

Mt. Trumbull Ponderosa Pine Ecosystem Restoration Project

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Abstract—This paper describes recent and current studies on the Parashant National Monument in northern Arizona. These studies support the Mt. Trumbull Ponderosa Pine Ecological Restoration Project. A major goal of the project is to allow wildfire to resume its historic role in maintaining forest health following decades of declining sustainable conditions.

Background

The frequent, low intensity fire regime that naturally occurred in southwestern ponderosa pine forests (Covington et al. 1999) was disrupted when European-American settlers arrived in the area in the late 1800s and early 1900s. Livestock grazing removed fine fuels that carry fire and logging altered the age class structure of forests. Wildfire suppression reduced the number of acres burned and increased the fire return interval. As a result, much of the ponderosa pine forest in the southwest is functioning outside of the range of natural variability and is in poor and declining health.

The most famous use of timber from the area was for use in the Church of Jesus Christ of Latter Day Saints' St. George Temple. Due to the technological limitations of logging using mule and oxen to skid in the remote, rugged mountains, as well as those imposed by the use of portable steam sawmills (which were not able to handle the largest trees), a sizeable portion of the old growth was not harvested and remains standing today.

Today the forest consists of the remnants of the pre-settlement forest along with approximately 100 years of regeneration. The previously open, park-like stand, with tree densities around 50 per acre (Mast et al. 1999), has changed to "dog hair," with stand densities over 400 trees per acre. These stands are susceptible to disease, insect infestations, catastrophic wildfire, and drought (figure 1).

Introduction

For the past seven years, the Bureau of Land Management, working with the Ecological Restoration Institute (ERI) at Northern Arizona University and the Arizona Game and Fish Department, have been implementing a large scale, ponderosa pine ecosystem restoration project in the Mt. Trumbull / Mt. Logan area.

The Mt. Trumbull Ponderosa Pine Ecosystem Restoration Project involves public lands managed by the Bureau of Land Management within the newly designated Grand Canyon-Parashant National Monument in northern

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Figure 1—“Dog hair” stand of post-settlement ponderosa pines at Mt. Trumbull, Arizona.

Arizona. As a “sky island,” the approximately 17,000 acre ponderosa pine forest sits atop 7,000-8,000 ft mountains amid a piñon-juniper / sagebrush / grassland community. The forest contains 500-year-old ponderosa pine along with old growth piñon, juniper, and New Mexican locust.

The goals of the Mt. Trumbull restoration project are to 1) restore pre-settlement ecosystem health and function to a ponderosa pine forest in the recently designated Parashant National Monument, just north of the Grand Canyon; 2) reduce fuel loads and disrupt fuel continuity to reduce the risk of catastrophic wildfire; and 3) gather information on a wide variety of ecosystem components and processes in order to understand the effects of restoration treatments. By reducing fuel loads and reestablishing an herbaceous understory we hope to one day restore natural fire processes. Treatments include merchantable and non-merchantable timber harvesting, prescribed fire, and seeding of native herbaceous species. Due to the existing high fuel loads, a variety of techniques have been used to reduce mortality of pre-settlement ponderosa pine trees from treatment activities.

The project includes an adaptive management provision that allows managers to incorporate lessons learned into future treatments. For example, current treatments leave more trees than the earliest efforts. These additional “insurance trees” allow for some mortality from natural and anthropogenic impacts (such as prescribed burning).

The project can be broken out into seven distinct phases or efforts:

1. Project planning and regulatory compliance
2. Ecosystem inventory and timber marking
3. Merchantable and non-merchantable thinning
4. Prescribed burning
5. Restoration of native grasses and forbs by seeding
6. Maintenance of periodic low intensity grass fires in restored areas
7. Monitoring (occurs throughout all phases of the project)

Project Planning and Regulatory Compliance

This project was initiated prior to the designation of the area as a National Monument. Current efforts must balance the needs of the restoration experiment with Monument values. In order to ensure that project impacts do not impair Monument values and to provide our public interests with sufficient information to understand the project and its anticipated effects, we prepare environmental assessments for all treatment activities.

Ecosystem Inventory and Timber Marking

Table 1 shows pretreatment forest stand density data compiled from 128 20 × 50 meter ecosystem monitoring plots established by Northern Arizona University within all existing and proposed ecosystem restoration units. In these plots researchers tallied all stems of ponderosa pine, gambel oak (*Quercus gambelii*), juniper (*Juniperus osteosperma*), and piñon pine (*Pinus edulis*) ≥1 inch dbh. Stems / plot were extrapolated to stems / acre for the entire restoration

Table 1—Pretreatment forest stand density.

