio eremophilus</i>	0.3	<i>Poa fendleriana</i>	0.3
<i>Marrubium vulgare</i> *	0.3*			<i>Chamaesyce serpyllifolia</i>	0.3

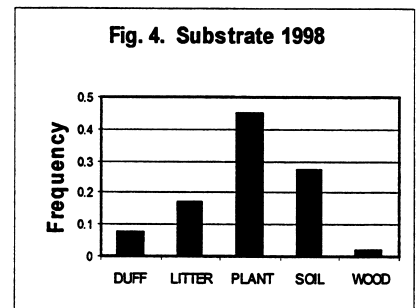
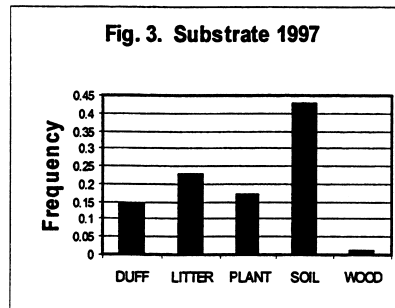
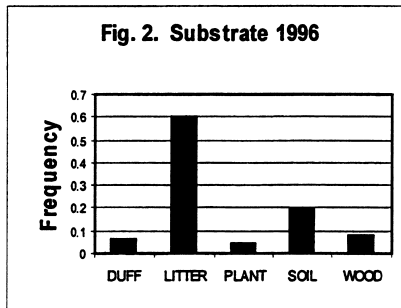
Forbs are well represented in both parcels, however many of them are annuals, such as *Collinsia parviflora* and *Gayophytum diffusum*. Annuals often are better at dispersal than perennials, and are often seen in early successional settings. Eventually annuals are replaced by perennials, such as *Penstemon* spp. and *Senecio* spp. Some forbs such as *Lupinus* are nitrogen fixers, which is important in early successional plant communities.

Overall plant species richness, or total number of plant species, has increased 5-fold in two years (Fig. 1). Correspondingly, Simpson's index of diversity, a measure of plant diversity, has doubled from 3.0 to 6.0. These increases show that both the number of species and the abundance of individual plants rose.

Figure 1. Plant Species Richness.



The data from the herbaceous transects allows us to look at the percentage of ground cover occupied by plant and non-plant substrate. These frequencies have changed drastically in the last 3 years, as is shown by Figures 2-4 below.



Prior to treatment, litter covered 60 % of the forest floor. One year after treatment, the majority of the forest floor was bare mineral soil, due to prescribed fire removing litter and duff material. The frequency of wood on the forest floor decreased as well.

Two years after treatment, plant cover is almost 45%, the highest of all categories. Litter and duff combined cover almost 25% of the forest floor leaving less than 30% of the ground cover bare mineral soil. Researchers have not noticed large erosion problems, although no quantitative data has been taken.

Tree density and basal area:

Thinning young trees was a major part of the treatment. Trees were remeasured on the 3 plots in 1997. The results presented in these tables are due to the thinning, and prescribed fire, which killed primarily oak in the 96-1 unit. Total tree density was reduced by 87% (Table 1), however, total basal area was reduced by only 60% because the largest trees were retained (Table 2). Quadratic mean diameter, or the stand average tree diameter, rose from 25 cm (10 in.) to 44 cm (17 in.).

Table 2. Trees per hectare (to convert to trees per acre, multiply by 0.4047)

	Pre-Treatment, n = 3		Post-Treatment, n = 3	
	Mean	s.e.	Mean	s.e.
Ponderosa pine	474	292.2	30	5.7
Gambel oak	155	57.8	58	52.8
Pinyon pine	10	10.0	0	0
New Mexican Locust	27	27.2	0	0
Total	666	283.0	88	48.2

Table 3. Basal area (m² per ha; to convert to ft² per ha, multiply by 4.355)

	Pre-Treatment, n = 3		Post-Treatment, n = 3	
	Mean	s.e.	Mean	s.e.
Ponderosa pine	26.2	14.42	11.1	3.60
Gambel oak	5.6	2.38	1.6	1.44
Pinyon pine	0.2	0.22	0	0
New Mexican Locust	0.03	0.03	0	0
Total	32.0	15.99	12.7	2.16

Fuel Loadings:

We compared pre-treatment fuel loadings to post-treatment fuel loadings (Table 4). In the interim, slash was piled on the unit, increasing woody fuel loadings. The results reflect this, showing large decreases in forest floor fuel, but some increases in woody fuels, due to remnant slash that was not entirely burned. Fuels are recorded and analyzed in English units, and so are reported here in tons/acre.

Table 4. Fuel loadings.

Woody fuel Loadings, tons/acre	Pre-treatment		Post-treatment	
	Mean	s.e.	Mean	s.e.
0-0.25 in. diameter	0.05		0.03	
0.25-1 in. diameter	0.38		0.79	
1-3 in. diameter	1.17		1.50	
>3 in. diameter sound	7.57		4.16	
>3 in. diameter rotten	1.27		0	
Sub Total	10.44		6.48	
Duff & Litter Loadings, tons/acre	9.61		1.46	
Total Loadings: tons/acre	20.06		7.94	

Litter and Duff Depth, inches	Pre-treatment		Post-treatment	
	Mean	s.e.	Mean	s.e.
Litter	0.66		0.11	
Duff	0.96		0.13	
Total Depth	1.62		0.24	

Post-treatment analysis allows us to measure the success of restoration treatments, and monitor the responses of different variables. The results raise new questions, such as the value of reseeding, the potential need for active exotic plant control, and what other variables should be included. The initial sample size of 3 plots is small, but these data will increase in the next few years as more units are treated.

Status: 3 plots remeasured and analyzed.

Year 4: Plots in units treated in 1998 will be remeasured.

Completion: Multi-year.

Experimental Block Study

Experimental blocks for controlled testing of the effects of ecosystem restoration manipulations are an important component 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.

In each treatment, 20 experimental block plots were established and permanently marked with rebar. Basic measurements at each experimental block include contemporary and presettlement (circa 1870) forest structure (species composition, size distribution, age distribution), current understory composition and density, canopy closure, fuel loading, and photographs. 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. All pretreatment data was collected for the seedbank study (J. Springer), butterfly community study (A. Waltz), the small mammal study (C. Chambers et al.), and the edge effects study (T. Sisk et al.).

Status: Five blocks in place, 40 experimental block plots per block completed, all pretreatment data collected.

Year 4: A restoration prescription will be applied to the treatment halves of the blocks in 1998-99 winter, with prescribed fire applied in fall 1999.

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 needed with the complete data set to explore the landscape-scale fire regime. In 1997 the entire area proposed for treatment at Mt Trumbull, in addition to the wilderness areas and forested surrounding regions, was sampled. The sample set from the Mt. Logan wilderness was analyzed and reported to the BLM in May, 1998 (*Changes in ponderosa pine forests of the Mt. Logan wilderness*). Reconstructed fire histories show that fires recurred about every 5-6 years prior to settlement, with larger fires burning every 9-12 years. Frequent fires ceased after 1869-1879 in the Mt. Logan Wilderness, coincident with the time of Euro-American settlement, beginning a fire-free period that has lasted up to the present except for a few fires in the 1930's.

Status: approximately 4000 acres sampled, analysis completed for initial treatment area (96-1) and Mt. Logan Wilderness.

Year 4: analysis and publication of fire history.

Completion: 1999.

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. After maximizing the correlations between samples, a chronology is developed. 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 4: Climatic reconstruction

Completion: 1999.

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 ecosystem 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 carried out. 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. Results will be reported at the Society for Ecological Restoration conference, Austin, TX, September 30, 1998

Status: Mt Trumbull and Durango, Mexico fires sampled.

Year 4: Analysis of data and continued sampling of larger fires elsewhere in northern Arizona.

Completion: 1999.

Indigenous Land Management Practices

In 1998, a project was initiated to explore indigenous land management practices, focussing on the Kaibab Paiute band. In particular, researchers are seeking to determine the use of fire in the Paiute culture, as well as Paiute knowledge of the ethnobotanical uses of the plants found in the Mt. Trumbull area. This information will be used to explore relationships between indigenous knowledge and contemporary restoration practices.

This year, researchers and graduate students established relationships with Paiute elders, and conducted interviews. This information will be combined with on-site field trips to help elucidate pre-Euro-American settlement land uses.

In addition, researchers are seeking information from early Euro-American settlers and ranchers, to develop a description of historic land-use practices including burning and grazing.

Status: Project design completed, contacts established.

Year 4: Continued interviews with Paiute elders and early Euro-American settlers.

Completion: Multi-year.

Wilderness Restoration Study

The 34 ecosystem monitoring plots in the Mt. Logan Wilderness were analyzed, and the data was used to reconstruct the forest structure in 1870, the date of the last natural fire in the wilderness area. These data are presented in the April 1998 progress report to the Arizona Strip Bureau of Land Management, "Changes in Ponderosa Pine Forest in the Mt. Logan Wilderness" (Waltz and Fulé 1998).

In addition to this forest inventory study, Marcy DeMillion and Dr. Marty Lee are working on a social survey in to assess public response to wilderness restoration. A social survey to assess the local populations of St. George, Hurricane, Fredonia, Colorado City, and Kanab on their attitudes towards Mt. Logan Wilderness restoration treatments was completed. Treatments were defined as mechanical, non-mechanical, or prescribed burning. Currently, there is a 54% response rate after the third and final mailing. Data will be analyzed in September. The social research on Mt. Logan Wilderness restoration treatments will be complete December, 1998.

Data analysis will include the urban population (St. George) versus the rural populations

(Hurricane, Fredonia, Colorado City, and Kanab) to see if attitudes differ. Managers will be able to use this information to help make restoration treatment decisions concerning the Mt. Logan Wilderness.

Status: Mt. Logan wilderness sampling completed and analyzed. Social survey completed

Year 4: Analysis of social survey data.

Completion: Multi-year.

A Potential Wilderness Treatment: Restoration Without Wood Removal

This study tests a treatment that would be suitable for application in areas where wood removal is not practical. Experimental treatment areas approximately 100m x 200m were designated along the peripheries of experimental blocks 2, 3, 4 and 5 (four treatment areas total). These areas will be marked and cut in roughly the same fashion as the experimental blocks. To address higher tree densities, and corresponding higher fuel loads, in experimental blocks 4 and 5, more trees may be left standing, or some trees might be girdled instead of felled. However, no wood will be removed from the sites. Instead, the felled trees will be lopped, bucked into 4-foot sections, and moved away from the retained trees as far as is practical.

In each experimental treatment area we placed three standard 0.10-acre circular vegetation monitoring plots. These will be in addition to the 40 plots already installed in the EB's. Each of these plots will be paired with two similar plots in the corresponding EB; one in the treatment area and one in the control area. These will be measured before the cut, between the cut and the initial burn, and after the initial burn. The study will compare the effects of the no wood removal treatment to those of the full restoration treatment, focusing on the following areas:

- invasion of exotic species
- understory establishment and productivity
- site damage (including soil disturbance and leave tree damage)
- fire effects of the initial burn

Status: During the 1998 field season the experimental treatment areas were located and initial data were collected on all 12 monitoring plots.

