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Mt. Trumbull Ecosystem Restoration Project

**Progress Report
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Introduction

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

This report summarizes data collected in 1995 and 1996 on permanent ecosystem monitoring plots. These data are considered *preliminary results*. Further sampling in the field as well as continuing data analysis will lead to a more thorough understanding of present and past ecosystems at Mt. Trumbull. We are presenting these early summaries to rapidly communicate preliminary findings to resource managers and the public. Contemporary forest conditions, including herbaceous composition, overstory tree structure, tree regeneration, canopy cover, and forest fuels—coarse woody debris and forest floor biomass, are presented first. Reconstruction of forest structure in 1870—the year of settlement by Euro-Americans in which livestock grazing and logging led to fire exclusion—is presented next for approximately 1/3 of the data here dendrochronological analysis is complete. These “presettlement” forest conditions serve as point of reference for natural forest structure and as a guide to planning and evaluating ecological restoration treatments (Covington and Moore 1994a, Covington et al. 1997).

Contemporary Forest Conditions

Mt. Trumbull Ecosystem Monitoring Plots

Long-term monitoring is essential to assess current conditions, reconstruct presettlement ecosystem structure, and evaluate the effects of restoration treatments. The standard ecosystem monitoring plot is 50 X 20 meters (0.1ha or 0.25 acre), designed with permanent markers to be a long-term monitoring unit. Rebar stakes and rock cairns mark the center origin and the four outer corners to ensure identical setup in subsequent surveys. The plot design is adapted from the Western Region Fire Monitoring protocol (National Park Service 1992), and measures various components of forest structure, including trees, shrubs, herbaceous plants, forest floor fuels, canopy closure, and photographic records. Further information is available in the 1996 Annual Report prepared by NAU.

In 1995 and 1996, 167 plots were installed, making up primarily the eastern portion of the project area where the first restoration treatments and long-term studies were initiated. The monitoring plot data presented in this report are divided for analysis into “treatment plots”(110) and “control plots”(57). However, all data presented is pre-treatment data; at the time of plot placement, no treatments had been installed. The control plots refer to approximately 400 ha (988ac) located in the southern end of the project area. This 400 ha serves as a control for two years worth of post-treatment data for the passerine bird study led by Dr. Paul Beier as well as other landscape-scale wildlife studies coordinated by the Arizona Game and Fish Department. It does not serve as control for the ecosystem restoration as a whole and will be eligible for restoration treatments upon completion of the passerine bird study. An additional 60 treatment plots will be measured in 1997. Plot remeasurements on 1996 treated plots (thinned, burned, seeded) will also begin in 1997 and continue in succeeding years.

1. Contemporary Herbaceous Composition and Density

On each monitoring plot, two 50 m (164 ft) transects were surveyed for herbaceous composition and density using the point intercept method. Herbaceous species, species height, and floor substrate (i.e., litter, rock, bare mineral soil) were recorded at every 30 cm along each 50 m transect, for a total of 166 points per transect and 332 points per plot. In addition, if the plot was located in a shrubby area (e.g.,

sagebrush), a belt transect was created by widening the herbaceous transect to 1 m, and tallying all shrubs, living and dead, by maturity state, within that 50 m X 1 m belt transect.

Pre-treatment substrate proportions from the 110 treatment plots and 57 control plots were very similar. Plant material accounted for only 10% - 12% of the ground cover, while about 72% was litter (Fig 1.1). Presettlement ground cover was probably reverse of this, with plant material accounting a much larger percentage of cover; although the exact amount is not known (Cooper 1960, Madany and West 1983, Covington and Sackett 1984, Covington and Moore 1994a). Bare mineral soil, wood, rock and duff were also present; combined they represented the remaining 15% - 18% ground cover.

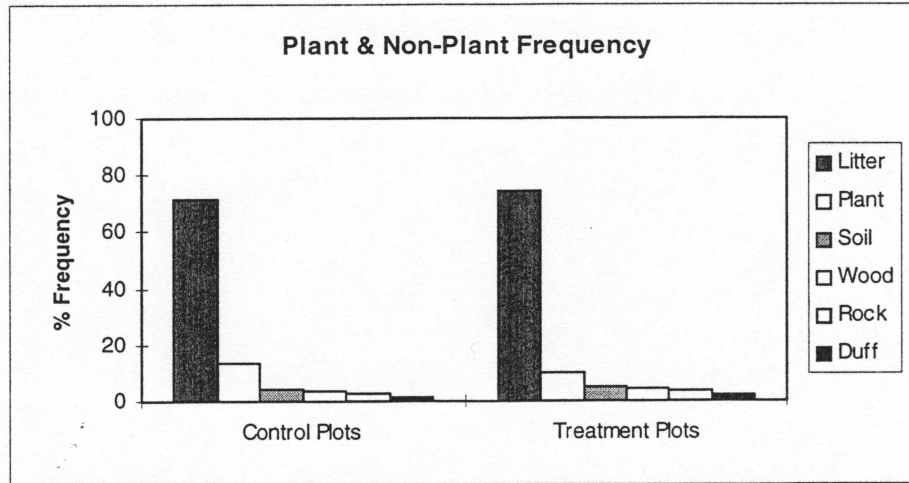


Fig. 1.1: Substrate Frequency. Litter covered approximately 72% of the forest floor.

Plant diversity was relatively low, averaging only 5.5 and 4.8 plant species per plot in the treatment plots and the control plots, respectively. Plant frequency was also low. The 20 most frequent plants found are listed in tables 1.1 (treatment plots) and 1.2 (control plots), ranked by frequency. Sagebrush (*Artemisia tridentata*) was the most frequent plant, found on 2.3% to 2.9% of the landscape. Some species of the five most frequent taxonomic groups were exotics (*Bromus tectorum* and a few species of *Agropyron*). However, native plant species were the major component of the understory structure, making up 82% of the species found on plots. A complete species list, by family, is provided in Appendix A.

Sample collections of plants were brought back to NAU. Unknown species were identified and representatives of all species were mounted on herbarium sheets and prepared for storage. Mounted specimens were provided to the BLM AZ Strip District (see Appendix B for list), and also to the Deaver Herbarium at NAU (see Appendix C for list). These collections represent a substantial new contribution to knowledge about the herbaceous component of the forest ecosystem. Approximately 100 of these species had not been collected from Mt. Trumbull prior to our sampling.