Unit(# plots)	Overstory ponderosa	Pole ponderosa	Overstory oak	Pole oak	Overstory: juniper/piñon	Pole: juniper/piñon	Overstory locust	Pole locust	Total
Lava (3)	84	108	46	17	- / 4	- / -	-	11	270
Trick Tank (11)	131	83	82	111	- / -	- / 6	1	15	429
Rye Flat (10)	126	100	42	67	7 / 2	7 / 5	-	-	356
N. Sawmill (8)	229	263	7	44	29 / 2	67 / 27	-	-	668
High Meadow (16)	117	103	74	166	6 / 2	9 / 13	3	6	499
Lower Sawmill (5)	57	26	62	76	26 / 9	29 / 16	-	10	311
EB-1 (4)	55	33	3	5	- / -	- / -	-	-	96
EB-2 (4)	88	57	117	50	- / -	- / -	-	-	312
EB-3 (5)	62	48	-	-	- / 1	- / -	-	-	111
EB-4 (2)	260	577	-	41	10 / -	33 / 33	-	-	954
EB-5 (6)	168	89	22	22	29 / 2	54 / -	-	-	386
Cinder (8)	87	27	33	22	- / -	- / 3	1	-	173
Hi-Lo (13)	134	103	20	73	14 / 7	20 / 15	20	10	416
Nixon (9)	124	100	20	4	18 / 4	38 / 13	-	-	321
Spring (10)	64	26	15	34	30 / 18	23 / 55	-	-	265
Boundary (4)	55	11	16	11	19 / 18	49 / 43	-	-	222
War Club (4)	104	106	1	16	22 / 3	174 / 24	-	-	450
Corner (6)	154	252	2	16	25 / 10	68 / 25	-	-	552
Mean stems/acre	117	117	31	43	13 / 4	31 / 15	1	3	377

units. The table shows overstory stems (≥ 5.9 in. dbh) and pole stems (≥ 1 in., ≤ 5.9 in. dbh) and total stems per acre for the restoration units.

Ecosystem monitoring plots used to collect the data shown in table 1 are based on National Park Service long term vegetation and fuels monitoring plots as described in the Western Region Fire Monitoring Handbook (1992). Under conventions described in this handbook, all trees greater than or equal to 5.9 inches dbh are classed as overstory trees. Trees that are greater than 1 inch and less than 5.9 inches are classed as pole trees. Growth increment core samples, used to determine age, are taken from all live pre-settlement trees on each long term ecosystem monitoring plot. In addition, a 10% random sample of all living post-settlement age trees are cored for accurate age determination. This information is available upon request from the BLM, St. George Field Office.

The ecosystem monitoring plots established by NAU in proposed treatment areas and in the control area show that current forest conditions are dense. Overstory, pole, and regeneration data show a mean of 569 trees / acre in the treatment unit plots and 600 trees / acre in the control unit plots. Treatment unit plots and control unit plots show very similar composition before implementation of restoration prescriptions on treatment areas, with 47% and 48% ponderosa pine, respectively and 30% and 33% gambel oak, respectively. 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 unit plots respectively. Juniper and piñon pine have higher densities in treatment unit plots. New Mexico locust appears to have higher densities in the control unit plots but variability is very high due to the patchy distribution of locust. In terms of basal area, juniper, piñon, and locust collectively contribute less than 10% of the stand basal area on treatment unit plots, and less than 3% on control unit plots (NAU 1997).

Diameter distributions show that 50% of current live trees are less than 20 cm (7.8 in.) dbh. Of these smaller trees, ponderosa pine are the major component. Numbers of non-ponderosa pine drop off at the higher diameter classes (NAU 1997). NAU has reconstructed the forest structure from long term ecosystem monitoring plots. 1870 was chosen as the pre-disturbance date based on preliminary fire scar data, which shows the last widespread naturally occurring fire to be in 1870, in addition to logging and grazing records, which place domestic livestock grazing in the Mt. Trumbull area around 1870 (Altschul and Fairley 1989). Increment cores were taken from all live trees identified as pre-settlement in the field, based on conservative size criteria and bark coloration. After laboratory analysis of the tree core data, age data were used to confirm or reject the field determination. For each cored pre-settlement tree of any species, the 1870-1996 radial growth increment was measured on the core and the 1870 diameter at breast height was 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, NAU used a predictive regression relationship between diameter and basal area increment that was developed for pre-settlement pine trees from samples taken from Camp Navajo Army Depot, Bellemont, AZ.