Year 4: The areas are scheduled to be marked for cutting in the fall of 1998, and cut in the winter/fall 1998/99. Post-cut data will be collected summer 1999 and the areas will be burned fall 1999. Fire behavior will be measured during the burns of the experimental blocks. Post burn data will be collected the following spring, and after each successive burn.

Completion: Multi-year.

Fire ecology and forest structure in 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, 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. In 1998, we have focused on analysis of fire history data (manuscript in review for *Conservation Biology*) and forest structure data (presentation at Society for Ecological Restoration conference, Austin, TX, September 30, 1998). Additional support for expanding restoration research in Mexican forests is being sought through the Fulbright program and the National Science Foundation.

Status: sampling completed at La Michilía Biosphere Reserve, Durango, Mexico, and Guachochi, Chihuahua, sites. Analysis and publication of results are in progress.

Year 4: data analysis and sampling at additional Sierra Madre 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). In 1998, a version of FIRESUM in the C computer language was calibrated and tested using long-term vegetation dynamics data acquired from studies at the Gus Pearson Natural Area and other northern Arizona sites. Changes in ponderosa pine forest structure were successfully modeled for multi-century periods with and without fire.

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

Year 4: Incorporate additional species and simulate ecosystem changes at additional sites.

Completion: Multi-year

Soil Characterization

This project was initiated to provide a general description of the soils in each experimental block and to examine the variability between the control and treatment areas. In July of 1998 eight-soil profile descriptions were completed and eighteen soil samples (by horizon) were collected in each of the five experimental blocks. Both the treatment and control were sampled in EB 2, 3, and 5. All soil pits

were excavated by hand with a shovel or a sampler to at least 50-cm unless bedrock or a hard clay Bt was encountered.

The soil collected was stored in cold storage until it was air dried and passed through a 2-mm sieve. Distribution of fine earth and coarse fragments was determined by mass. Macroscopic organic matter was removed by hand. Lab analysis will include: particle size by the hydrometer method, total C and N by dry combustion using the CE Elantech auto sampler in the School of Forestry at NAU, and pH using an electrode in a CaCl₂ solution. Samples will be ground in a mortar and pestle for C and N analysis. Existing soil data for the area will be compared to the data collected and a final report for this project will be completed by the end of 1998.

Status: Soils described from all experimental blocks, and soil samples collected.

Year 4: Soil samples analyzed and final report completed.

Completion: December 1998.

2. VEGETATION RESPONSE:

The Soil Seed Bank: Implications for Ecological Restoration

Southwestern ponderosa pine forests have been adversely affected by direct and indirect human causes, particularly since Euro-American settlement in the late nineteenth century. These effects have negatively impacted many understory shrub and herbaceous species, while other species have benefited. Studies of the species in the soil seed bank, and of the effects of ecological restoration on the seed bank, are important for predicting the species that will emerge following ecological restoration treatments at Mt. Trumbull and other sites. A series of seed bank studies was initiated in 1996 to: 1) obtain a baseline of the species (both native and non-native) found in the soil seed bank in five vegetative types at Mt. Trumbull before undergoing ecological restoration, 2) determine how ecological restoration practices affect the soil seed bank, 3) determine whether there are more seeds in organic or mineral soil and at different depths in the mineral soil, and 4) ultimately suggest if additional seeding of native species, or control of non-native species, may be necessary to restore diversity and structure to areas undergoing ecological restoration.

Seed bank soil samples were collected from the 96-1 demo unit, and the experimental blocks. All soil seed bank samples were collected with a bulk density hammer (slide hammer), cold treated if collected in the fall, and placed in the NAU research greenhouses for a minimum of six months. Seedlings were tallied and removed upon identification. Results from the baseline seed bank study indicate that both annual and perennial species utilize the seed bank. However, annual species (some non-native) are found in greater numbers in the soil than most other species. Two non-native species, common mullein (*Verbascum thapsus*) and motherwort (*Leonurus cardiaca*), are very prolific in the seed bank. Few perennial grasses were found to occupy the soil seed bank at Mt. Trumbull. Woody species were also uncommon, one exception being big sagebrush (*Artemisia tridentata*).

Preliminary results indicate there is not a significantly larger number of seeds in organic soil (or litter and duff) than in mineral soil. However, a greater number of non-native seeds occur in the organic soil rather than in the mineral soil. Although a greater number of species is found at the 0-5 cm depth than at the 5-10 cm depth in the mineral soil after thinning, the actual numbers of seeds do not vary greatly between these two depths, probably due to some soil churning action during thinning operations. After thinning the overstory, a greater number of seedlings was inventoried in the aboveground herbaceous vegetation (mainly from sources in the seed bank) than in a nearby unthinned control area. The number of seedlings in the aboveground vegetation inventory will be compared to the number of seedlings that emerged in the greenhouse from seed bank samples to determine if there are similarities in number and/or species. This aboveground inventory will continue to be monitored over time to track the colonization of

a site that has undergone ecological restoration treatments, including thinning and prescribed burning.

All of the above portions of the study are currently undergoing statistical analysis. Results may give an indication of whether the soil seed bank will be sufficient as a source of colonization after ecological restoration treatments, or whether additional seeding is necessary. Further research is also needed to determine the effects of fire on the soil seed bank.

Status: Field and greenhouse work completed; currently undergoing statistical analysis.

Year 4: Statistical analysis and final report.

Completion: 1998

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.

This study used soil characteristics to examine whether presettlement southwestern ponderosa pine tree groups and open grassy areas were spatially persistent for more than several hundred years, and whether postsettlement stands of trees presently occupy former open grassy areas. Study sites were located in northern Arizona, within the Fort Valley Experimental Forest, 15-km northwest of Flagstaff, AZ. We compared soil profile morphology, pH, organic carbon and total nitrogen accumulation and distribution with depth, C:N ratios, lipid content, and phytolith content by mass from six transects crossing ecotones between presettlement pine tree clumps, postsettlement pine stands, and relict grass patches. Presettlement plots showed higher C:N ratios and higher C and N accumulation throughout their soil profile, as compared to grass plots (Table 1). Surface organic matter content for the presettlement plots dropped off more rapidly as compared to grass and postsettlement plots (Table 2). Increased lipid accumulation beneath presettlement stands as compared to grass and postsettlement stands may indicate that tree clumps have occupied their position for more than one life span (Table 3). Organic matter distribution with depth, pH values and amount of phytoliths recovered (Table 4) suggest that the historic expansion of ponderosa pine has occurred at the expense of open grassy areas, supporting previous studies focusing on dendrochronology and inference from population structure.

Phytolith analysis is also being used to examine vegetation change within a southwestern ponderosa pine community in northern Arizona. Phytoliths are particles of taxonomically distinct hydrated silica that form in living plants and remain in soil after decomposition. Soil was collected at the surface (0-2 cm) and subsurface (2-7 cm) from five plots within three vegetation strata: 1) old-growth pine, 2) grass, and 3) small-diameter, younger pine. Phytoliths found at the surface will represent a modern analog and validate the use of this technique. Phytoliths found at 2-7 cm will be used as an indicator of presettlement reference conditions. Soil organic carbon isotope ratios will also be obtained on soil humates from these same depths to examine changes in C₃ and C₄ plant community structure. Radiocarbon dating by liquid scintillation counting will also be done on soil humates to provide a chronological context and understanding of soil organic matter mean residence time. Present day community structure was characterized by tree density, tree diameter at breast height, tree age and direct measurements of understory biomass. We are now finalizing a phytolith classification scheme based on 20

grass species found in the local and extra-local area. Results thus far indicate that surface soil phytolith assemblages do reflect present day community structure. Subsurface phytolith assemblage results thus far indicate that presettlement species composition was different than present-day conditions and does not correlate with present day community structure. Phytolith morphotype percentages indicate that cool-season, C₃ grasses dominated presettlement grasslands. Carbon isotope analysis and radiocarbon dates have not yet been completed.

Table 1. Mineral soil organic C and N content (concentration by mass) and C:N ratios by depth for horizons and subsamples grouped by plot type from the two presettlement-transition-grass study.

Transect	Plot Type														
	Presettlement					Transition					Grass				
	Horizon	Depth (cm)	% C	% N	C:N	Horizon	Depth (cm)	%C	%N	C:N	Horizon	Depth (cm)	%C	%N	C:N
1	A	0-7.5	3.37	0.17	19.67	A	0-11	3.52	0.14	24.76	A1	0-7	1.67	0.09	19.31
	BA	7.5-15	1.34	0.09	14.86	Bt1	11-48	0.72	0.05	14.63	A2	7-17	1.24	0.08	14.67
	Bt	15-40	1.02	0.07	13.62	Bt2	48-95	0.32	0.02	16.11	Bt1	17-39	0.80	0.07	11.64
		40-65	0.76	0.05	14.09						Bt2	39-67	0.24	0.02	10.26
											Bt3	67-103	0.26	0.03	8.77
18	A	0-7	3.66	0.17	22.04	A1	0-5	3.02	0.15	20.73	A	0-9	0.99	0.07	13.91
		7-15	2.06	0.11	17.93	A2	5-22	1.17	0.08	15.37		9-18	1.39	0.09	15.16
	Bt	15-40	1.05	0.07	15.98	Bt	22-40	0.91	0.05	16.81		18-28	2.13	0.13	16.05
		40-60	0.96	0.06	17.35		40-60	0.68	0.04	15.58	Bt	28-49	0.71	0.05	13.05
		60-73	0.89	0.05	18.83						BCt	49-70	0.48	0.04	12.08
	BCt	60-73	0.89	0.05	18.83						BCt	70-94	0.52	0.04	13.85
	Cbt/Cr	73-110+	0.27	0.03	10.10										

Table 2. Mineral soil organic C and N content (concentration by mass) and C:N ratios by depth for horizons and subsamples grouped by plot type from the four presettlement-transition-postsettlement study transects.