Table 1.1: Treatment Plots

Species	Native	% Frequency
Artemisia tridentata	native	2.2837
Bromus tectorum	exotic	1.046
Lupinus argenteus	native	1.0022
Sitanion hystrix	native	0.8844
Agropyron spp.	exotic*	0.4299
Amelanchier alnifolia	native	0.345
Penstemon	native	0.2108
Carex occidentalis	native	0.1588
Poa fendleriana	native	0.1561
Lichen	native	0.1287
Poa spp.	native*	0.1177
Berberis repens	native	0.0767
Penstemon pachyphyllus	native	0.0685
Ribes cereum	native	0.0657
Arctostaphylos spp.	native*	0.0602
Agoseris spp.	native*	0.0602
Viola spp.	native*	0.0493
Unknown moss	native	0.0411
Bouteloua gracilis	native	0.0383
Phlox spp.	native*	0.0383

Table 1.2: Control Plots

Species	Native	% Frequency
Artemisia tridentata	native	2.9653
Bromus tectorum	exotic	1.9059
Lupinus argenteus	native	1.8592
Sitanion hystrix	native	1.3035
Agropyron spp.	exotic*	0.322
Carex occidentalis	native	0.2545
Chrysothamnus nauseosus	native	0.2129
Poa fendleriana	native	0.1558
Verbascum thapsus	exotic	0.1298
Amelanchier alnifolia	native	0.1143
Ptelia trifoliata	native	0.1091
Berberis repens	native	0.0935
Viola spp.	native*	0.0779
Convulvulus arvensis	exotic	0.0779
Solidago sp.	native*	0.0727
Amelanchier spp	native	0.0675
Galium bifolium	native	0.0571
Phlox longifolia	native	0.0519
Rosa woodsii	native	0.0519
Chaenactis douglasii	native	0.0467

*Nativity assignments of taxonomic groups such as *Agropyron spp.*, and unknown species such as *Solidago sp.* are based on preliminary identifications. Taxonomic group nativity represents the majority of species observed (i.e., the majority of *Agropyron* species identified were exotic). Currently, we are updating the database to include our final identifications.

Soil Seed Bank

The soil seed bank can form an important source of the species that may dominate the site following disturbance. Preliminary results from a seed bank experiment conducted by Judy Springer and Dr. Margaret Moore of NAU are summarized here.

Background: The seed bank (or the store of seeds buried in the soil) is made up of both seeds produced in the area and seeds blown in from other areas. The seeds are normally dormant and need special conditions for them to germinate (Harper 1997). Few seed bank studies have been conducted on ponderosa pine forests. A seed bank study from a mature ponderosa pine forest near Flagstaff indicated a depauperate seed bank: only three species germinated from soil samples, with an estimated 8 to 22 viable seeds per square meter, depending on the treatment (Vose and White 1987). Another study conducted in a ponderosa pine forest in Washington resulted in the germination of 57 species with an overall approximate density of 13,000 - 14,500 viable seeds per square meter, depending on the season (Pratt et al. 1984). The high number of viable seeds in the latter study is attributed to several factors including the location of the study, which was in a forest-steppe transition zone, and the intermediate successional status of the stand.

Mt. Trumbull seed bank: Seed bank samples were collected in August 1996 from the 33-acre portion of the 96-1 treatment unit at Mount Trumbull after thinning of the overstory and prior to prescribed burning. Samples were collected at 0-5 cm and 5-10 cm depths. These samples were cold-treated and placed in the Northern Arizona University greenhouses for a seed emergence study. Additional samples were collected from the same unit in November (after the prescribed burn), and placed in the greenhouse under the same conditions. These samples were not artificially cold treated. They were obtained for the purpose of identifying plants which require fire for seed germination. Plants from all samples were

identified and removed after flowering. Seventeen species germinated with a total estimated density of 7425 viable seeds per square meter in the samples collected before the prescribed burn (Table 1.3).

Samples collected at the 0-5 cm depth had significantly higher emergence than those collected at 5-10 cm (ANOVA, $p < 0.05$). Twelve of the species that emerged in the study are annuals. At least three of the species (*Chenopodium album*, *Conyza canadensis*, *Verbascum thapsus*) are thought to be exotics. Three species emerged only in the samples collected after the burn (*Argemone munita*, *Nama dichotomum*, *Nicotiana attenuata*). Six of the species found in the seed bank study were not found aboveground in the vicinity of Mount Trumbull during the fire monitoring plot surveys in 1996. These species were *Nicotiana attenuata*, *Nama dichotomum*, *Mimulus rubellus*, *Conyza canadensis*, *Camissonia chamaenerioides*, and *Verbena bracteata*. There were no perennial grasses that emerged from the seed bank samples. Perennial grass species may exist for short periods in the seed bank, or the correct environmental cues for germination may not have occurred in the study. The latter question is currently being investigated.

Additional seed bank samples will be collected in April 1997, and further research will be conducted to determine if there are differences between the species and viable number of seeds in the seed bank of samples collected in the 96-1 unit, which has been burned, as compared to adjacent non-burned areas.

Table 1.3 - Estimated seed density (per m²) and total number of viable seeds that emerged from seed bank samples collected at Mount Trumbull

Species	Total viable seeds	Seed density (seeds/m ²)*
<i>Argemone munita</i>	1	-
<i>Camissonia chamaenerioides</i>	2	22
<i>Chenopodium album</i>	6	88
<i>Chenopodium graveolens</i>	1	13
<i>Chenopodium</i> sp.	2	25
<i>Collinsia parviflora</i>	149	2807
<i>Conyza canadensis</i>	20	1517
<i>Erigeron</i> sp.	4	25
<i>Euphorbia serpyllifolia</i>	2	13
<i>Mimulus rubellus</i>	75	930
<i>Muhlenbergia minutissima</i>	2	13
<i>Nama dichotomum</i>	3	-
<i>Nicotiana attenuata</i>	6	-
<i>Polygonum douglasii</i>	3	35
<i>Senecio macdougallii</i>	2	13
<i>Verbena bracteata</i>	3	38
<i>Verbascum thapsus</i>	155	1886
Total	436	7425

* To convert to seed/ft², multiply by 0.0929.