Results from plots show the reconstructed 1870 forest had an average of 22 trees / acre (55 trees / ha) versus 349 trees / acre (863 trees / ha) in 1996 for all species, while basal area in the reconstructed forest was only 35.7 ft² / acre versus 130.7 ft² / acre in 1996. These values are within the low range of pre-settlement forest densities and basal areas found in ponderosa pine forests in the southwest. Pine density in the Mt. Trumbull area falls within the range of

7-116 ponderosa pine/ha reported in several early National Forest inventories and other studies in the region (Covington and Moore 1994).

Merchantable Timber Harvest and Non-Merchantable Thinning

BLM uses a combination of timber sales, thinning contracts, and its own workforce to reduce the density of trees within restoration units. Only post-settlement trees are cut. Timber sales remove between 2,500 and 3,000 board ft/ac from the units. The primary products are boards, poles, palettes, grape trellis, sawdust, and fuelwood. Trees less than 18" DBH are logged at a loss, which is amortized by profits from larger trees (up to 28"). Loggers are required to protect residual trees from their harvest operations. Loggers are hauling 12"-28" trees, all post-settlement.

Early in the project BLM reduced the maximum size of ponderosa that was allowed to be cut from 28" to 22" and received no bids; the project lost one year due to the failure to attract any commercial partners. We now include larger (up to 28" DBH) post-settlement trees, although few of the trees cut are of the maximum size. We now mark more leave trees than we did originally to provide insurance against losses during burning and logging operations.

In addition, ladder fuels composed of post-settlement ponderosa pine, piñon pine, or juniper trees of less than 10 inches diameter breast height (dbh) are thinned with power saws. Post-settlement trees are limbed with power saws to reduce fire spread from the forest floor into the canopy. Pre-settlement trees are limbed to a height of approximately 6-8 feet. Snags greater than 12 inches dbh are prepped (e.g., fireline is constructed around these features) in an effort to reduce ignition.

The BLM fuels reduction crew prepares units for burning by reducing the height of any activity fuels, thinning unmerchantable trees, preparing firelines, and raking litter from the base of pre-settlement trees. Logging slash is lopped and scattered, then a low intensity broadcast burn is started under environmental conditions conducive for burning (hot and dry enough to allow for consumption of litter, but not so hot and dry as to allow tree mortality from scorch height or canopy damage).

Consumption of deep layers of forest floor litter generates high amounts of heat energy. Studies at Fort Valley and Long Valley Experimental Forests showed very high mineral soil temperatures during burning. Smoldering combustion takes place in deep layers of forest litter and may continue for durations of 72 hours. Burning for this length of time can result in either temperatures exceeding 140°F, causing cambium death, or lower temperatures for longer durations, which also cause tissue death (Harrington and Sackett 1988).

Prescribed Burning

Following preparation of burn units, BLM introduces low intensity prescribed fires to reduce duff depth from a range of 1-10" to a range of .25-2", and to reduce fuel loading from an average of 10 tons per acre to a range of 1-6 tons per acre. To prevent degradation of the Grand Canyon airshed,

favorable winds that carry particulate matter away from the canyon are necessary. Sagebrush that exists in places as a significant understory shrub are not excluded from prescribed fire.

Table 2—Prescription parameters in the use of prescribed fire.

Prescription parameters (forest understory)	Prescribed fire behavior			
	Cool	Hot	Desired	Outside (max.)
Fuel model (s)	9	9	9	9
Live fuel moisture (%)	n/a	n/a	n/a	n/a
1000 hr. moisture (%) used in lieu of duff moisture	16% = 50% duff reduction	6% = 90% duff reduction	10% = 75% duff reduction	6%
Soil moisture (%)	n/a	n/a	n/a	n/a
Rate-of-spread (ch/hr)	2 chains/hour	2-6 chains/hour	2 chains/hour	2-6 chains/hour
Flame length (ft)	1 foot	2-3 feet	2 foot	2-3 foot
Scorch height (ft)	2 feet	3-4 feet	1 foot	3-4 feet
Type of fire	strip headfire	backing	backing	
Probability of ignition (%)				60%
Spotting distance (mi)				.3 - .4 mile

Table 3—Environmental parameters in the use of prescribed fire.