Transect		Plot Type													
Presettlement						Transition					Postsettlement				
	Horizon	Depth	%C	%N	C:N	Horizon	Depth	%C	%N	C:N	Horizon	Depth	%C	%N	C:N
11	A	0-15	2.60	0.14	19.04	A1	0-10	2.12	0.11	18.89	A	0-7	2.50	0.12	20.63
	Bt	15-43	1.12	0.06	19.09	A2	10-24	1.23	0.08	15.27	2A2	7-21	1.66	0.08	21.39
		43-67	0.71	0.05	14.50	Bt1	24-50	0.54	0.06	9.71	3Bt	21-68	0.86	0.07	12.97
						Bt2	50-82	0.41	0.03	12.39					
12	A	0-5	1.55	0.09	17.65	A	0-9	1.93	0.10	18.88	A	0-7	1.72	0.07	23.00
		5-10	1.33	0.09	14.69	Bt1	9-22	1.48	0.08	17.87		7-14	1.41	0.07	20.81
		10-15	1.25	0.08	16.46	Bt2	22-58	0.53	0.04	13.92	Bt1	14-31	0.85	0.06	13.98
	Bt	15-38	0.66	0.06	10.58	Bt3	58-82	0.49	0.04	12.46	Bt2	31-62	0.46	0.04	10.69
	Bt2	38-56	0.46	0.05	10.13						Bt3	62-82	0.35	0.03	10.32
	Bt3	56-88	0.46	0.03	15.20										
16	A	0-17	2.05	0.10	20.48	A1	0-9	1.86	0.10	19.55	A	0-20	1.77	0.10	18.45
	Bt	17-37	0.84	0.06	13.59	A2	9-19	1.08	0.08	14.38	BA	20-39	1.78	0.08	22.31
		37-77	0.47	0.03	13.57	Bt	19-50	0.53	0.05	11.21	Bt1	39-68	0.99	0.06	15.66
		77-117	0.33	0.03	12.91		50-100	0.29	0.03	9.63	Bt2	68-111	0.38	0.03	14.18
20	A	0-21	3.20	0.15	20.85	A1	0-9	2.70	0.15	17.89	A1	0-6	1.97	0.11	17.47
	Bt1	21-44	1.17	0.07	16.36	A2	9-25	1.15	0.08	14.72	A2	6-20	1.23	0.07	16.56
	Bt2	44-80	1.01	0.06	16.00	Bt1	25-50	0.78	0.06	13.08	Bt	20-68	0.73	0.06	12.44
	BC	80-130	0.58	0.04	13.85	Bt2	50-100	0.75	0.05	14.65	BCt	68-104	0.87	0.05	15.90
						BC	100-120	0.50	0.03	15.33					

Table 3. Percent by mass of extractable soil lipids from each vegetation type within the six study transects. All lipid values are weighted mean averages from horizon subsampling and depths are reported in centimeters.

Transect		Plot Type	
		Presettlement	Grass
1	Depth	0-40	0-39
	% Lipids	0.46	0.37
18	Depth	0-40	0-49
	% Lipids	0.48	0.43
		Presettlement	Postsettlement
11	Depth	0-67	0-68
	% Lipids	0.19	0.28 ¹
12	Depth	0-38	0-31
	% Lipids	0.26	0.25
16	Depth	0-77	0-68
	% Lipids	0.32	0.20
20	Depth	0-80	0-68
	% Lipids	0.18	0.16

¹ Difference may be due to lithological discontinuity.

Table 4. Average percent recovery (by mass) of phytolith material at 0-2 and 2-7 cm depths from fifteen plots. Standard deviations are marked in parenthesis and different lowercase letters indicate statistical significance ($p < 0.10$, two sample t-tests).

Depth	Plot Type		
	Presettlement	Postsettlement	Grass
0-2	1.4 (.38) ^a	0.88 (.46) ^{ab}	0.87 (.34) ^b
2-7	1.3 (.53) ^{ab}	1.2 (.19) ^a	0.90 (.07) ^b

Status: All field collection finished.

Year 4: Final phytolith analysis and final report.

Completion: 1998.

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

Gambel oak (*Quercus gambelii*) is an essential component of ponderosa pine-oak forests in Arizona, Utah, Colorado, and New Mexico. Since the time of Euro-American settlement to the present, younger age classes of Gambel oak have increased in abundance. It is also possible that like old-growth ponderosa pine populations, the vigor of old-growth Gambel oak may have also declined. The purpose of this

research is to examine the potential ecological restoration of Gambel oak, specifically by discovering ways in which the growth rate of existing old-growth Gambel oak can be increased, and the growth rate of replacement large-sized oak can be enhanced. This study uses replicated experimentation in combination with retrospective ecosystem analysis techniques to determine the effect of thinning and sprouting on Gambel oak. Thus, the goal of this research is consistent with the ecosystem management paradigm in that it will provide working hypotheses to land managers from which they can conduct a suite of adaptive management experiments on the land.

Mount Trumbull is one of two northern Arizona field sites selected for this study. Mount Trumbull was selected because it is currently the site of a large-scale ecosystem restoration project. This study uses 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.) Does thinning within oak clumps result in an increase in the growth of residual large oaks? 2.) What is the effect of sprouting on the growth rate of large oak trees?

Preliminary results from Mount Trumbull show no effect of thinning within an oak clump or of sprouting on the growth rate of mature Gambel oak. Similar results were obtained from a site at the William-Chalendar District for the effect of sprouting. However, different results were obtained at the two sites regarding the effect of thinning oak 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 at Mount Trumbull may have been dead before removal. In contrast, much of the oak thinning sampled at the Williams-Chalendar District was the result of a systematic thinning from below that the Forest Service conducted about 15 years ago. In this case, live Gambel oak were removed. At Williams-Chalendar 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 live Gambel oak from below 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 and other sites have been processed and analyzed.

Year 4: Completion of project.

Completion: December 1998.

3. ARTHROPOD, AVIAN AND MAMMAL RESPONSE:

Butterfly Response to Ecosystem Restoration

Butterflies are suggested to be potential indicators of arthropod communities, bird communities and even forest health. Because of this, we are monitoring butterflies in the Mt. Trumbull ecosystem area. Monitoring transects were established in the 5 experimental blocks in 1997. The 1998 field season completed the pre-treatment phase of data collection in these blocks. The treatment half of the blocks will be thinned according to restoration prescriptions in the fall and winter of 1998-1999, and then burned in fall of 1999. Remonitoring of both control and treatment within the units will commence summer 2000.

In addition to the experimental block design, we monitored butterfly populations in the treated 96-1 unit, comparing this year's abundances with butterfly abundances in the neighboring, untreated 98-2 unit. The untreated area served as a control for the 96-1 transects. Results of this comparison will be presented at the Society for Ecological Restoration meetings, on September 28 in Austin, TX. Briefly, the restored area supported 5 times as many butterflies in the same size area as in the control. The predominant behavior in the restored area was nectaring, while the predominant behavior in the control area was flying. All species found in the treatment were found in untreated forests as well, just not in the same abundances. One species, the Arizona Sister, was not seen in the treatment, and seems to prefer the untreated, denser forest type.

This field season added 5 species to the butterfly species list. Even more exciting, twice as many butterflies were censused in 1998 than in the same sampling period in 1997. This is most likely due to the increased moisture in 1998, resulting in increased herbaceous growth. A partially completed species list can be found in Appendix B.

Abiotic variables were also measured in the 96-1 treated area, control area, and all the experimental blocks. The data collected from the experimental blocks was pre-treatment, and will be analyzed to test for similarity or difference between the control and treatment prior to treatment. Abiotic data collected from the 96-1 treated area and the control area adjacent were analyzed for differences. Preliminary results show slight differences in ground temperature, ground humidity and ground insolation (light intensity) between treated and control areas. The same variables at 1-meter high were not different. This suggests that the response to the treatment is more likely due to plant nectar resources, or host plant abundances.

Status: Pre-treatment data collection complete, species list compiled and some life history data collected.

Year 4: Analysis of abundance and species data. Sampling of butterfly communities in presettlement-like forests, (i.e., Powell Plateau, Rainbow Plateau in the Grand Canyon National Park) to establish potential reference butterfly conditions.

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.

Our 1998 effort provided a 3rd year of pre-treatment data on diversity, abundance, reproduction, nest site selection, and foraging site selection by passerine birds on the Bureau of Land Management's (BLM) Mount Trumbull Resource Conservation Area (MTRCA). We collected these observations and data on 2 areas (approximately 350 ha each) of ponderosa pine forest. One of these 2 areas will be thinned and burned starting in late 1999 to restore Old Growth conditions to the ponderosa pine forest. We are using a paired design (i.e., we collected data on both a Control and a Treatment Area), with data collected both pre- and post-treatment. This will allow relatively strong inferences about treatment effects; inferences will be stronger when viewed together with the outcome of a replicate experiment at Camp Navajo, AZ. Both the Trumbull and Camp Navajo studies use identical methods.

Results from all 3 years have been entered in a computerized database. Our methods are described in detail, and quantitative data summaries and analyses for the first 2 years (i.e., 1996 and 1997) are available at <http://www.for.nau.edu/~pb/pipobird.html>. The 1998 field season was especially productive because:

- We gained 1 extra technician from Dr. Thomas Sisk's study (avian response to the edges between treated and untreated areas), and the Principal Investigator was available for the full field season (instead of half the season). Despite time spent by our crew to collect data for Dr. Sisk, this arrangement brought a substantial increase in field hours.
- Bird reproductive effort apparently was higher than in previous years, so there were more nests to observe, and more parents out foraging.
- We had the hardest working crew imaginable. I thank Justin Waskiewicz, Stephanie Jentsch, Meike Mosel, and Holly Petrillo for their enthusiastic and tireless efforts.

The following tables summarize the data collected by year, and indicate that the 1998 season was most productive.

Table 1. Number of 20x20-m vegetation plots measured in connection with passerine bird studies as Mt. Trumbull. For available plots (plot located on the MTRCA 300-m rectangular grid), the year indicates the year in which vegetation was measured. For nest plots (plot center = bird nest) and foraging plots (plot center = foraging location), the year indicates the year in which the nest or foraging observation was made.

Plot Type	Year			Total
	1996	1997	1998	
Available (grid)	0	89	86	175
Nest	51	90	146	287
Foraging	0	70	249	319
Total	51	249	481	781

Table 2. Nest discovered at Mt. Trumbull RCA study area, by species and year. We measured vegetation on a 20x20-m plot centered on each nest.

Species	Year			Total
	1996	1997	1998	
Dark-eyed junco	3	1	3	7
Hairy woodpecker	3	0	9	12
Mountain chickadee	3	9	22	34
Pygmy nuthatch	7	5	4	16
Solitary vireo	7	22	23	52
White-breasted nuthatch	8	16	22	46
Western bluebird	9	18	38	65
Western tanager	11	19	25	55
Total	51	90	146	287

Table 3. Foraging observations at Mt. Trumbull RCA study area, by species and year. We measured vegetation on a 20x20-m plot centered on each foraging observation. We did not make foraging observations in 1996.

Species	YEAR		Total
	1997	1998	
Dark-eyed junco	7	32	39
Hairy woodpecker	7	34	41
Mountain chickadee	24	40	64
Pygmy nuthatch	7	29	36
Solitary vireo	0	36	36
White-breasted nuthatch	24	41	65
Western tanager	1	37	38
Total	70	249	319

Status and Plans for future research:

When this study was originally designed, I decided to locate the Treatment Area in a cluster of units scheduled to be treated during 1997-1998. However, due to delays in implementing the restoration treatments, the Treatment Area probably will not be treated until 1999-2000. With a successful 1998 season, we have obtained a substantial pre-treatment data set. In the coming weeks, I will use the expanded data set to re-run the power analyses conducted on the 1996-1997 data. I expect that this will show relatively small marginal gains from collecting a 4th year of pretreatment data in 1999. In this event, I will focus my 1999 effort in areas away from collecting “more of the same” and toward activities with a bigger immediate payoff.