2. Contemporary Forest Overstory Structure

The overstory component of the ecosystem was measured by size classes on appropriately scaled subplots within each ecosystem monitoring plot. Trees 15 cm (5.9 in) and larger at diameter at breast height (dbh) (= "overstory") were inventoried in the entire 0.1 ha (.25ac) plot. Trees between 2.5 and 14.9 cm (1 and 5.89 in) at dbh (= "poles") were inventoried in a 10 X 25 m quadrant of the plot (0.25 ha, 0.62 ac). "Seedlings," trees under 2.5 cm (1 in) dbh, were inventoried in a 5 X 10 m portion of the plot (0.005 ha, 0.012 ac). All overstory trees and pole trees were inventoried for diameter at breast height, canopy dominance and damage, and were determined to be presettlement or postsettlement based on conservative

diameter cut-offs and bark color (White 1985). All trees called presettlement were cored, while 20% of the postsettlement trees were cored. Presettlement and postsettlement calls were more accurately determined in the lab after tree ring analysis to determine the age of trees. Tree seedlings were tallied based on size classes by species.

Density

Current forest conditions are dense with a mean of 1,406 trees per hectare (tph) (569 trees per acre) in the treatment plots and 1,482 tph (600 tpa) in the control plots (Table 2.1). Treatment plots and control plots show very similar composition before treatment, with 47% and 48% ponderosa pine, respectively, and 30% and 33% gambel oak, respectively. Ponderosa pine densities (~650 tph, 275 tpa) are very close to the Arizona average of 776 tph (314 tpa) reported by Garrett et al (1990) and similar to densities found at Camp Navajo (720 tph, 291 tpa) (Fulé et al. 1997), but well below the 3,098 tph (1,253 tpa) at the Gus Pearson Natural Area where logging, thinning, and firewood cutting have been excluded (Covington et al 1997). Oak is a dominant species in terms of tree density, but makes up only 10.5% and 13% of the basal area in treatment and control plots, respectively. In contrast, ponderosa pine makes up 79% and 85% of the basal area in treatment and control plots, respectively (Table 2.2). Junipers and pinyon pine have higher densities in the treatment plots. New Mexican locust appears to have higher densities in the control plots but variability is very high (see S.E., Table 2.1) due to the patchy distribution of locust. In terms of basal area, juniper, pinyon, and locust collectively contribute less than 10% of the stand basal area on treatment plots, and less than 3% of the stand basal area on control plots.

Table 2.1 Trees Per Hectare (trees above 2.5cm @ dbh), *Pre-treatment data

Species	Treatment Plots*		Control Plots	
	Mean	S.E.	Mean	S.E.
Ponderosa pine	610.84	86.39	674.50	102.64
Gambel oak	166.57	25.77	192.83	40.23
Utah juniper	104.81	17.86	12.95	3.98
Pinyon pine	59.99	10.37	5.19	2.85
New Mexican Locust	7.58	3.97	44.71	35.04
Total	949.79	86.05	933.21	100.21

Table 2.2 Basal Area (trees above 2.5cm @ dbh), *Pre-treatment data

Species	Treatment Plots*		Control Plots	
	Mean	S.E.	Mean	S.E.
Ponderosa pine	23.33	1.24	27.10	2.14
Gambel oak	3.10	0.45	4.21	0.82
Utah juniper	2.17	0.32	0.23	0.07
Pinyon pine	0.84	0.16	0.02	0.02
New Mexican Locust	0.04	0.02	0.21	0.12
Total	29.48	1.18	31.77	1.92

Diameter Distributions

Diameter distributions show that 50% of live trees are less than 20 cm (7.8 in) dbh (Fig. 2.1). Of these smaller trees, pines are the major component. Numbers of non-ponderosa pine species drop off at the higher diameter classes. While a number of large ponderosa pine trees were found (maximum diameter tree found was 85 cm [34 in]), the largest trees had been cut. Seven stumps per ha greater than 90 cm (35 in) were found (max. stump diameter = 118 cm [46.5 in] dsh, Fig. 2.4). The smaller snags are dominated by Gambel oak snags, making up more than 50% of all snags less than 20 cm (7.9 in, Fig. 2.2).

Similar analysis of dead material (Fig. 2.3, 2.4) show patterns of reduced numbers of non-ponderosa pine species at the higher diameter classes. The largest non-ponderosa pine snag was less than 80 cm (31in) while the largest ponderosa pine snag was 147 cm (58 in) dsh.

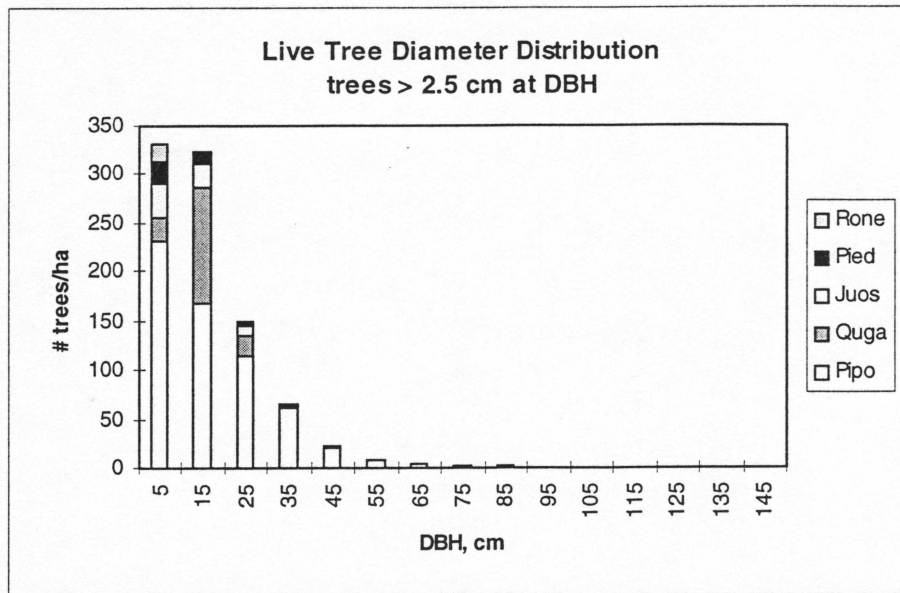


Fig. 2.1 Live Tree Diameter Distribution. X-axis is the mid-point of 10 cm diameter classes.