Environmental parameters (forest understory)	Acceptable range			
	Cool	Hot	Desired	
Air temperature (degrees F)	30°	75°	50°	
Relative humidity (%)	46%	20%	35%	
Wind speed (midflame, mph)	2	8	5	
Wind direction	west	northeast, northwest, east	south, southwest, southeast	Outside burn block at critical holding point—minimum acceptable moisture
1 hr fuel moisture (%)	11	5	7	5
10 hr fuel moisture (%)	n/a	n/a	n/a	n/a
1000 hr fuel moisture (%)	16	6	10	6

Restoration of Native Grasses and Forbs by Seeding

The herbaceous and shrub understory of southwestern ponderosa pine forests is important for many ecological reasons, including food and habitat for herbivores, nutrient cycling, soil formation and stabilization, and its contribution to biological diversity and aesthetic appeal. Understory species composition and cover have been adversely modified since Euro-American settlement and understory production has declined with increasing tree density. Key to restoring the understory is an understanding of the on-site plant material, including above ground vegetation as well as viable seeds in the soil bank.

To obtain a baseline of the species in the current soil seed bank at Mt. Trumbull, soil samples were collected in September 1997 from 5 vegetation types within three of the experimental block units. Soil samples were collected in April 1997 from unburned, lightly burned, and severely burned patches within the 33 acre subunit of the 96-1 restoration unit. Samples were placed

in the NAU greenhouse for several months. Germination from these samples was compared to samples taken in a control (untreated) area to determine where recruitment of plants from the seed bank occurs in a restored area. Preliminary results indicate that a large number of seeds survive in the soil seed bank in unburned and lightly burned patches within the landscape mosaic. The survival of these seeds has implications for seeding and recruitment, as well as exotic species control. Samples will be collected in the future from the experimental units to document changes in the seed bank over time and with ecological restoration treatments.

Further research is needed to determine if perennial grasses and forbs utilize the soil seed bank for seed storage. The majority of species that store seeds in the soil seed bank are early successional annuals. In order to restore areas to historic species composition and frequency, seeding of species that have been extirpated from an area may be required, especially if those species are not found in the soil seed bank. BLM has been applying seed to the units after they have been burned in order to reduce exotic weed invasion and to assess the effectiveness of seeding.

Efforts to use local genotypes are made, although local varieties are not always available. Some seed used on the project was collected far away, even though the species is considered to be an historic native of Mt. Trumbull. Seed is applied using hand-held spreaders, usually within six months of the burn treatment. Open sites are “back-dragged” using rakes or chains dragged behind an ATV.

Table 4—2001 Rye Flat seeding. Example of seed mix and application rates used at the Mt. Trumbull Restoration Project.

Species	Total weight (lbs PLS*)	Lbs/acre (80 acres)
Big bluegrass (<i>Poa ampla</i>)	50	0.6
Sand dropseed (<i>Sporobolus cryptadrus</i>)	40	0.5
Sideoats grama (<i>Bouteloua curtipendula</i>)	120	1.5
Utah serviceberry (<i>Amelanchier utahensis</i>)	40	0.5
Fringed sagebrush (<i>Artemisia frigida</i>)	40	0.5
Wood's rose (<i>Rosa woodsii</i>)	40	0.5
Arizona fescue (<i>Festuca arizonica</i>)	140	1.75
Prairie Junegrass (<i>Koeleria cristata</i>)	80	1.0
Bottlebrush squirreltail (<i>Sitanion hystrix</i>)	100	1.25
Slender wheatgrass (<i>Agropyron trachycaulum</i>)	100	1.25
Mountain brome (<i>Bromus marginatus</i>)	100	1.25
Western wheatgrass (<i>Agropyron smithii</i>)	100	1.25
TOTAL	950	11.85

* Percent live seed

Maintenance of Periodic Low Intensity Grass Fires in Restored Areas

Due to delays in implementing the project, re-entries have not yet occurred. The plan is to complete the restoration process phase 1 throughout the area, then re-enter blocks with fire as funding and conditions allow.