Until I analyze the 1996-1998 data, it would be premature to decide what activities will occur in 1999. However, I expect that, including Dr. Sisk’s technician, there will be a crew of only 3 persons studying birds at Mt. Trumbull in 1999, focussing on:

- bird responses to the edges created by the treatments that have already been implemented.
- reproduction and nest site selection by hairy woodpeckers, mountain chickadees, and pygmy nuthatches. (These are the 3 species for which we detected <40 nests – see Table 2).
- additional data on foraging behavior by birds in the Control Area and in the areas already treated.
- data on food delivery rates at nests, in cooperation with AGFD.

Completion: Multi-year.

Impacts of Edges Created by Restoration Treatments

Restoration of forest ecosystems results in altered stand structure, potentially affecting microclimatic factors such as air temperature, light intensity, and relative humidity. These microclimatic changes may alter habitat suitability for understory vegetation, invertebrates, and other forest organisms.

At Mt. Trumbull, compact, portable data loggers were used to collect microclimatic measurements at fixed intervals along 400 m long transects crossing existing and future edges between the two different forest structures. A total of 16 microclimatic transects were set up, 8 in areas where restoration has already occurred and 8 in areas where it will occur in the future. These transects were each sampled once for microclimatic data. Butterfly surveys were also conducted along these same transects. The transects were each surveyed at least twice for butterfly distribution. By coupling the microclimatic and butterfly data, we plan to learn about the magnitude of edge effects in ponderosa pine and also gain insight into the impacts of fragmentation in ponderosa pine forest ecosystems.

Status: Pre-treatment monitoring completed.

Year 4: Post-treatment monitoring of abiotic variables, butterfly populations and bird populations in the experimental blocks will commence, if blocks are treated in time.

Completion: Multi-year.

Habitat relationships of the Kaibab squirrel and other sciurids

In 1997 a project was initiated to investigate habitat relationships of Kaibab squirrels, rock squirrels, and cliff chipmunks in the five Mt. Trumbull ecological restoration experimental blocks (EB-1 through EB-5). As a continuation of that study, track stations and a tassel-eared squirrel feeding index were used in the five experimental blocks in May and August of 1998 in the same locations in which they were used in August of 1997. Track stations measure relative abundance of the three species, while the feeding index provides additional information on the type of food resources being utilized by tassel-eared squirrels in an area. An additional project to map significant habitat features—including Kaibab squirrel twig and cone feed trees, squirrel nests, large woody debris, rock outcrops, oak clumps, all yellow pines, and general vegetative and topographic characteristics—was initiated to provide additional detail regarding habitat characteristics, level of seasonal use by Kaibab squirrels, and the nature of feed tree distribution in stands with varying structures. This mapping of control and treatment halves of EB-3 and EB-5, and the treatment half of EB-1, was accomplished between May and August of 1998.

Mapping Summary

Mapping was confined to the regions within the vegetation sampling/track station grids, and totaled 5.4 hectares (13.3 acres) per block, or 27 hectares (66.7 acres) combining all mapped areas. Mapping accuracy is estimated at 10-15 meters for absolute location, with a finer accuracy of 1-2 meters for relative position of neighboring objects. All trees with 10 or more clipped terminal clusters or 20 or more cone cores less than one year old were mapped as feed trees. This protocol resulted in a total of 650 feed trees, with a low of 81 feed trees in the control half of EB-5 and a high of 169 feed trees in the treatment half of EB-3. In addition to location, additional information collected on each feed tree included DBH, leave or take status based on previous marking of sale, number of clipped clusters, number of cone cores, number of fungi digs, relative abundance of old clipped clusters, number of clipped twigs, aspect, dominance, damage (due to squirrel use and other causes), presence of yellow bark, and azimuth and distance to a permanent rebar grid point. Elevation and soil type information will be collected

from topographical maps and soil surveys and then be overlaid on the tree locations. This map will make it possible to characterize the pattern of distribution of both twig and cone feed trees in greater detail and over larger areas than has previously been possible. It will also be possible to predict possible effects of restoration treatments in different stand types by simulating the treatment based on the marked status of trees and their level of use by squirrels. Studies of Kaibab squirrel responses to restoration treatments could be facilitated with this map by investigating how the level of use of each feed tree changes following treatment, and determining if trees previously unused become feed trees.

In addition to providing information on the nature and distribution of Kaibab squirrel feed trees and their relation to restoration treatments, the habitat map will also provide additional habitat use information. By totaling the number of clips on each unit squirrel days per unit will be determined very precisely for the winter season when cambium is the primary food source for Kaibab squirrels. By overlaying track station hits for all three-target species on the habitat map it is anticipated that additional habitat relationships will become apparent.

Status: Pre-treatment data collection complete.

Year 4: Analyze and produce pretreatment report.

Completion: Multi-year.

Response of small mammal communities and Sin Nombre virus

We established 12 grids on 6 sites at Mt. Trumbull (5 experimental blocks and 96-1). We placed a 10x10 trapping grid on the control and treatment stands of each EB unit and 1 grid on each of the 2 sections of the 96-1 unit. Grid points were spaced 20m apart and overlaid the permanent vegetation sampling points already established. Grid design was slightly modified in EB-1 control, EB-2 treatment, and EB-4 treatment stands to accommodate 100 traps because irregular stand shapes limited our ability to place a 10x10 grid.

We trapped each EB unit for 5 consecutive nights and the 96-1 units for 3 consecutive nights. We captured approximately 311 individuals representing 4 species during 5600 trap nights. Small mammals captured included deer mouse (*Peromyscus maniculatus*; 135 individuals), pinyon mouse (*Peromyscus truei*; 74 individuals), brush mouse (*Peromyscus boylii*; 61 individuals), and cliff chipmunk (*Tamias dorsalis*; 14 individuals). For each animal we measured body, tail, right foot and right ear lengths, weight, and noted reproductive condition and age class (juvenile, sub-adult, adult). We collected a blood sample from each animal in good condition, excluding juveniles under 8.0 g and birthing females.

We sent 285 blood samples to the Center for Disease Control (CDC) for hantavirus testing. Preliminary results indicate that hantavirus was most prevalent in brush mice (17.3% of animals tested positive), lower in pinyon mice (10.4% tested positive), deer mice (4.7% tested positive), and absent in the chipmunks we captured (0% tested positive).

Status: All pre-treatment data collection finished.

Year 4: We will complete data entry and preliminary analyses by December 1998. We intend to compare home range sizes within populations of hantavirus-infected vs. uninfected individuals, and to relate animal abundance (hantavirus-infected vs. uninfected individuals) to habitat features such as logs, shrubs, and tree density. The large number of captures and recaptures will allow us to present preliminary results at the upcoming Southwest Chapter of the National Wildlife Society meeting in February 1999.

Cooperators: Additional support for this project was received from Yavapai College and the CDC. Yavapai College supplied materials for collecting and storing blood samples and an additional field technician. CDC conducted all blood testing.

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:

On-going Annual Participation			
	Smith, Doc	Grand Canyon Forests Partnership	Flagstaff, AZ
	Covington, Wally	Grand Canyon Forests Partnership	Flagstaff, AZ
	Fulé, Pete	Grand Canyon Forests Partnership	Flagstaff, AZ
	Heinlein, Tom	Grand Canyon Forests Partnership	Flagstaff, AZ
	Smith, Doc	Ponderosa Fire Advisory Council	Flagstaff, AZ
October 97	Smith, Doc	Society of Environmental Journalist	GRCA
	Smith, Doc	SW Fire Council	Scottsdale, AZ
	Smith, Doc	ASU, Dr. Steve Pyne, Field Trip to Gus Pearson	Flagstaff, AZ
	Smith, Doc	SAF Rest of PIPO	Rapid City, SD
November 97	Smith, Doc	Senior Exec Team GRCA	GRCA
December 97	ERP Students & Lab Staff	Senator Kyl and Co-op Members, Indoor and BH site visit	Flagstaff, AZ
February 98	Keltner, Dean	Presentation, Undergraduate Research Day	Flagstaff, AZ
	Meyer, Cecilia	Presentation, Undergraduate Research Day	Flagstaff, AZ
	Smith, Doc, et.al	Workshop, NPS on GRCA	Flagstaff, AZ
	Smith, Doc	Coordination Meeting, BLM, AZG&F, NAU	Flagstaff, AZ
March 98	Smith, Doc	Presentation, Americorps	Flagstaff, AZ
	Waltz, Amy	Presentation, Americorps	Flagstaff, AZ
April 98	ERP Lab	High School Visit, Lab Tour & Discussion	Flagstaff, AZ
May 98	Smith, Doc	Workshop, present & fieldtrip Region 3 Silviculture, MT	Kanab, UT
	Smith, Doc	Presentation, Sechrist School FV Project, GCFP	Flagstaff, AZ
	Smith, Doc	Field Trip, Public, GCFP tour (two trips)	GPNA, AZ
	ERP Lab	Lab Tour & Discussion, 8th grade award winning class in land management	Flagstaff, AZ
	Smith, Doc	Field Trip, City & County Officials	GPNA, AZ
	Smith, Doc	Tour, KNF, Congressional members, Williams Demo	Williams, AZ

June 98	Smith, Doc	Presentation, Earth Circles Conference, lab site	Flagstaff, AZ
	Smith, Doc	Coordination Meeting, MT, BLM, NAU & AZG&F	MT, AZ
July 98	Smith, Doc	Presentation, N, AZ Amateur Radio Club	Flagstaff, AZ
	Smith, Doc	Presentation & Field Trip, Federated Church Hiking Club	GPNA, AZ
August 98	Smith, Doc	Tour, GCFP	GPNA, AZ
	ERP	Host, Field Trip, Presentation, Discussion, Vermejo Ranch Park	Flagstaff, AZ
	Smith, Doc	Presentation & Field Trip AZ Orthopedic Surgeons Convention	Flagstaff, AZ
September 98	Smith, Doc	Festival of Science, GPNA	Flagstaff, AZ
	Covington, Wally	AZ, NM, CO, SD, WY, MT field tour, trip	
	Moore, Margaret	AZ, NM, CO, SD, WY, MT field tour, trip	
October 98	Smith, Doc	Field Trip, Dr. Steve Pyne, ASU class field trip, GPNA	Flagstaff, AZ
	Smith, Doc	Coordination Meeting, BLM, AZG&F, NAU	Flagstaff, AZ

LOOKING FORWARD

This project is continuing to become more exciting. As more of the landscape are treated and post-treatment variables are measured, we will see the kinds of impacts these treatments have on not only forest tree species, but the herbaceous community, the arthropod community, the small mammal and passerine bird community. While the participating agencies have experienced frustrations with some aspects of the projects, all researchers and managers involved understand the value of this kind of experimentation. This project will continue to raise important questions about land management and restoration principles.

