

# Appendix B • Research Proposals

## Evaluating Ponderosa Pine Forest Restoration Effects On Mule Deer—A Research and Monitoring Proposal - Emphasizing the Kachina Village Forest Health Restoration Project - Mormon Lake Ranger District, Coconino National Forest

Arizona Game and Fish Department  
Research Branch  
2221 W. Greenway Road  
Phoenix, AZ 85023

September 1, 2001

### Introduction

We are seeking funding to answer key ecological questions about restoring fire-adapted western forests to healthier, more natural conditions. Exclusion of natural surface fires, logging, and historical overgrazing have led ponderosa pine forests across the West to become over-dense with small trees and accumulated fuels, leading to costly tragedies such as the May 2000, Cerro Grande Fire that burned across Los Alamos, N.M. Other effects include reduced tree vigor, reduced herbaceous diversity and biomass, and type conversions from fire-adapted species to assemblages of fire intolerant species (Cooper 1960, Covington and Moore 1994; Belsky and Blumenthal 1997, Mast et al. 1999). In addition to fire danger, these changes have led to poor nutrient cycling and have altered wildlife community composition.

Forest restoration treatments target reducing tree stand densities and forest floor fuel loads through selective cutting and prescribed burning. Such treatments will result in more open, park-like forests with an understory of herbs and grasses rather than flammable organic litter. It is believed these forests will better sustain natural processes like periodic, cool fires and nutrient cycling, and not promote catastrophic fire or threaten old-growth trees.

However, sharp debate and controversy exist due to the lack of knowledge of both the effectiveness of wildland-urban interface (WUI) wildfire reduction treatments and their corresponding effects on wildlife. While restoration treatments won't result in truly "restored" forests for decades or longer, they are expected to drastically alter the structure and composition of treated stands. In this regard, restoration treatments have the potential to affect

the wildlife community living in the ponderosa pine forest in unknown ways. The expected increases in biodiversity and productivity at the herbaceous layer should be immediately exploited by some wildlife species. Conversely, other species rely on current forest structures that will be reduced by restorative treatments. Therefore, some species are expected to decline in treated areas unless adaptations are made to accommodate them. For these reasons, empirical data are needed regarding the effects of ecosystem restoration on all fauna within the ponderosa pine community so that true adaptive management can be applied to forest restoration efforts.

### Justification and Need for Wildlife Monitoring and Research

As indicated above, forests have changed drastically in the past 100 years. Complicating matters is the fact that no historic, quantitative data exists against which to compare present wildlife population numbers and distributions. However, many proposed forest restoration treatments will cause rapid and drastic changes in forest structure (e.g. the reduction of tree stem densities on Mt. Trumbull by up to 85 percent). The degree and temporal rapidity of these changes has great potential to affect populations of wildlife in treated areas.

The primary subjects of controversy surrounding the Grand Canyon Forests Partnership fire risk reduction/forest health restoration treatments, as demonstrated in 6 administrative appeals and one lawsuit, are the efficacy of treatments and the effects of such treatments on wildlife. Larger-scale environmental opposition to fire risk reduction treatments in the urban interface is demonstrated by the recent filing of a Notice of Intent by the Center for Biologi-

cal Diversity to sue over urban interface projects and their perceived effects on threatened and endangered species.

To achieve success in implementing fire risk reduction projects in the urban interface, we must be able to demonstrate both the effectiveness of fuels reduction treatments *and* the corresponding effects on wildlife. Only by evaluating the relationships of key wildlife to various treatments can we responsibly inform the adaptive restoration process. Therefore, more detailed information on the effects of various restoration treatments on wildlife are needed to guide the discussion of the most desirable prescription or blend of prescriptions to restore WUI forests.

Limited wildlife response data have been available to date with which to inform and adapt optimal fire risk reduction/forest health treatment prescriptions. These data have come primarily from the Mt. Trumbull restoration project. While fire-risk reduction treatments planned for north of Kelly Canyon in the Kachina Village Restoration Block are similar to that applied at Mt. Trumbull, the majority of treatments planned for south of Kelly Canyon are dissimilar due to the retention of patches of understory trees, and the planned retention of buffers of untreated forest along canyon rims.