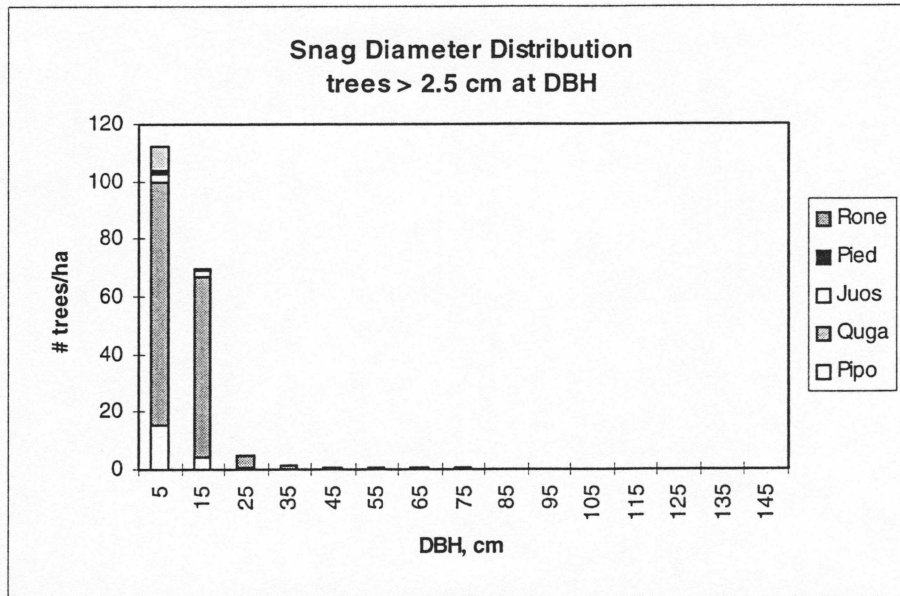


Fig. 2.2 Snag Diameter Distribution. Oaks predominate the smaller snag numbers, while no non-ponderosa pine species snags are found > than 80 cm dbh.

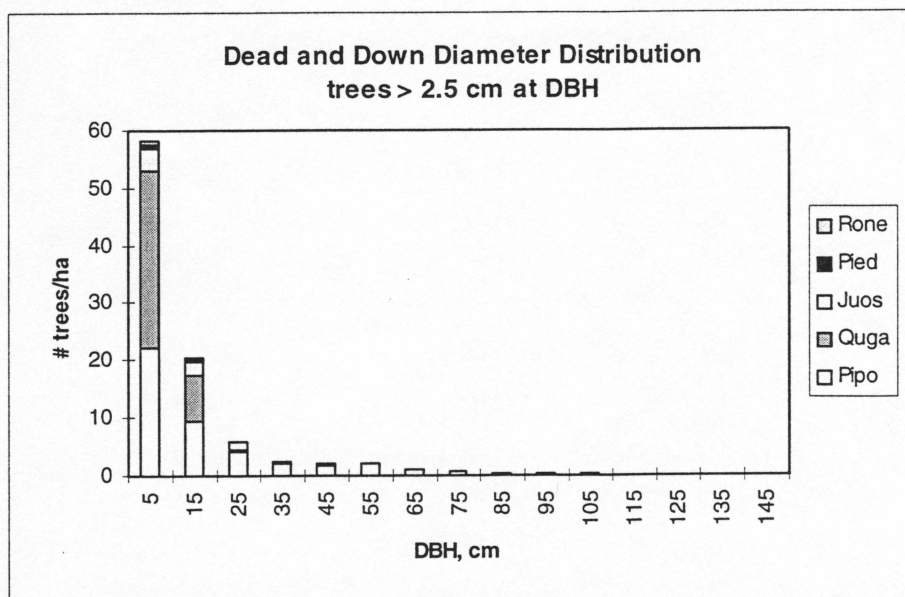


Fig. 2.3 Dead and Down Diameter Distribution.

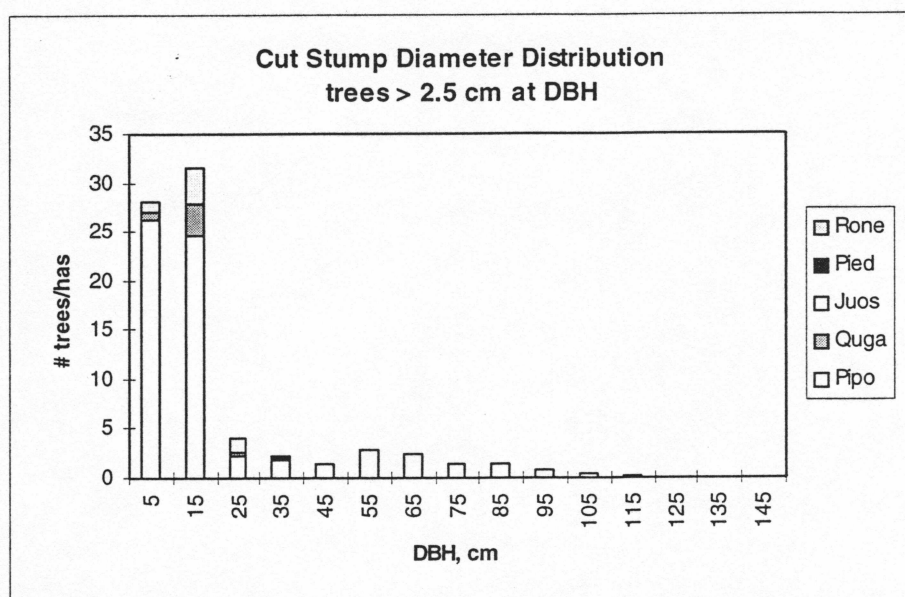


Fig. 2.4 Cut Stump Diameter Distribution.

Age Distribution

Tree increment cores were mounted and surfaced in the lab, and then dated using dendrochronological methods and chronologies from the Mt. Trumbull area (Stokes and Smiley 1968). The age distribution is shown in Fig. 2.5, with center dates at 40 cm (15.75 in) sampling height from 1510 to 1995. Large pulses of Gambel oak appeared in the late 1800's, while large pulses of ponderosa pine can be seen between 1910 and 1959. Because of the high density of postsettlement trees, the trees established before the turn of the century do not even appear on this graph's scale. Presettlement tree establishment patterns are shown in Fig. 6.2.