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. The successional changes are important to understand, as some plants may be preparing the habitat for plants appearing later.

The response of plants, arthropods, mammals and birds will also be tracked on a decadal scale. Initial responses within a year or two of treatment 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.). But initial effects, although important, may not represent long-term patterns developing from ecosystem restoration. Again, these successional changes in these populations allow researchers to understand how ecosystems change through time.

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, 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.

CONTRIBUTORS

Thomas Alcoze-Goulard
Victor Alm
Paul Beier
Jay Benallie
Julie Blake
Jason Brooks
Cheryl Casey
Walker Chancellor
Janelle Clark
Carol Chambers
Liza Comita
Brienne Commanda
Wally Covington
Scott Curran
Marcy DeMillion
Mike Elson
Peter Fulé
Brian Gideon

JeanPaul Gladu
Peter Gould
Brandon Harper
Robert Heyduck
Andrew Hubbs
Matt Hurteau
Stephanie Jentsch
G. Alan Kaufmann
Dean Keltner
Barbara Kent
Becky Kerns
Lauren Labate
Henry Lewis
Lisa Machina
Joy Mast
Jennifer McKnight
Cecilia Meyer
Margaret Moore

Meike Mosel
Ted Ojeda
Jeanmarie Onkonburi
Don Povatah
Holly Petrillo
Kevin Price
John Paul Roccaforte
Heather Shanes
Tom Sisk
Judy Springer
Mike Stoddard
Gerald Tuma
Gina Vance
Alex Viktora
Amy Waltz
Justin Waskiewicz
Matt Wencel
Jennifer Wood

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APPENDIX A: 1998 96-1 PLANT SPECIES LIST, MT. TRUMBULL, AZ

96-1 UNIT, 13-ACRE PARCEL

Mount Trumbull Species List--96-1 13 Acre Parcel

<u>FAMILY</u>	<u>SPECIES</u>	<u>COMMON NAME</u>	<u>STATUS</u>
Amaranthaceae	Amaranthus sp. (two species)		
Asteraceae	Artemisia tridentata	big sagebrush	native
	Conyza canadensis	horseweed	native
	Erigeron divergens*	spreading daisy	native
	Erigeron flagellaris	trailing daisy	native
	Rudbeckia hirta*		
	Senecio eremophilus	desert groundsel	native
	Senecio multilobatus	Uinta groundsel	native
Berberidaceae	Mahonia repens	Oregon-grape	native
Boraginaceae	Hackelia sp.		
	Lappula occidentalis*	western stickseed	exotic
Brassicaceae	Arabis sp.		
	Descurainia sp.		
Capparaceae	Cleome serrulata	Rocky Mt. beeplant	native
	Cleome lutea	yellow beeplant	native
	Polanisia dodecandra	clammy-weed	native
Caprifoliaceae	Sambucus nigra	blue elderberry	native
	Symphoricarpus oreophilus	mountain snowberry	native
Chenopodiaceae	Chenopodium album var. berlandieri	lambsquarter	exotic
	Chenopodium leptophyllum	narrowleaf goosefoot	native
	Chenopodium botrys	Jerusalem-oak	native
	Salsola iberica	Russian thistle	exotic
Convolvulaceae	Convolvulus arvensis	bindweed	exotic
Cyperaceae	Carex occidentalis	common sedge	native
Euphorbiaceae	Chamaesyce serpyllifolia*	thymeleaf sandmat	native
	Euphorbia lurida	San Fransisco Mt. spurge	native
Fabaceae	Lotus sp.		
	Lupinus argenteus	silver lupine	native
	Medicago sp.		
	Robinia neomexicana	New Mexico locust	native
Fagaceae	Quercus gambelii	Gambel oak	native
Fumariaceae	Corydalis aurea	golden corydalis	native
Garryaceae	Garrya flavescens	ashy silktassel	native
Geraniaceae	Geranium caespitosum	pinewoods geranium	native
Grossulariaceae	Ribes cereum	wax currant	native
Hydrophyllaceae	Phacelia egena	varileaf phacelia	native
Lamiaceae	Dracocephalum parviflorum	smallflower dragonhead	native
	Leonurus cardiaca	common motherwort	exotic
	Marrubium vulgare	horehound	exotic
Linaceae	Linum lewisii	blue flax	native
Loascaeae	Mentzelia pumila	dwarf mentzelia	native
Nyctaginaceae	Mirabilis sp.		
Onagraceae	Gayophytum diffusum	diffuse groundsmoke	native
	Oenothera caespitosum	tufted evening primrose	native
Papaveraceae	Argemone munita	flatbud pricklypoppy	native
Poaceae	Bouteloua gracilis	blue grama	native
	Bromus sp. (two species)		
	Bromus tectorum	cheatgrass	exotic
	Koeleria macrantha	Junegrass	native
	Sitanion hystrix	squirreltail	native
Pinaceae	Pinus ponderosa	Ponderosa pine	native
Polemoniaceae	Microsteris gracilis	little polecat	native
Polygonaceae	Eriogonum sp. (annual)		
	Polygonum aviculare*		exotic
	Polygonum douglasii var. johnstoni	Sawatch knotweed	native
Portulacaceae	Portulaca oleracea	purslane	exotic
Rosaceae	Amelanchier sp.		
	Purshia tridentata	antelope bitterbrush	native

96-1 UNIT, 13-ACRE PARCEL

<u>FAMILY</u>	<u>SPECIES</u>	<u>COMMON NAME</u>	<u>STATUS</u>
Scrophulariaceae	Collinsia parviflora	blue-eyed Mary	native
	Penstemon sp. (deep purple flowers)		
	Penstemon barbatus	beardlip penstemon	native
	Penstemon pachyphyllus	thick-leaf penstemon	native
	Penstemon palmeri	Palmer's penstemon	native
Solanaceae	Verbascum thapsus	common mullein	exotic
	Datura wrightii	sacred datura	native
	Nicotiana attenuata	coyote tobacco	native
	Solanum jamesii	wild potato	native
	Solanum rostratum	buffalobur	adventive
	Solanum triflorum	cutleaf nightshade	native
Tamariceae	Tamarix sp.*		
Verbenaceae	Verbena bracteata	bigbract verbena	native
Unknown Species	Shrub--possibly Arctostaphylos sp.		

* not yet positively identified

96-1 UNIT, 33-ACRE PARCEL

Mount Trumbull Species List--96-1 33 Acre Burn

FAMILY	SPECIES	COMMON NAME	STATUS
Amaranthaceae	Amaranthus sp.		
Asclepidaceae	Asclepias asperula	antelope horn	native
Asteraceae	Agoseris glauca	mountain dandelion	native
	Artemisia sp.		
	Artemisia tridentata	big sagebrush	native
	Cirsium sp.		
	Conyza canadensis	horseweed	native
	Erigeron divergens*	spreading daisy	native
	Hymenopappus filifolius	fineleaf hymenopappus	native
	Lactuca sp.		
	Senecio eremophilus	desert groundsel	native
	Senecio multilobatus	Uinta groundsel	native
Boraginaceae	Lappula occidentalis*	western stickseed	exotic
Brassicaceae	Arabis fendleri*	Fendler rockcress	native
	Descurainia sp.		
	Lepidium densiflorum	common pepperweed	
Capparaceae	Cleome serrulata	Rocky Mt. beeplant	native
Chenopodiaceae	Chenopodium album var. berlandieri	lambsquarter	exotic?
	Chenopodium botrys	Jerusalem-oak	native
	Chenopodium leptophyllum	narrowleaf goosefoot	native
Cupressaceae	Juniperus osteosperma	Utah juniper	native
Euphorbiaceae	Chamaesyce serpyllifolia*	thymeleaf sandmat	native
	Euphorbia lurida	San Fransisco Mt. spurge	native
Fabaceae	Astragalus sp.		
	Lotus sp.		
	Lupinus argenteus	silver lupine	native
	Lupinus kingii	King's lupine	native
	Robinia neomexicana	New Mexico locust	native
	Trifolium sp.		
Fagaceae	Quercus gambelii	Gambel oak	native
Fumariaceae	Corydalis aurea	golden corydalis	native
Garryaceae	Garrya flavescens	ashy silktassel	native
Geraniaceae	Erodium cicutarium	redstem storksbill	exotic
Grossulariaceae	Ribes cereum	wax currant	native
Hydrophyllaceae	Phacelia egea	varileaf phacelia	native
Lamiaceae	Dracocephalum parviflorum	smallflower dragonhead	native
Linaceae	Linum lewisii	blue flax	native
Loasaceae	Mentzelia pumila	dwarf mentzelia	native
Onagraceae	Gayophytum diffusum	diffuse groundsmoke	native
Orobanchaceae	Orobanche fasciculatum	clustered broomrape	native
Papaveraceae	Argemone munita	flatbud pricklypoppy	native
Pinaceae	Pinus ponderosa	Ponderosa pine	native
	Pinus edulis	two-needle pine	native
Poaceae	Bouteloua gracilis	blue grama	native
	Bromus sp.		
	Bromus tectorum	cheatgrass	exotic
	Festuca sp.*		
	Poa fendleriana	muttongrass	native
	Sitanion hystrix	squirreltail	native
Polemoniaceae	Microsteris gracilis	little polecat	native
	Phlox longifolia	longleaf phlox	native
Polygonaceae	Eriogonum sp. (two annual species)		
	Eriogonum racemosum	redroot buckwheat	native
	Polygonum aviculare*		exotic
	Polygonum convolvulus	black bindweed	exotic
	Polygonum douglasii var. johnstoni	Sawatch knotweed	native

96-1 UNIT, 33-ACRE PARCEL

FAMILY	SPECIES	COMMON NAME	STATUS
Portulacaceae	Portulaca oleracea	purslane	exotic
Rosaceae	Amelanchier sp.		
Scrophulariaceae	Collinsia parviflora	blue-eyed Mary	native
	Penstemon barbatus	beardlip penstemon	native
	Penstemon pachyphyllus	thick-leaf penstemon	native
	Penstemon palmeri	Palmer's penstemon	native
	Verbascum thapsus	common mullein	exotic
Solanaceae	Datura wrightii	sacred datura	native
	Nicotiana attenuata	coyote tobacco	native
	Solanum jamesii	wild potato	native
	Solanum triflorum	cutleaf nightshade	native
Verbenaceae	Verbena bracteata	bigbract verbena	native
Violaceae	Viola canadensis	Canada violet	native
Unknown Species	Shrub--possibly Arctostaphylos sp.		