Monitoring

The Mt. Trumbull Ecosystem Restoration Project combines landscape scale operational restoration treatments with comprehensive research. The Ecological Restoration Institute at NAU and the Arizona Game and Fish Department are heading up the research efforts tied to BLM's operational treatments. The research / monitoring studies accompanying this project are varied, but focus on the effects of ponderosa pine ecosystem restoration treatments on vegetation structure and composition, and wildlife. To determine the effects of treatments upon vegetation, 250 long term ecosystem monitoring plots have been established across 4,500 acres of ponderosa pine forest. In addition, studies are in place to monitor the effects of restoration treatments upon small mammals, Abert's squirrels, mule deer, bats, Merriams's turkey, reptiles, passerine birds, and insects.

To achieve sustainable management of ponderosa pine forest ecosystems, a scientific basis must be developed for understanding the structure and dynamics of healthy ecosystems. To quantify the effects of present day disturbances, forests where high-intensity wildfires, bark beetle outbreaks, and other factors are resetting the pattern of succession must be measured and compared. However, NAU and BLM believe the threat to current unsustainable ecosystems is so imminent that carefully planned and closely monitored treatments to restore ecosystem health, based upon the best existing knowledge and designed to adapt rapidly as new information is learned need to be carefully initiated now. NAU, AGFD and BLM are providing a program of scientific study which is providing the information and technologies needed by BLM to carry out ecosystem restoration in an adaptive, "learn by doing manner." NAU, AGFD and BLM are providing an integrated plan of research, experimentation, and feedback, intended to lay the groundwork for integrated ecosystem management by providing scientists, land managers, and the public with tested procedures for restoring ecosystem health.

NAU Scientific Study

NAU scientific study consists of three elements:

- systematic analysis of changes in forest structures and disturbance regimes since disruption of the natural fire regime;
- comparison of the effects of contemporary disturbances from high-intensity wildfire, bark beetle mortality, prescribed fire, and understory thinning; and
- initiation of restoration treatments in an adaptive management setting.

Sampling is occurring at a series of study areas, ranging from those with extended fire exclusion to those still under frequent regimes. Sampling is being carried out at Mt. Trumbull, Beaver Creek Biosphere Reserve, Arizona; the Sierra Tarahumara, Chihuahua, Mexico; La Michilia Biosphere Reserve, Durango, Mexico; and other sites within the southwestern ponderosa pine forest. NAU has carefully selected sampling sites that maximize efficient collection of data most valuable to ecological understanding and management planning at regional, national, and international levels. By applying the same sampling and analysis methods on a range of study areas stretching across the southwestern ponderosa pine ecosystem of North America, this systematic approach is aiding in producing a unified, comparable data set for addressing the natural range of variability of pre-disruption forests, as well as the range of contemporary forest conditions. These quantitative data are being used to support the development of operational ecosystem restoration and management

plans across portions of the Southwest, not only within the Mt. Trumbull/Logan area.

Specific NAU studies include:

1) Permanent ecosystem monitoring plots for long-term monitoring.

Long-term monitoring is essential to assess current conditions, reconstruct pre-settlement ecosystem structure, and evaluate the effects of restoration treatments. Monitoring involves recordation of pre-treatment data, assessing current conditions, followed by multiple post-treatment recordation of data and analysis on the same plots to determine changes to the ecosystem. Permanent monitoring plots have been established on a 300 × 300 meter grid across Mt. Trumbull. A total of 249 permanent ecosystem monitoring plots are in place across approximately 4,800 acres of ponderosa pine / gambel oak forest.

2) Experimental blocks.

The experimental blocks are designed for detailed measurements of the effects of ecosystem restoration treatments, and complement the landscape scale sampling provided by the permanent ecosystem monitoring plots for long-term monitoring described above. The purpose of the experimental blocks is to quantify restoration effects through intensive measurements at a series of five controlled study sites. Each block consists of a 50-140 acre area divided into two similar units. Treatments—ecosystem restoration and control—have been randomly assigned to each unit. Basic measurements at each experimental block include contemporary and pre-settlement (pre-1870) forest structure (species composition, size distribution, age distribution), current understory composition and density, canopy closure, fuel loading, and photographs.

3) Passerine bird habitat and population responses to ecological restoration.

The diversity and abundance of passerine birds is being quantified with point counts over approximately 2000 acres in the Mt. Trumbull/Logan area using a before-after-control-impact-pairs design. Habitat characteristics, assessed on the permanent monitoring plot grid, are correlated with bird counts. Baseline data collected over three breeding seasons (1996-98) will be compared with post-treatment data.