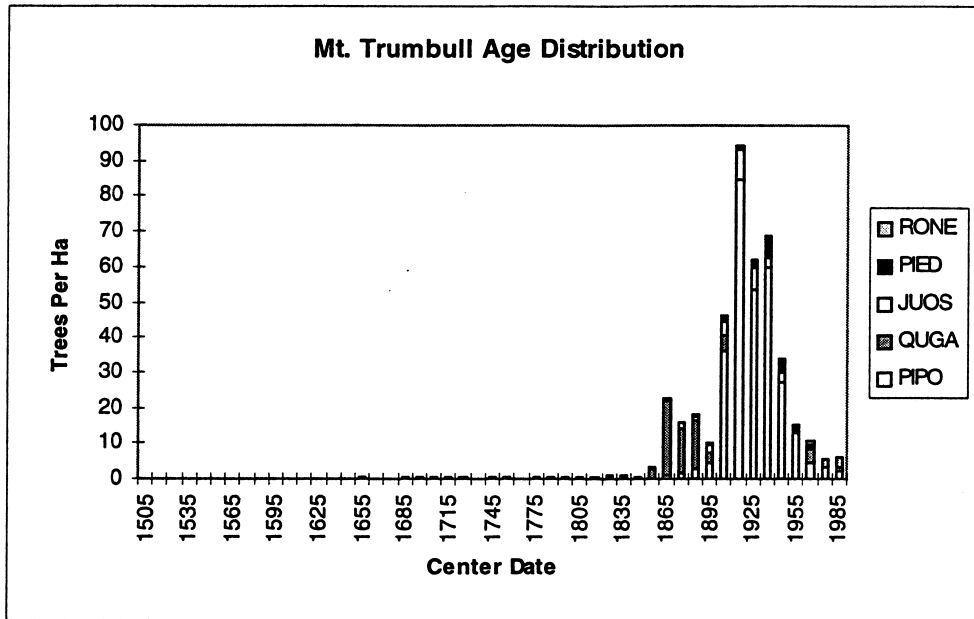


Fig. 2.5 Center date distribution at Mt. Trumbull; x-axis is the mid-point of 10 year center date classes.

3. Tree Regeneration

Tree regeneration at Mt. Trumbull is shown in Tables 3.1 and 3.2. Tree species less than 2.5 cm (1 in) diameter at breast height were recorded in a 5 m by 10 m (0.005ha, 0.012 ac) portion of the monitoring plot by species and height. Height class codes used were as follows:

- | | | |
|---------------|--------------------------|-----------------|
| 1: 0-15 cm | 4: 60.1-100 cm (1 meter) | 7: 300.1-400 cm |
| 2: 15.1-30 cm | 5: 100.1-200 cm | |
| 3: 30.1-60 cm | 6: 200.1-300 cm | |

No seedlings above 4 meters were found. The most frequent seedling or sprout in both treatment plots and control plots was Gambel oak, accounting for 75% - 80% of all seedlings found across the landscape (all height classes summed).

Tables 3.1 and 3.1 Tree regeneration by species and height class. The most frequent seedling or sprout was Gambel oak, height class 1 (less than 15 cm [6 in]).

Table 3.1 Treatment plots tree regeneration

Species	Hgt.	#	%Freq	#/ha
Quercus gambelii	1	472	26.6	858.2
Quercus gambelii	2	370	20.9	672.7
Quercus gambelii	3	268	15.1	487.3
Quercus gambelii	4	168	9.5	305.5
Quercus gambelii	5	123	6.9	223.6
Robinia neomexicana ¹	3	49	2.8	89.1
Robinia neomexicana ¹	4	45	2.5	81.8
Robinia neomexicana ¹	5	30	1.7	54.5
Robinia neomexicana ¹	2	29	1.6	52.7
Pinus ponderosa	5	20	1.1	36.4
Pinus ponderosa	3	18	1	32.7
Pinus edulis	2	17	1	30.9
Robinia neomexicana ¹	6	15	0.8	27.3
Pinus edulis	3	13	0.7	23.6
Pinus ponderosa	4	13	0.7	23.6
Juniperus osteosperma	1	12	0.7	21.8
Pinus edulis	5	12	0.7	21.8
Robinia neomexicana ¹	1	11	0.6	20
Juniperus osteosperma	5	10	0.6	18.2
Pinus edulis	4	9	0.5	16.4
Quercus gambelii	6	8	0.5	14.5
Juniperus osteosperma	3	7	0.4	12.7
Pinus edulis	1	7	0.4	12.7
Pinus ponderosa	1	7	0.4	12.7
Pinus ponderosa	2	7	0.4	12.7
Pinus ponderosa	6	6	0.3	10.9
Juniperus osteosperma	2	5	0.3	9.1
Pinus edulis	6	5	0.3	9.1
Ribes cereum ¹	5	3	0.2	5.5
Ribes cereum ¹	6	3	0.2	5.5
Robinia neomexicana ¹	7	3	0.2	5.5
Juniperus osteosperma	4	2	0.1	3.6
Juniperus osteosperma	7	2	0.1	3.6
Pinus ponderosa	0	2	0.1	3.6
Juniperus osteosperma	6	1	0.1	1.8
Pinus ponderosa	7	1	0.1	1.8
Total		1773		3223.4

Table 3.2 Control plots tree regeneration

Species	Hgt.	#	%Freq	#/ha
Quercus gambelii	1	229	25.7	789.7
Quercus gambelii	2	211	23.7	727.6
Quercus gambelii	3	116	13	400
Quercus gambelii	5	68	7.6	234.5
Quercus gambelii	4	57	6.4	196.6
Robinia neomexicana ¹	3	47	5.3	162.1
Robinia neomexicana ¹	4	45	5.1	155.2
Robinia neomexicana ¹	5	45	5.1	155.2
Quercus gambelii	6	12	1.3	41.4
Robinia neomexicana ¹	6	12	1.3	41.4
Pinus ponderosa	5	11	1.2	37.9
Amelanchier alnifolia	3	9	1	31
Robinia neomexicana ¹	2	7	0.8	24.1
Pinus ponderosa	4	5	0.6	17.2
Pinus ponderosa	1	3	0.3	10.3
Robinia neomexicana ¹	7	3	0.3	10.3
Juniperus osteosperma	4	2	0.2	6.9
Pinus edulis	1	2	0.2	6.9
Pinus ponderosa	2	2	0.2	6.9
Robinia neomexicana ¹	1	2	0.2	6.9
Juniperus monosperma	5	1	0.1	3.4
Juniperus osteosperma	2	1	0.1	3.4
Total		890		3068.9

¹ Robinia neomexicana (New Mexican locust) and Ribes cereum (wax currant) are classified as shrubs. At this site, they can reach tree stature, and thus were considered tree species.

of any species, the 1870-1995 radial growth increment was measured on the core and the 1870 diameter at breast height calculated. For dead trees (snags and logs), the year of death of each tree was estimated based on tree diameter and condition class. To determine the 1870 diameter of dead trees, growth estimates over the 1870 to death date periods were applied. For these preliminary data, we used a predictive regression relationship between diameter and basal area increment which was developed for presettlement pine trees from samples taken from Camp Navajo Army Depot, Bellemont, AZ. Equations specific to Mt. Trumbull will be used in the future. A detailed description of the presettlement reconstruction procedures is presented in Fulé et al. (1997).