* not yet positively identified

APPENDIX B: 1998 BUTTERFLY LIST, MT. TRUMBULL, AZ

1998 MT. TRUMBULL BUTTERFLY SPECIES LIST

Code	Family	Genus	Species	Common Name	Host Plant
	Hesperiidae	*		Black skipper	
	Hesperiidae	*		Brown skipper	
EPCL	Hesperiidae	Epargyreus	clarus	Silver-spotted skipper	Robinia neomexicana
ERTE	Hesperiidae	Erynnis	telemachus	Gambel-oak Dusky Wing	Quercus gambelii
HEER	Hesperiidae	Heliopetes	ericetorum	Great Basin White Skipper	Malvaceae
PYCO	Hesperiidae	Pyrgus	communis	Checkered skipper	Malvaceae
	Lycaenidae	*		Blues	
HYCR	Lycaenidae	Hypaurotis	crysalus	Colorado Hairstreak	Quercus gambelii
STME	Lycaenidae	Strymon	melinus	Gray Hairstreak	Fabaceae, Malvaceae, others
PLAC	Lycaenidae	Plebejus	acmon	Silver-studded Blue	Polygonaceae
CEME	Nymphalidae	Cercyonis	meadii	Red Wood Nymph	Poacea
CHCA	Nymphalidae	Chlosyne	californica	California Patch	Asteraceae
DAGI	Nymphalidae	Danaus	gillippus	Queen	Asclepiadaceae
DAPL	Nymphalidae	Danaus	plexippus	Monarch	Asclepias
EUCH	Nymphalidae	Euphydryas	chalcedona	Western Checkerspot	Scrophulariaceae
EUCL	Nymphalidae	Euptoieta	claudia	Variegated Fritillary	Violaceae, Asclepiadaceae, others
LIBR	Nymphalidae	Limenitis	bredowii	Arizona Sister	Quercus gambelii
LIWE	Nymphalidae	Limenitis	weidemeyerii	Western Admiral	Populus tremuloides, Amelanchier utahensis, Ribes cereum
NYAN	Nymphalidae	Nymphalis	antiopa	Mourning Cloak	variety
NYCA	Nymphalidae	Nymphalis	californica	Western Tortoise Shell	Ceanothus sp.
	Nymphalidae	Phycoides		crescent	
POGR	Nymphalidae	Polygonia	gracilis	Hoary Comma/ Hoary Angelwing	Ribes sp.
PRCO	Nymphalidae	Precis	coenia	Buckeye	Scrophulariaceae & others
VACA	Nymphalidae	Vanessa	cardui	Painted Lady	variety
VAAT	Nymphalidae	Vanessa	atalanta	Red Admiral	Urticaceae, Moraceae
VACA2	Nymphalidae	Vanessa	carye	Western Painted Lady	Malvaceae
PAMU	Papilionidae	Papilio	multicaudata	Two-tailed Swallowtail	variety
ANSA	Pieridae	Anthocharis	sara	Western Orange Tip	Cruciferae
COEU	Pieridae	Colias	eurytheme	Orange sulfur	Fabaceae
NAIO	Pieridae	Nathalis	iola	Dainty sulfur	Asteraceae
PIPR	Pieridae	Pieris	protodice	Checkered white	Cruciferae
HELI	Sphingidae	Hyles	lineata	White-lined sphinx	variety

* may represent multiple species, identification is not yet complete.

APPENDIX C: 1998 PLANT LIST, MT. TRUMBULL, AZ

1998 PLANT LIST, MT TRUMBULL, AZ

All species on this list were updated from Kartesz & Kartesz (1994) and the PLANTS Database based on the Flora of North America Project

Family	Species	Common name	Nat'y	Form	Comments/Synonyms
Aceraceae	<i>Acer grandidentatum</i> Nutt.	bigtooth maple	N	T	Wash near EB-4
Amaranthaceae	<i>Amaranthus albus</i> L.	prostrate pigweed	I	A	Adventive from tropical America
Anacardiaceae	<i>Rhus glabra</i> L.	smooth sumac	N	T	Lava Fire
	<i>Rhus trilobata</i> Nutt.	skunkbush sumac	N	S	
Apiaceae	<i>Cymopterus multinervatus</i> (Coult. & Rose) Tidestrom	purplenerve springparsley	N	P	Collected by Cottam, but not NAU
	<i>Cymopterus purpureus</i> S. Wats.	purple springparsley	N	P	Base of MT - p-j zone
	<i>Lomatium foeniculaceum</i> ssp. <i>macdongalii</i> (Coult. & Rose) Theobald	MacDougal's biscuitroot	N	P	Mt. Logan overlook
Asclepiadaceae	<i>Asclepias asperula</i> (Dcne.) Woods.	spider milkweed	N	P	
	<i>Asclepias subverticillata</i> (Gray) Vail	whorled milkweed	N	P	
Asteraceae	<i>Ageratina herbaceae</i> (Gray) King & H.E. Robins.	fragrant snakeroot	N	P	Similar to <i>Brickellia grandiflora</i> , EB-4 wash
	<i>Agoseris glauca</i> (Pursh) Raf.	pale agoseris	N	P	
	<i>Artemisia carruthii</i> Wood ex Carruth.	Carruth's sagewort	N	P	
	<i>Artemisia dracunculus</i> L.	wormwood	N	P	Cottam - Uinkaret Plat. (Check NAU plots)
	<i>Artemisia frigida</i> Willd.	fringed sagewort	N	P	Cottam - Mt. Emma
	<i>Artemisia tridentata</i> Nutt.	big sagebrush	N	S	
	<i>Brickellia eupatorioides</i> var. <i>chlorolepis</i> (Woot. & Standl.) B.L. Turner	false boneset	N	P	<i>Brickellia chlorolepis</i>
	<i>Chaenactis douglasii</i> (Hook.) Hook. & Arn.	Douglas' dustymaiden	N	P	
	<i>Chrysothamnus depressus</i> Nutt.	longflower rabbitbrush	N	S	
	<i>Chrysothamnus viscidiflorus</i> (Hook.) Nutt.	green rabbitbrush	N	S	Cottam - east slope of Mt. Trumbull
	<i>Cirsium wheeleri</i> (Gray) Petrak	Wheeler's thistle	N	P	
	<i>Conyza canadensis</i> (L.) Cronq.	Canadian horseweed	N?	A	Probably introduced
	<i>Erigeron bellidiastrum</i> Nutt.	western daisy fleabane	N	A	Cottam - hill N. of N.S., not coll. by NAU
	<i>Erigeron divergens</i> Torr. & Gray	spreading fleabane	N	P	
	<i>Erigeron flagellaris</i> Gray	trailing fleabane	N	P	
	<i>Erigeron speciosus</i> (Lindl.) DC.	aspen fleabane	N	P	
	<i>Gutierrezia sarothrae</i> (Pursh) Britt. & Rusby	broom snakeweed	N	P	
	<i>Helianthus anomalous</i> Blake	western sunflower	N	A	Cottam - Uinkaret Plateau in pipo
	<i>Helianthus multiflorus</i> var. <i>multiflorus</i> Nutt.	showy goldeneye	N	A/P	<i>Viguiera multiflora</i>
	<i>Hymenopappus filifolius</i> Hook.	fineleaf hymenopappus	N	P	
	<i>Hymenoxys cooperi</i> var. <i>cooperi</i> (Gray) Cockerell	Cooper's hymenoxys	N	P/B	
	<i>Machaeranthera canescens</i> (Pursh) Gray	hoary aster	N	P	
	<i>Onopordum acanthium</i> L.	Scotch cottonthistle	I	P	

1998 PLANT LIST, MT TRUMBULL, AZ

Family	Species	Common name	Nat'y	Form	Comments/Synonyms
	<i>Sanvitalia abertii</i> Gray	Albert's creeping zinnia	N	A	
	<i>Senecio eremophilus</i> var. <i>macdougalii</i> (Heller) Cronq.	Macdougal's groundsel	N	A/P	<i>Senecio macdougalii</i>
	<i>Senecio multilobatus</i> Torr. & Gray ex Gray	lobeleaf groundsel	N	P	
	<i>Solidago velutina</i> DC.	threenerve goldenrod	N	P	<i>Solidago sparsiflora</i>
	<i>Stephanomeria tenuifolia</i> (Raf.) Hall	narrowleaf wirelettuce	N	P	
	<i>Taraxacum officinale</i> G.H. Weber ex Wiggers	common dandelion	I	P	
	<i>Tetradymia canescens</i> DC.	spineless horsebrush	N	P	
	<i>Tetranneuris acaulis</i> var. <i>acaulis</i> (Pursh) Greene (<i>v. arizonica</i> ?)	stemless hymenoxys	N	P	<i>Hymenoxys acaulis</i> - crest of Mt. Logan
	<i>Townsendia incana</i> Nutt.	hoary townsendia	N	P	Cottam?
	<i>Tragopogon dubius</i> Scop.	yellow salsify	I	P	
	<i>Verbesina encelioides</i> (Cav.) Benth. & Hook.f.ex Gray	golden crownbeard	N	A	96-1 after the burn
Berberidaceae	<i>Mahonia fremontii</i> (Torr.) Fedde	Fremont's mahonia	N	S	<i>Berberis fremontii</i>
	<i>Mahonia repens</i> (Lindl.) G. Don	Oregon-grape	N	S	<i>Berberis repens</i>
Boraginaceae	<i>Cryptantha cinerea</i> var. <i>cinerea</i> (Greene) Cronq.	James's catseye	N	P	
	<i>Lappula occidentalis</i> (S. Wats.) Greene	flatspine stickseed	N?	A	May be introduced
	<i>Mertensia macdougalii</i> Heller	Macdougal's bluebells	N	P	Not enough plant mat'l for positive ID
Brassicaceae	<i>Arabis fendleri</i> var. <i>fendleri</i> (S. Wats.) Greene	Fendler's rockcress	N	P/B	
	<i>Chorispora tenella</i> (Pallas) DC.	crossflower	I	A	Logan Burn
	<i>Descurainia californica</i> * (Gray) O.E. Schulz	Sierran tansymustard	N?	A/B	Not enough plant mat'l for positive ID
	<i>Descurainia pinnata</i> ssp. <i>intermedia</i> (Rydb.) Detling	western tansymustard	N?	A	Introduced?
	<i>Draba</i> sp. L.	whitlowgrass	N	A/B	One spec. in 96-1 after burn, not coll.
	<i>Lepidium densiflorum</i> Schrad.	common pepperweed	N	A	
	<i>Streptanthus cordatus</i> Nutt.	heartleaf twistflower	N	P	Trail up Mt. Trumbull
Capparaceae	<i>Cleome lutea</i> Hook.	yellow spiderflower	N	A	
	<i>Cleome serrulata</i> Pursh	Rocky Mtn. bee plant	N	A	
Caprifoliaceae	<i>Sambucus nigra</i> ssp. <i>cerulea</i> (Raf.) R. Bolli	elderberry	N	T	<i>Sambucus cerulea</i>
	<i>Symphoricarpos oreophilus</i> Gray	whortleleaf snowberry	N	S	
Caryophyllaceae	<i>Arenaria eastwoodiae</i> Rydb.	Eastwood's sandwort	N	P	
	<i>Arenaria fendleri</i>	Fendler's sandwort	N	P	Crest of Mt. Logan, check author
	<i>Arenaria lanuginosa</i> ssp. <i>saxosa</i> (Gray) Maquire	spreading sandwort	N	P	
	<i>Pseudostellaria jamesiana</i> (Torr.) W. A. Weber & R.L. Hartman	tuber starwort	N	P	<i>Stellaria jamesiana</i> - EB4 in wash
	<i>Silene scouleri</i> Hook.	Scouler's campion	N	P	NE aspect - Mt. Logan
Chenopodiaceae	<i>Chenopodium berlandieri</i> var. <i>berlandieri</i> Moq.	Berlandier's goosefoot	N	A	<i>Chenopodium album</i> var. <i>berlandieri</i>