4) Restoration of grasses, wildflowers, and shrubs.

The objective of this study is to develop practical methods for restoring native understory diversity and productivity. Key to restoring the understory is an understanding of the on-site plant material, including above ground vegetation as well as viable seeds in the soil bank. Soil samples were collected from different treatment areas and germination compared to samples taken in a control (untreated) area.

5) Butterfly response to ecological restoration

Butterflies are an excellent group to study to examine changes in habitat. Because the butterfly larval stage is typically host specific, butterfly diversity can be a good indicator of host-plant species diversity. Different species of butterflies feed on a variety of plants, including trees, shrubs, grasses, and forbs. Because both adult and larval stages are important food sources for birds and other animals, population studies of this trophic level will provide habitat information complementing studies on birds and mammals. Butterfly species diversity and abundance is examined before and after treatment in the restoration units, as well as compared between control and treated units. Primarily, NAU is looking for changes in butterfly community structure in response to the changes in forest structure and herbaceous structure caused by

the restoration treatments. In addition, analysis of abundance and species data is occurring, as well as sampling of butterfly communities in pre-settlement like forests.

6) Effects of high-intensity fire.

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 in the Mt. Trumbull/Logan area were sampled in 1996, the Lava fire (approximately 20 acres), and the Logan fire (approximately 150 acres). This study follows permanent plots over several years in a forest which burned with high intensity following approximately 60 years of fire exclusion.

7) Effect of thinning and sprouting in gambel oak.

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 how the growth rate of replacement large-sized oak can be enhanced. 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?

8) Wilderness restoration study.

Thirty-four ecosystem monitoring plots in the Mt. Logan Wilderness Area were analyzed in 1998, and the data was used to reconstruct the forest structure in 1870, the date of the last natural fire in the wilderness area. In addition, a social survey is being conducted 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 has been completed.

9) A potential wilderness treatment: forest restoration without wood removal.

This study will apply a variation of a full restoration treatment that does not remove any wood from the sites. All logs and slash generated from the thinning have been left on the ground. Cut trees were limbed to put as much wood as possible in contact with the ground to accelerate decomposition. The logs were bucked into four-foot sections to reduce the chances of an Ips beetle outbreak and slash was moved from under the crowns of the residual trees to prevent fire damage. Comparisons will be made between this technique and conventional wood removal techniques to an untreated area. The effects to be studied include site damage, understory recovery, and fire behavior.

10) Dendroclimatic reconstruction.

Increment cores collected in 1996 from old ponderosa pine trees were cross dated and measured to develop a long tree-ring width chronology for the Mt. Trumbull area. Currently, a third dendrochronologist is checking the chronologies to improve correlations. This chronology will be correlated with weather data to create a model that will reconstruct past climatic trends and will be compared with tree age data and fire history results to search for past climate-plant-disturbance connections and to suggest potential future changes.

11) Fire History.

Frequent, low intensity fire regimes are characteristic of ponderosa pine throughout its range, but specific knowledge of the characteristics of

pre-settlement fire patterns in the Mt. Trumbull/Logan area is important to guide the reintroduction of fire and to permit evaluation of the restored fire disturbance regime. Fire history reconstruction based on dendrochronological measurement of fire scarred trees, stumps, and logs is being undertaken in the Mt. Trumbull/Logan area to estimate the frequency and seasonality of pre-settlement fire, determine the date of fire exclusion, and develop a record of post-settlement fires. A key feature of the project is the landscape scale of sampling across the entire ponderosa pine forest, allowing researchers to explore questions of fire size, intensity, and variability within the ecosystem, issues that have exceeded the scope of many previous studies.

12) Modeling forest structure 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. NAU is applying a 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. The model has been calibrated to southwestern ponderosa pine forests and will be initialized with data from the permanent monitoring plots in the Mt. Trumbull/Logan area. Comparisons among past and present ecosystem structures, as well as potential future alternatives, will be made.

13) 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 these same locations which were used in August of 1997. This study will provide information on the nature and distribution of Kaibab squirrel feed trees and their relation to restoration treatments, as well as habitat use information.

14) Indigenous land management practices.

In 1998, a project was initiated to explore indigenous land management practices, focusing 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 areas. This information will be used to explore relationships between indigenous knowledge and contemporary restoration practices.