Density and Basal Area

Results show the reconstructed 1870 forest had an average of 55 tph (22 tpa) versus 863 tph (349 tpa) in 1996 (Table 6.1), while basal area in the reconstructed 1870 forest was only 8.2 m²/ha (35.7 ft²/ac) versus 30 m²/ha (130.7 ft²/ha) in 1996 (Table 6.2). These values are within the low range of presettlement forest densities and basal areas found in ponderosa pine forests in the southwest. For example, the 35 ponderosa pines/ha found at Mt. Trumbull are slightly less than the 43 ponderosa pines/ha at Bar-M Canyon (Covington and Moore 1994b) and much less than the 61 ponderosa pines/ha found at the Gus Pearson Natural Area (Covington et al. 1997), and the 65 ponderosa pines/ha found at Camp Navajo (Fulé et al. 1997). However, pine density falls within the range of 7 to 116 ponderosa pines/ha reported in several early National Forest inventories and other studies in the region (Covington and Moore 1994a).

Table 6.1 Trees per hectare* (n = 58 0.1ha plots)

Species	1870 Forest		1996 Forest	
	Mean	S.E.	Mean	S.E.
Ponderosa pine	35.85	4.04	626.75	87.72
Gambel oak	16.46	3.83	158.92	38.04
Utah juniper	2.42	1.05	17.00	5.96
Pinyon pine	0.35	0.35	13.79	5.78
New Mexican Locust	0	0	43.47	34.60
Total	55.08	4.93	862.91	94.54

*multiply by 0.4047 to convert to trees per acre

Table 6.2 Basal Area, m²/ha* (n = 58 0.1 ha plots)

Species	1870 Forest		1996 Forest	
	Mean	S.E.	Mean	S.E.
Ponderosa pine	7.91	0.86	26.56	1.80
Gambel oak	0.20	0.08	2.90	0.63
Utah juniper	0.03	0.01	0.28	0.09
Pinyon pine	0.05	0.05	0.11	0.05
New Mexican Locust	0	0	0.13	0.11
Total	8.20	0.84	29.98	1.76

*multiply by 4.355 to convert to ft²/ha

Diameter Distribution

The diameter distribution of the reconstructed 1870 forest reflects these changes in forest structure, showing overall smaller numbers of all size classes. The largest size classes of 1870 ponderosa pines are found in the 50 cm (19.7 in) and 60 cm (23.6 in) size classes (Fig 6.1). The peaks found in the smaller size classes are mostly oak, replicating a very similar pattern found in the Camp Navajo study (Fulé et al. 1997). Oaks can regenerate rapidly, both from seed as well as from sprouts. Their thin bark makes them highly susceptible to fire-caused death, which probably acted as a significant thinning process on the oaks prior to fire exclusion. The lack of fire after 1870 allowed a large amount of oak seedlings and sprouts to live which might have otherwise been thinned by fire. The current diameter distribution is shown in Fig. 6.2 for only the 58 plots we reconstructed; a more direct comparison than using all the current forest data (167

plots). Please note that current forest structure did not include trees below 2.5 cm in the sampling; to be consistent, we excluded trees below 2.5 cm in the presettlement forest analysis.

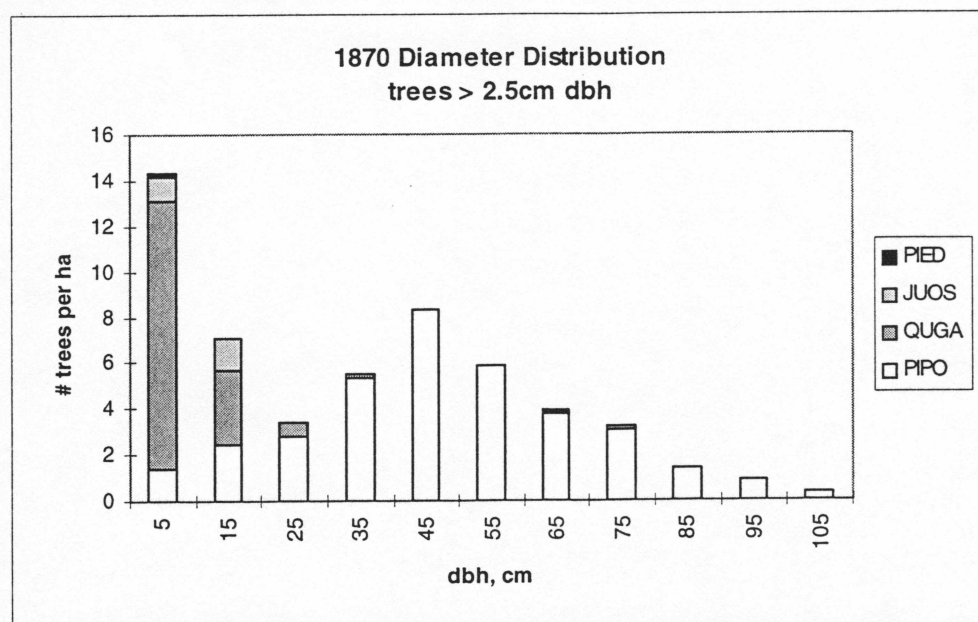


Figure 6.1 Diameter distribution of 1870 trees. Note the smallest size classes dominated by oak (n = 58 plots).