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	<i>Chenopodium botrys</i> L.	Jerusalem oak goosefoot	I	A	2 spec. in 96-1 after burn, common in seed bank
	<i>Chenopodium graveolens</i> Willd.	fetid goosefoot	N	A	
	<i>Chenopodium leptophyllum</i> (Moq.) Nutt. ex S. Wats.	narrowleaf goosefoot	N	A	
Convolvulaceae	<i>Convolvulus arvensis</i> L.	field bindweed	I	P	
Cupressaceae	<i>Juniperus osteosperma</i> (Torr.) Little	Utah juniper	N	T	
Cyperaceae	<i>Carex occidentalis</i> Bailey	western sedge	N	P	
Ericaceae	<i>Arctostaphylos patula</i> Greene	greenleaf manzanita	N	S	Cottam - called it <i>A. platyphylla</i>
	<i>Arctostaphylos pungens</i> Kunth	pointleaf manzanita	N	S	
Euphorbiaceae	<i>Chamaesyce serpyllifolia</i> var. <i>serpyllifolia</i> (Pers.) Small	thymeleaf sandmat	N	A	<i>Euphorbia serpyllifolia</i>
	<i>Euphorbia brachycera</i> Engelm.	horned spurge	N	P	
	<i>Euphorbia lurida</i> Engelm.	San Francisco Mtn. spurge	N	P	
Fabaceae	<i>Astragalus argophyllus</i> Nutt.	silverleaf milkvetch	N	P	
	<i>Astragalus argophyllus</i> var. <i>stocksii</i> Barneby ex Isely	silverleaf milkvetch	N	P	
	<i>Astragalus castaneiformis</i> S. Wats.	chestnut milkvetch	N	P	Cottam - Mt. Emma
	<i>Astragalus oophorus</i> var. <i>caulescens</i> (M.E. Jones)	egg milkvetch	N	P	
	<i>Dalea candida</i> var. <i>oligophylla</i> (Torr.) Shinnery	white prairieclover	N	P	
	<i>Dalea polygonoides</i> Gray	sixweeks prairieclover	N	P	Cottam, but not collected by NAU
	<i>Dalea searsiae</i> (Gray) Barneby	Searls' prairieclover	N	P	
	<i>Lathyrus laetivirens</i> Greene ex Rydb.	aspen peavine	N	P	
	<i>Lotus humistratus</i> Greene	foothill deervetch	N	A	Check McKee for occurrence, not coll. by NAU
	<i>Lotus utahensis</i> Otteley	Utah birdsfoot trefoil	N	P	
	<i>Lotus wrightii</i> (Gray) Greene	Wright's deervetch	N	P	
	<i>Lupinus argenteus</i> Pursh	silvery lupine	N	P	
	<i>Lupinus formosus</i> var. <i>robustus</i> C.P. Sm.	summer lupine	N	P	Cottam - <i>L. greenei</i> , not in AZ per PLANTS
	<i>Lupinus kingii</i> S. Wats.	King's lupine	N	A	
	<i>Medicago sativa</i> L.	alfalfa	I	P	
	<i>Melilotus officinalis</i> (L.) Lem.	yellow sweet-clover	I	P	
	<i>Phaseolus angustissimus</i> Gray	slimleaf bean	N	P	Logan Burn
	<i>Psoraleidium tenuiflorum</i> (Pursh.) Rydb.	slimflower scurfpea	N	P	
	<i>Robinia neomexicana</i> Gray	New Mexico locust	N	P	
	<i>Vicia americana</i> Muhl. ex Willd.	American vetch	N	P	
Fagaceae	<i>Quercus gambelii</i> Nutt.	Gambel's oak	N	T	
	<i>Quercus gambelii</i> Nutt. x <i>Quercus turbinella</i> Greene	hybrid	N	S	

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	<i>Quercus turbinella</i> Greene	shrub live oak	N	S	
Fumariaceae	<i>Corydalis aurea</i> Willd.	scrambled eggs	N	A	disturbed areas, fires, 96-1
Garryaceae	<i>Garrya flavescens</i> S. Wats.	ashy silktassel	N	P	
Gentianaceae	<i>Frasera albomarginata</i> var. <i>albomarginata</i> S. Wats.	desert elkweed	N	P	<i>Swertia albomarginata</i> , along C.R. 5
	<i>Frasera speciosa</i> Dougl. ex Griseb.	showy frasera	N	P	<i>Swertia radiata</i>
Geraniaceae	<i>Erodium cicutarium</i> (L.) L'Her. ex Ait.	redstem stork's bill	I	A	
	<i>Geranium caespitosum</i> James	pinewoods geranium	N	P	
	<i>Geranium richardsonii</i> Fisch. & Trautv.	Richardson's geranium	N	P	
Grossulariaceae	<i>Ribes cereum</i> Dougl.	wax currant	N	S	
	<i>Ribes</i> sp. L.	currant	N	S	Slide Mtn. - has spines - spec. missing
Hydrophyllaceae	<i>Nama dichotomum</i> (Ruiz & Pavon) Choisy	wishbone fiddleleaf	N	A	Looks very similar to <i>Phlox gracilis</i>
	<i>Phacelia crenulata</i> var. <i>corrugata</i> (A. Nels.) Brand	cleftleaf wild heliotrope	N	P	Cottam
	<i>Phacelia egna</i> (Greene ex Brand) Greene ex J.T. Howell	Kaweah River scorpionweed	N	P	<i>P. magellanica</i>
	<i>Phacelia</i> sp.		N	P	Lava Burn, only one, not coll., not flwrng.
Lamiaceae	<i>Dracocephalum parviflorum</i> Nutt.	American dragonhead	N	A/B	<i>Moldavica parviflora</i>
	<i>Leonurus cardiaca</i> (L.)	common motherwort	I	P	common under oaks
	<i>Marrubium vulgare</i> L.	horehound	I	P	
	<i>Monardella odoratissima</i> Benth.	Pacific monardella	N	P	Lava flows
	<i>Nepeta cataria</i> L.	catnip	I	P	Based on leaf shape, no flowers observed
Liliaceae	<i>Allium bisceptrum</i> var. <i>palmeri</i> (S. Wats.) Cronq.	aspen onion	N	P	
	<i>Calochortus nuttallii</i> Torr. & Gray	sego lily	N	P	
	<i>Fritillaria atropurpurea</i> Nutt.	spotted missionbells	N	P	
Linaceae	<i>Linum australe</i> Heller	southern flax	N	A	Keyed using IMF. <i>L. aristatum</i> w/Macdoug.
	<i>Linum lewisii</i> Pursh	prairie flax	N	P	
Loasaceae	<i>Mentzelia dispersa</i> S. Wats.	bushy blazingstar	N	A	May be first occurrence in AZ
	<i>Mentzelia pumila</i> Nutt. ex Torr. & Gray	dwarf mentzelia	N	P	
Malvaceae	<i>Spharalcea parvifolia</i> A. Nels.	smallflower globemallow	N	P	
Monotropaceae	<i>Pterospora andromedea</i> Nutt.	woodland pinedrops	N	P	
Nyctaginaceae	<i>Mirabilis decipiens</i> (Standl.) Standl.	broadleaf four o'clock	N	P	
	<i>Mirabilis linearis</i> (Pursh) Heimerl	narrowleaf four o'clock	N	P	
	<i>Mirabilis oxybaphoides</i> (Gray) Gray	smooth spreading four o'clock	N	P	
	<i>Mirabilis pumila</i> ? (Standl.) Standl.	dwarf four o'clock	N	P	
Onagraceae	<i>Epilobium angustifolium</i> ssp. <i>angustifolium</i> L.	fireweed	N	P	Lava flow - EB1

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	<i>Gayophytum diffusum</i> Torr. & Gray	spreading groundsmoke	N	A	
	<i>Oenothera caespitosa</i> Nutt.	tufted eveningprimrose	N	P	
	<i>Oenothera coronopifolia</i> Torr. & Gray	crownleaf eveningprimrose	N	P	Roadside - CR 5
	<i>Oenothera flava</i> (A. Nels.)	yellow eveningprimrose	N	P	Sawmill Tank
Orobanchaceae	<i>Orobanche fasciculata</i> Nutt	clustered broomrape	N	P	parasitic on ARTR, check current listing status
Papaveraceae	<i>Argemone munita</i> Dur. & Hilg.	flatbud pricklypoppy	N	P	
	<i>Eschscholzia californica</i> ssp. <i>mexicana</i> (Greene) C. Clark	California poppy	N	A	Cottam
Pinaceae	<i>Pinus edulis</i> Engelm.	twoneedle pine	N	T	
	<i>Pinus ponderosa</i> P. & C. Lawson	ponderosa pine	N	T	
Poaceae	<i>Achnatherum hymenoides</i> (Roemer & J.A. Schultes) Barkworth	Indian ricegrass	N	P	<i>Oryzopsis hymenoides</i>
	<i>Agropyron cristatum</i> (L.) Gaertn.	crested wheatgrass	I	P	
	<i>Aristida purpurea</i> var. <i>longiseta</i> (Steud.) Vasey	Fendler threeawn	N	P	
	<i>Bouteloua curtipendula</i> (Michx.) Torr.	sideoats grama	N	P	
	<i>Bouteloua gracilis</i> (Willd. ex Kunth) Lag. ex Griffiths	blue grama	N	P	
	<i>Bromus ciliatus</i> L.	fringed brome	N	P	
	<i>Bromus inermis</i> Leyss.	smooth brome	I	P	
	<i>Bromus marginatus</i> Nees ex Steud.	mountain brome	N	P	Cottam - Mt. Emma
	<i>Bromus tectorum</i> L.	cheatgrass	I	A	
	<i>Elymus elymoides</i> ssp. <i>elymoides</i> (Raf.) Swezey	wildrye	N	P	<i>Sitanion hystrix</i>
	<i>Elymus trachycaulus</i> ssp. <i>trachycaulus</i> (Link) Gould ex Shinnars	slender wheatgrass	N	P	
	<i>Elytrigia elongata</i> (Host) Nevski	tall wheatgrass	I	P	<i>Agropyron elongatum</i>
	<i>Elytrigia intermedia</i> (Host) Nevski	intermediate wheatgrass	I	P	<i>A. intermedium</i> var. <i>trichophorum</i>
	<i>Elytrigia intermedia</i> ssp. <i>intermedia</i> (Host) Nevski	intermediate wheatgrass	I	P	<i>A. intermedium</i> var. <i>intermedium</i>
	<i>Eragrostis mexicana</i> (Hornem.) Link	Mexican lovegrass	N	A	Cottam - not collected by NAU
	<i>Festuca arizonica</i> Vasey	Arizona fescue	N	P	Only in Logan burn
	<i>Hesperostipa comata</i> ssp. <i>comata</i> (Trin. & Rupr.) Barkworth	ncn	N	P	<i>Stipa comata</i>
	<i>Koeleria macrantha</i> (Ledeb.) J.A. Schultes	prairie junegrass	N	P	<i>K. nitida</i> , <i>K. cristata</i>
	<i>Leymus cinereus</i> (Scribn. & Men.) A. Love	basin wildrye	N	P	
	<i>Monroa squarrosa</i> (Nutt.) Torr.	false buffalograss	N	A	Logan burn
	<i>Muhlenbergia minutissima</i> (Steud.) Swallen	annual muhly	N	A	
	<i>Muhlenbergia repens</i> (J. Presl.) A. S. Hitchc.	creeping muhly	N	P	
	<i>Muhlenbergia wrightii</i> Vasey ex Coult.	spike muhly	N	P	
	<i>Piptatherum micranthum</i> (Trin. & Rupr.) Barkworth	smilgrass	N	P	<i>Oryzopsis micrantha</i>