Arizona Game and Fish Department Scientific Study

NAU studies focus mainly upon vegetative response to restoration treatments. Given the acknowledged need to incorporate a wildlife component into this research, the Arizona Game and Fish Department (AGFD) has taken the lead in securing additional funding and devising studies to determine the effects of restoration treatments upon a variety of wildlife species. AGFD has assumed responsibility for overall wildlife research coordination and implementation.

AGFD has identified a number of focal wildlife species and species groups for evaluating the effects of forest restoration treatments. Focal species were selected and evaluated with respect to the following criteria:

- their use of or association with habitat components that will be altered by restoration treatments;

- AGFD's ability to measure changes in population density and / or habitat use;
- roles in ecosystem function; and
- economic / recreational value.

The selected species and species groups are: passerine birds, mule deer, Kaibab squirrel, Merriam's turkey, and herpetofauna. Sampling arrays for these focal species are overlaid to the fullest degree possible, to maximize efficiency and increase AGFD's ability to assess the effects of restoration treatments on all forest wildlife.

Specific objectives of wildlife studies are to:

- describe the short-term effects of restoration treatments on forest habitat characteristics;
- quantify short-term effects of restoration treatments on selected wildlife species, including response variables describing diversity, abundance, reproduction, and habitat use;
- identify focal species and areas for long-term monitoring of treatment effects on wildlife populations, communities, and habitats; and
- develop habitat management recommendations for future implementation of restoration treatments in southwestern forests.

Data are being collected at two scales, reflecting the home range sizes and anticipated responses of focal species to the restoration treatments. For passerine birds and herpetofauna, a large number of individual home ranges have been encompassed within individual treatment blocks, as well as the control area. Consequently, detectable responses in population and community parameters may occur within these subunits, which is the focus of sampling. Mule deer, Merriam's turkey, and Kaibab squirrel have home ranges encompassing multiple treatment blocks and / or occur at relatively low densities on the study area. For these species, responses to treatment are only detectable at larger scale and may primarily be reflected in patterns of habitat use, rather than population parameters. Sampling for these species is occurring over larger aggregate units of treatment blocks.

Passerine bird studies

AGFD will extend the NAU passerine bird studies into the post treatment phase. Point count and nest monitoring procedures conducted during the pre-treatment phase in 1996 and 1997 will be repeated following treatments in the area of the study for 2-3 years. The impacts of the treatments upon avian abundance, diversity, and reproductive success will be analyzed. The preliminary phase of this study is now complete and results are available in *Final Report—Heritage Grant 196008, Bird Abundance and Diversity Prior to Restoration Treatments for Old Growth Ponderosa Pine*.

Aerial photographs and GIS vegetative covers

In spring of 1997 low altitude, high resolution aerial photographs were taken of the entire RCA. Cartographers at the Bureau of Land Management National Applied Sciences Center will scan, ortho-photographically correct, and prepare digital copies of the original photos. Once completed, AGFD will incorporate these into a GIS Arc / Info data base for the Mt. Trumbull RCA. AGFD will employ photo interpretation, site visits, and GIS overlays of NAU's 300 m grid vegetation data to define and delineate the major vegetative cover types present. This GIS information will then be applied to various wildlife / vegetation studies in the RCA.

Mule deer studies

Mule deer have been captured and radio-telemetered at Mt. Trumbull. Following collection of field data, habitat selection analysis will be conducted. Landscape scale habitat selection analyses will be conducted on the first two years of data once aerial photographs for the area are entered into GIS. Telemetered deer were located once monthly during the winter of 1998 to learn where they travel during this season. General and micro-habitat data collection components of the study are ongoing.

Kaibab squirrel studies

Tests of a track count index in ponderosa pine habitats on the Coconino National Forest (Dodd 1996) have shown extremely high correlations ($r=0.98$) between squirrel abundance and habitat use on the Mt. Trumbull restoration study area. Count data is obtained from track plate arrays established in both treatment and control areas. Each array consists of a randomly located grid of track plates. Treatment and control arrays are sampled concurrently, for a 48 hour period, annually. Feeding and sign counts (fungi digs, cone cores, peeled twigs, and terminal clippings) are counted in a sampling grid. To date, 6 sampling grids have been installed in untreated areas, and sign counts and population estimates have been completed for the areas of sampling.