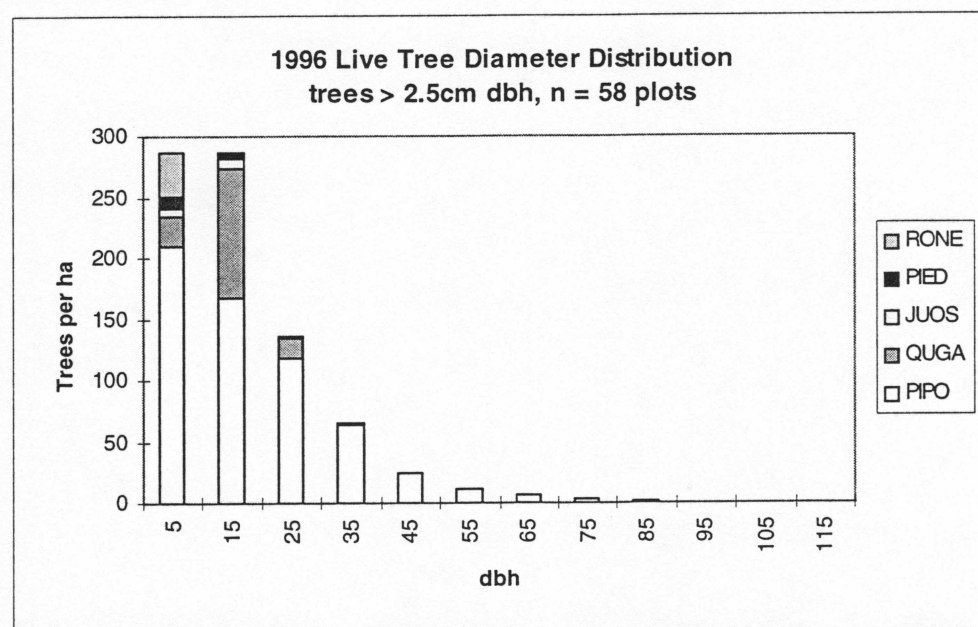


Figure 6.2 1996 live tree diameter distribution, trees greater than 2.5cm. Similar to figure 2.1, but including only those 58 plots used in the presettlement reconstruction.

Age Distribution

The age distribution of the reconstructed 1870 forest is derived from living presettlement trees only (Fig. 6.3), and is the same graph as Fig. 2.5, showing only trees established before 1870. Age data from all 167 plots were analyzed. Because of the extent of logging, the Mt. Trumbull age distribution of live trees is only a reduced estimate of the true distribution. For example, at the Gus Pearson Natural Area, dead wood samples were also dated, giving a more representative presettlement age distribution (Mast et

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Appendix A: Mt. Trumbull Plant Species List, updated 3/17/97

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

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

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

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

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

Appendix B: Donations to BLM herbarium

Family	Species	Common Name	Nat/Exotic	Location
Asteraceae	<i>Artemisia carruthii</i>	Carruth's sagewort	native	plot 1441
	<i>Hymenoxys cooperi</i>	Cooper's hymenoxys	native	1 mile E. of Mt. Logan overlook
	<i>Senecio multilobatus</i>	lobeleaf groundsel	native	1 mile E. of Mt. Logan overlook
Caryophyllaceae	<i>Stellaria longipes</i>	longstalk starwort	exotic?	plot 1387
Cyperaceae	<i>Carex occidentalis</i>	common sedge	native	plot 676
Euphorbiaceae	<i>Euphorbia lurida</i>	San Francisco mountain spurge	native	1 mi. East of Mt. Logan overlook
Fabaceae	<i>Astragalus argophyllus</i>	Silverleaf milkvetch	native	open pipo forest
	<i>Lupinus argenteus</i>	silver lupine	native	
	<i>Psoralidium tenuiflorum</i> (<i>Psoralea tenuiflora</i>)	slimflower scurfpea	native	1200m SW of Nixon Spring Admin Site
Lamiaceae	<i>Leonurus cardiaca</i>	common motherwort	exotic	in oaks near aspen catchment
	<i>Moldavica parviflora</i>	smallflower dragonhead		
Onagraceae	<i>Oenothera coronopifolia</i>	crownleaf eveningprimrose	native	2000m S of Nixon Spring Admin Site
Papaveraceae	<i>Argemone munita</i>	flatbud pricklypoppy	native	near Logan fire
Poaceae	<i>Agropyron intermedium</i> var. <i>trichophorum</i>	intermediate wheatgrass	exotic	plot 1136
	<i>Aristida purpurea</i> var. <i>longiseta</i>	purple three-awn	native	open pipo forest
	<i>Bromus inermis</i>	Smooth brome	exotic	near plot 1135
	<i>Bromus tectorum</i>	Cheatgrass	exotic	plot LO-22
	<i>Muhlenbergia wrightii</i>	Spike muhly	native	plot 1526
	<i>Poa fendleriana</i>	muttongrass	native	plot 1331
	<i>Poa pratensis</i>	Kentucky bluegrass	exotic	plot 1522
	<i>Sitanion hystrix</i>	Bottlebrush squirreltail	native	Lava fire
	<i>Ipomopsis multiflora</i> (= <i>Gilia multiflora</i>)	manyflowered gilia	native	plot 1224
	<i>Phlox longifolia</i> (= var. <i>stansburiana</i>)	longleaf phlox	native	plot 1185 (1135?)
Polygonaceae	<i>Eriogonum racemosum</i>	redroot buckwheat	native	plot 1186
	<i>Eriogonum umbellatum</i>	sulphur wildbuckwheat	native	plot 725
Scrophulariaceae	<i>Collinsia parviflora</i>	blue-eyed mary	native	plot 1332
	<i>Penstemon linarioides</i> ssp. <i>sileri</i> (= var. <i>sileri</i>)	toadflax penstemon	native	plot LO-30
	<i>Penstemon pachyphyllus</i>	thick-leaf penstemon	native	1 mile E. of Mt. Logan overlook
Solanaceae	<i>Nicotiana attenuata</i>	coyote tobacco	native	meadow near plot 1987
	<i>Physalis hederifolia</i> var. <i>palmeri</i>	Palmer's ground cherry	native	plot 1236
	<i>Solanum jamesii</i>	wild potato	native	in field near aspen catchment