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	<i>Poa fendleriana</i> (Steud.) Vasey	muttongrass	N	P	
	<i>Poa pratensis</i> L.	Kentucky bluegrass	I	P	
	<i>Schizachyrium scoparium</i> (Michx.) Nash	little bluestem	N	P	
	<i>Secale cereale</i> L.	cultivated rye	I	A	
	<i>Sporobolus cryptandrus</i> (Torr.) Gray	sand dropseed	N	P	
Polemoniaceae	<i>Gilia sinuata</i> Dougl. Ex Benth.	rosy gilia	N	A	Cottam
	<i>Ipomopsis aggregata</i> (Pursh) V. Grant	skyrocket gilia	N	P	
	<i>Ipomopsis arizonica</i> (Greene) Wherry	Arizona skyrocket	N	P	
	<i>Ipomopsis multiflora</i> (Nutt.) V. Grant	manyflowered gilia	N	P	
	<i>Navarretia breweri</i> (Gray) Greene	Brewer's navarretia	N	A	Near Mt. Trumbull 5900' - N. Brian list
	<i>Phlox austromontana</i> Coville	desert phlox	N	P	Nixon Springs pipeline
	<i>Phlox gracilis</i> (Hook.) Greene	slender phlox	N	A	
	<i>Phlox longifolia</i> Nutt.	longleaf phlox	N	P	
Polygonaceae	<i>Eriogonum alatum</i> Torr.	winged buckwheat	N	P	C.R. 5
	<i>Eriogonum corymbosum</i> var. <i>corymbosum</i> Benth.	crispleaf buckwheat	N	P?	
	<i>Eriogonum cernuum</i> Nutt.	nodding buckwheat	N	A	
	<i>Eriogonum pharnaceoides</i> var. <i>cervinum</i> Reveal	wirestem buckwheat	N	A	
	<i>Eriogonum racemosum</i> Nutt.	redroot buckwheat	N	P	
	<i>Eriogonum trichopes</i> Torr.	little deserttrumpet	N	A	Cottam
	<i>Eriogonum umbellatum</i> Torr.	sulphur wildbuckwheat	N	P	
	<i>Eriogonum</i> sp. Michx.	buckwheat	N	A	Slide Mtn. - missing specimens
	<i>Polygonum convolvulus</i> L.	black bindweed	I	A	
	<i>Polygonum douglasii</i> ssp. <i>johnstonii</i> (Munz) Hickman	Johnston's knotweed	N?	A	<i>P. sawatchense</i>
Polypodiaceae	<i>Cheilanthes feei</i> T. Moore	slender lipfern	N	P	Cottam
	<i>Cystopteris fragilis</i> (L.) Bernh.	brittle bladderfern	N	P	
	<i>Woodsia scopulina</i> D. C. Eat.	Rocky Mountain woodsia	N	P	Cottam
Portulacaceae	<i>Portulaca oleracea</i> L.	little hogweed	N?	A	May be introduced
Ranunculaceae	<i>Ceratocephala testiculata</i> (Crantz) Bess.	curvedseed butterwort	I	A	<i>Ranunculus testiculatus</i>
	<i>Clematis ligusticifolia</i> Nutt.	western white clematis	N	P	EB4
	<i>Delphinium nuttallianum</i> var. <i>nuttallianum</i> Pritz. ex Walp.	Nuttall's larkspur	N	P?	
	<i>Ranunculus oreogenes</i> Greene	Oregon buttercup	N	P	
	<i>Thalictrum fendleri</i> Engelm. ex Gray	Fendler's meadowrue	N	P	
Rhamnaceae	<i>Ceanothus fendleri</i> Gray	Fendler's ceanothus	N	S	

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Rosaceae	<i>Ceanothus martinii</i> M.E. Jones	Martin's ceanothus	N	S	
	<i>Amelanchier alnifolia</i> (Nutt.) ex M. Roemer	Saskatoon serviceberry	N	S/T	
	<i>Amelanchier utahensis</i> Koehne	Utah serviceberry	N	S/T	
	<i>Antennaria</i> sp. Gaertn.	pussytoes	N	P	
	<i>Cercocarpus ledifolius</i> var. <i>intermontanus</i> N. Holmgren	curleaf mountain mahogany	N	S/T	Mt. Logan - Hell's Hole Overlook
	<i>Fallugia paradoxa</i> (D. Don) Endl. ex Torr.	Apacheplume	N	S	
	<i>Petrophyton caespitosum</i> (Nutt.) Rydb.	mat rockspirea	N	P	Cottam
	<i>Prunus emarginata</i> (Dougl. ex Hook.) Walp.	bitter cherry	N	S/T	
	<i>Purshia stansburiana</i> (Torr.) Henrickson	Stansbury cliffrose	N	S	
	<i>Purshia tridentata</i> (Pursh) DC.	antelope bitterbrush	N	S	
	<i>Rosa woodsii</i> var. <i>ultramontana</i> (S. Wats.) Jepson	Woods' rose	N	S	
Rubiaceae	<i>Galium bifolium</i> S. Wats.	twinleaf bedstraw	N	A	Check current listing status
	<i>Galium</i> sp. L.	bedstraw	N	P	Slide Mtn. - missing specimens
	<i>Galium wrightii</i> Gray	Wright's bedstraw	N	P	
	<i>Kelloggia galioides</i> Torr.	milk kelloggia	N	P	
Rutaceae	<i>Ptelia trifoliata</i> ssp. <i>pallida</i> (Greene) V. Bailey	common hoptree	N	S/T	
Salicaceae	<i>Populus tremuloides</i> Michx.	quaking aspen	N	T	
Santalaceae	<i>Comandra umbellata</i> ssp. <i>pallida</i> (A. DC.) Pichl	pale bastard toadflax	N	P	
Saxifragaceae	<i>Heuchera parvifolia</i> Nutt. Ex Torr. & Gray	littleleaf alumroot	N	P	Cottam - Mt. Emma
	<i>Heuchera rubescens</i> Torr.	pink alumroot	N	P	Check current listing status
Scrophulariaceae	<i>Castilleja integra</i> Gray	wholeleaf Indian paintbrush	N	P	
	<i>Castilleja linariifolia</i> Benth.	Wyoming Indian paintbrush	N	P	
	<i>Collinsia parviflora</i> Lindl.	smallflower blue-eyed Mary	N	A	
	<i>Cordylanthus parviflorus</i> (Ferris) Wiggins	purple bird's beak	N	A	
	<i>Mimulus bigelovii</i> var. <i>bigelovii</i> (Gray) Gray	Bigelow's monkeyflower	N	A	One spec. in 96-1 after burn, not collected
	<i>Mimulus rubellus</i> Gray	red monkeyflower	N	A	
	<i>Pedicularis centranthera</i> Gray	dwarf lousewort	N	P	
	<i>Penstemon barbatus</i> (Cav.) Roth	beardlip penstemon	N	P	
	<i>Penstemon eatonii</i> Gray	Eaton's penstemon	N	P	N.S. pipeline - side of Mt. Trumbull
	<i>Penstemon linarioides</i> ssp. <i>sileri</i> (Gray) Keck	Siler's penstemon	N	P	
	<i>Penstemon linarioides</i> ssp. unknown	mat penstemon	N	P	5 ssp. in AZ - don't have good key yet
	<i>Penstemon ophianthus</i> Pennell	coiled anther penstemon	N	P	Cottam - juniper slopes
	<i>Penstemon pachyphyllus</i> Gray ex Rydb.	thick-leaf beardtongue	N	P	Also have pink phase - expert ID?

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Solanaceae	<i>Penstemon pachyphyllus</i> var. <i>congestus</i> (M.E.Jones) N. Holmgren	thickleaf beardtongue	N	P	Cottam
	<i>Penstemon palmeri</i> Gray	Palmer's penstemon	N	P	
	<i>Penstemon rostriflorus</i> Kellogg	Bridge penstemon	N	P	P. bridgesii
	<i>Penstemon thompsoniae</i> (Gray) Rydb.	Thompson's beardtongue	N	P	uncommon at MT - not collected
	<i>Verbascum thapsus</i> L.	common mullein	I	B	
	<i>Datura wrightii</i> Regel	sacred thornapple	N	P	Logan burn
	<i>Nicotiana attenuata</i> Torr. Ex S. Wats.	coyote tobacco	N	A	
	<i>Physalis hederifolia</i> Gray	ivy leaf ground cherry	N	P	
	<i>Physalis hederifolia</i> var. <i>palmeri</i> (Gray) Cronq.	Palmer's groundcherry	N	P	Not in AZ per PLANTS database
	<i>Solanum jamesii</i> Torr.	wild potato	N	P	
Verbenaceae	<i>Solanum triflorum</i> Nutt.	cutleaf nightshade	N	A	
	<i>Glandularia gooddingii</i> (Briq.) Solbrig	southwestern mock vervain	N	P	Verbena gooddingii
Violaceae	<i>Verbena bracteata</i> Laq. & Rodr.	bigbract verbena	N	P	Only in seedbank? Check datasheets
	<i>Viola canadensis</i> L.	Canadian white violet	N	P	
Viscaceae	<i>Viola nuttallii</i> Pursh	Nuttall's violet	N	P	No AZ specimens in Deaver Herbarium
	<i>Phoradendron juniperinum</i> Engelm.	juniper mistletoe	N	P	

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