Herpetofauna studies

These studies are being conducted to document the effects of forest restoration treatments on reptile species richness and relative abundance. Data collection relies primarily upon pitfall trapping. Pitfall arrays are overlaid on the 300 m $\times$ 300 m grid system placed on the study area by NAU personnel. In addition to pitfall arrays, plywood shaders will be placed on the ground in conjunction with artificial PVC tubing burrows. Lizards caught or seen in the arrays / substrates are included in data tallies. Data has currently been collected at 76 pitfall arrays. Several arrays in the study area have never captured lizards, suggesting that lizards are influenced by the varying habitat types present in the RCA, and that certain current habitat conditions are not suitable for them.

Migrant songbirds

The objectives of the migrating songbird study are similar to those of the reptile study. AGFD is determining the current habitat relationships of autumn and spring migrant songbirds at the site through pre-treatment censusing. Then, AGFD will evaluate the response of migrating songbirds to ponderosa pine forest restoration at Mt. Trumbull. Pre-treatment data are being collected at 136 survey points, which are superimposed on NAU ecosystem monitoring plots. As treatment units are restored to pre-settlement conditions, post-treatment surveys will be conducted at the same grid points. Seventy-nine bird species were recorded on the RCA during fall surveys.

Nestling provisioning rates and fledging rates

In 1998 AGFD initiated a study of parental food provisioning rates to nestlings for several bird species that are currently common breeders in the area, and which may be affected by ecosystem restoration treatments. AGFD determined hatching dates, number of chicks, growth rates, food provisioning rates, fledge dates and fledging success for western bluebird nests and white-breasted

nuthatch nests. In addition, vegetation will be measured at nest sites for comparison with available habitat values.

Information on this subject is available in the report *Short-term Wildlife Responses to Ponderosa Pine Forest Restoration Treatments in the Mt. Trumbull Area, Arizona*, reports for 1997, 1998, and 1999.

BLM bat roost study

BLM's primary role in this ecosystem restoration project is implementation of operational treatments and assistance to NAU and AGFD studies where necessary. However, BLM is conducting one bat roost study that will complement NAU and AGFD's research.

Objectives of the Northern Arizona Bat Roost Inventory are to identify and map key use areas for bats on BLM-administered public lands on the Arizona Strip. Key use areas included roosts in trees, snags, caves, mines, cliff faces, bridges, and culverts; watering areas at springs, stock tanks, and catchments; and foraging areas. Priority was given to bat species of concern as listed on the AGFD's Wildlife of Special Concern in Arizona (AGFD 1997) and the Arizona BLM Sensitive Species List (BLM 1998). Within a 15 mile radius of the Mt. Trumbull Ecosystem Restoration project; the study was designed to:

- locate bat roosts in all habitat types;
- identify characteristics of trees / snags used as bat roosts;
- map the availability of suitable roost trees / snags;
- develop a model to predict which trees / snags are most likely to be occupied roosting sites during the active season;
- apply the model to control areas, pre-treatment, and treated areas within the context of the Ecosystem Restoration Project;
- evaluate the impacts of ecosystem restoration treatments on bat populations and the availability of roost habitat;
- where possible, document roost-switching and / or evidence of roost site fidelity; and
- evaluate the level of bat use of wildlife water developments in the area.

Future work will again focus primarily on *Myotis volans* in the Mt. Trumbull area in a continuing effort to document the impacts to forest dwelling bats from the ecosystem restoration project, and to develop the predictive model for identifying potential roost trees / snags. A minimum of 20 additional snag roosts will be required to lend statistical credibility to the sample size (Herder and Jackson 1999).

Results from all wildlife project components will be compiled by AGFD and project cooperators into a comprehensive final report. This report will assess the short term effects of restoration treatments, and identify research and management options for future treatments. Results will also be presented at appropriate professional meetings and conferences, and submitted for publication in peer reviewed journals.

Conclusion

BLM intends to continue implementing the treatments in the Mt. Trumbull and Mt. Logan area, while AGFD and NAU-ERI will continue their research on the impacts of those treatments. Some units will receive second and third burn and seed treatments. Land use planning for the newly designated Parashant National Monument will provide new goals and objectives for the area. BLM



Figure 2—Post treatment example from Mt. Trumbull.

fire and resources staff, along with our colleagues at NAU and AGFD, hope to restore the ponderosa pine forest ecological integrity. Ultimately, our goal is to allow wildfire to play its historic role in maintaining forest health.

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