Appendix C: Donations to Deaver Herbarium, NAU

Family	Species	Common Name	Nat/Ex	Location
Amaranthaceae	Amaranthus albus (= graecizans)	prostrate pigweed	exotic	
Anacardiaceae	Rhus glabra	smooth sumac	native	Lava fire
	Rhus trilobata	skunkbush sumac	native	southeast-facing rocky area
Asclepiadaceae	Asclepias asperula var. asperula	antelope horns	native	on County Road 5
	Asclepias subverticillata	whorled milkweed	native	
Asteraceae	Artemisia carruthii	Carruth's sagewon	native	plot LO-17
	Brickellia grandiflora	tasselflower brickellbush	native	plot 1432
	Chaenactis douglasii	Douglas' dustymaiden	native	Mt. Trumbull
	Gutierrezia sarothrae	broom snakeweed	exotic	LO-24
	Hymenopappus filifolius	fineleaf hymenopappus	native	plot 1389
	Hymenoxys acaulis	ncn	native	plot 1327
	Hymenoxys acaulis	ncn	native	crest of Mt. Logan
	Hymenoxys cooperi	Cooper's hymenoxys	native	near overlook
	Psilostrophe sparsiflora		native	35 miles south oh Hwy 389
	Senecio eremophilus (= macdougallii)	Macdougall's groundsel	native	96-3
	Senecio multilobatus	lobeleaf groundsel	native	near overlook
	Senecio multilobatus	lobeleaf groundsel	native	
	Senecio multilobatus	lobeleaf groundsel	native	
	Viguiera multiflora	showy goldeneye	native	near aspen catchment
Berberidaceae	Berberis repens	Oregon-grape	native	
Boraginaceae	Cryptantha cinerea var. cinerea (= C. jamesii)	James' catseye	native	plot 1491
	Lappula occidentalis (= L. redowskii)	desert stickseed	exotic	Logan fire
Brassicaceae	Arabis holboellii var. fendleri (=A. fendleri var. fend.)	Fendler's rockcress	native	near plot 724
	Sisymbrium altissimum		native	Mt. Trumbull
	Streptanthus cordatus	twistflower	native	on Mount Trumbull, near trail
Capparaceae	Cleome lutea	yellow spiderflower	native	sagebrush flat to Toroweap
Caprifoliaceae	Sambucus nigra ssp. cerulea (= S. glauca)	blue elder	native	plot 1381
	Symphoricarpos oreophilis	whortleleaf snowberry	native	Powell overlook
Caryophyllaceae	Arenaria fendleri var. glabrescens (= v. aculeata)	ncn	native	Mt. Logan
	Silene scouleri	Scouler's campion	native	Top of Mt. Logan
	Stellaria longipes	longstalk starwort	exotic?	plot 1287
Convolvulaceae	Convolvulus arvensis	field bindweed	exotic	plot 1136
Cyperaceae	Carex occidentalis	common sedge	native	plot 1424
Ericaceae	Arctostaphylos pungens	pointleaf manzanita	native	

Family	Species	Common Name	Nat/Ex	Location
Euphorbiaceae	<i>Euphorbia lurida</i>	San Francisco mountain spurge	native	
Euphorbiaceae	<i>Fallugia paradoxa</i>	Apache plume	native	plot 1381
Fabaceae	<i>Dalea candida</i> var. <i>oligophylla</i>	western prairie-clover	native	plot 1327
	<i>Lupinus argenteus</i>	silver lupine	native	
	<i>Lupinus argenteus</i>	silver lupine	native	
	<i>Lupinus argenteus</i>	silver lupine	native	
	<i>Lupinus argenteus</i>	silver lupine	native	near Swertia
	<i>Lupinus kingii</i>	King's lupine	native	plot 724
	<i>Phaseolus angustissima</i>	Arizona lima bean	native	plot 1074
	<i>Psoralea tenuiflora</i> (<i>Psoralea tenuiflora</i>)	slimflower scurfpea	native	
	<i>Psoralea tenuiflora</i> (<i>Psoralea tenuiflora</i>)	slimflower scurfpea	native	plot 1424
	<i>Robinia neomexicana</i>	New Mexican locust	native	plot 1231
Fabaceae	<i>Vicia americana</i>	American vetch	native	plot 726
	<i>Quercus turbinella</i>	turbinella oak	native	plot 1175
Fumariaceae	<i>Corydalis aurea</i>	golden corydalis	native	crest of Mt. Trumbull
Gentianaceae	<i>Swertia albomarginata</i>	white-margined swertia	native	
Geraniaceae	<i>Geranium caespitosum</i>	pinewoods geranium	native	Lava fire
	<i>Geranium richardsonii</i>	Richardson's geranium	native	plot 1381
Lamiaceae	<i>Leonurus cardiaca</i>	common motherwort	exotic	in oaks near aspen catchment
	<i>Moldavica parviflora</i>	smallflower dragonhead		plot 1136
	<i>Monardella odoratissima</i>	Pacific monardella	native	near plot 1433
Liliaceae	<i>Allium bisceptrum</i>	twincrest onion	native	
Linaceae	<i>Linum aristatum</i>	bristle flax	native	plot 1224
Loasaceae	<i>Mentzelia pumila</i>	dwarf mentzelia	native	plot LA-15
Nyctaginaceae	<i>Mirabilis decipiens</i>	broadleaf four o'clock	native	
	<i>Mirabilis linearis</i>	narrowleaf umbrellawort	native	plot LO-17
	<i>Mirabilis oxybaphoides</i>	smooth spreading four o'clock	native	near aspen catchment
Onagraceae	<i>Oenothera caespitosa</i>	tufted eveningprimrose	native	Lava fire
	<i>Oenothera coronopifolia</i>	crownleaf eveningprimrose	native	plot 1523
Papaveraceae	<i>Argemone munita</i>	flatbud pricklypoppy	native	plot LO-6
Poaceae	<i>Agropyron cristatum</i>	crested wheatgrass	exotic	plot 1526
	<i>Agropyron elongatum</i> (= <i>Elymus elongatus</i>)	tall wheatgrass	exotic	
	<i>Agropyron intermedium</i> var. <i>intermedium</i> (= <i>E. intermedium</i>)	intermediate wheatgrass	exotic	plot 1474
	<i>Agropyron intermedium</i> var. <i>trichophorum</i> (= <i>E. intermedium</i>)	intermediate wheatgrass	exotic	plot 1089
	<i>Agropyron trachycaulum</i> (= <i>E. trachycaulum</i>)	slender wheatgrass		
	<i>Aristida purpurea</i> var. <i>longiseta</i>	purple three-awn	native	plot 1389

Family	Species	Common Name	Nat/Ex	Location
Solanaceae	Penstemon pachyphyllus	thick-leaf penstemon	native	
	Penstemon rostriflorus (= bridgesii)	Bridge penstemon	native	
	Penstemon rostriflorus (= bridgesii)	Bridge penstemon	native	plot 1432
	Nicotiana attenuata	coyote tobacco	native	P-J area
	Solanum jamesii	wild potato	native	in field near aspen catchment
	Solanum triflorum	cutleaf nightshade	native	chained area
Verbenaceae	Verbena gooddingii	southwestern mock vervain	native	Loop Rd.
Violaceae	Viola canadensis	Canadian white violet	native	96-3
Viscaceae	Phoradendron juniperinum	juniper mistletoe	native	Loop Rd.