We (Arizona Game and Fish Department [AGFD], as partners in the Grand Canyon Forest Partnership) propose to monitor expected fire risk reduction treatments in two prescription types in the Kachina Village forest health and fire risk reduction block.

### ***Mule Deer as a Monitoring and Indicator Species***

Mule deer populations are in decline throughout the Western United States, and are considered a management indicator species in the Coconino N.F. and elsewhere (USDA 2000, Thomas et al. 1979). One factor leading to the decline of mule deer may be reduced abundance and quality of herbaceous ground cover associated with the over-dense forest conditions which now occur throughout the West. Mule deer can be an effective indicator of forest health because of their reliance on a mixture of open tree canopies with understory vegetation and dense hiding cover. Several studies have demonstrated the need for a mixture of adequate shrub and herbaceous vegetation and dense hiding cover to meet a variety of life history needs. The reduction in canopy closure as prescribed within Kachina Village Forest Health Project will allow for the return of

valuable forage in the form of herbaceous and shrub cover, but it is not known whether these treatments will leave proper ratios of open:hiding cover for continued mule deer use. The relationships between mule life history and habitat are reviewed briefly below.

### ***Existing Mule Deer Research and Implications to Forest Restoration***

Little information currently exists about responses of mule deer with which to inform restoration efforts. Several studies have related specific activities of mule deer to habitat type and structure, and one study (Germaine 1998) compared the characteristics of mule deer bed and forage sites between forested areas in which restoration treatments had been applied and controls in which no recent management activity had occurred. Implications of these studies are discussed below.

#### ***Foraging***

- Kufeld et al. (1988) found an inverse relationship between mule deer feeding activity and canopy cover in ponderosa pine forests.
- Patton (1974) found substantial increases in grass and forb production and deer use after thinning ponderosa forests.
- AGFD research at Mt. Trumbull has documented mule deer foraging in treated areas during the 1-2 years immediately following stand thinning, prescribed fire, and reseeded (Germaine and Germaine 1999). Treated units appear to have higher abundances of deer forage vegetation than untreated forest areas.

#### ***Hiding Cover***

- Hiding cover is important for predator avoidance, especially during fawning (Trainer 1975). Fawn bed sites are often within more densely vegetated areas (Fox and Krausman 1994, Gerlach and Vaughan 1991). The removal of sufficient hiding cover could result in decreased fawn recruitment (Fox and Krausman 1994).

#### ***Thermal Cover***

- Dense vegetation can provide relief from both extreme cold and extreme heat, minimizing thermal stress upon deer (Thomas et al. 1979, Parker and Gillingham 1990).

### **Bedding Sites**

- The dense horizontal and vertical vegetation typical of deer bedding sites contributes to both hiding and thermal benefits (Smith et al. 1986).
- AGFD research at Mt. Trumbull has described specific characteristics of mule deer day beds, and has documented a marked decrease in available vegetative structure for mule deer day bed placement within treated areas. Mule deer day bed placement in treated areas at Mt. Trumbull has been limited to oak motts, which appear to be the only features where thermal and hiding cover needs for day bedding are retained in the years immediately following forest restoration treatments (Germaine 1998).

### **Fire Effects**

- Fire has been considered beneficial to deer habitat. Carlson et al. (1993) and Hobbs and Spowart (1984) found increased deer forage quantity and quality after fire, and Stager and Klebenow (1987) documented increased use of pinyon-juniper woodlands by deer post fire. Kie (1984) reported increased use of pine-oak forests by deer after prescription burning.

### **Human Disturbance**

- Mule deer are sensitive to human disturbance (Freddy et al. 1986, Yarmoloy et al. 1988) causing greater energy expenditure and reduced reproduction. Adequate hiding cover can potentially reduce the stress of human-induced disturbance.

### **Economics**

- Mule deer are an economically important game species in AZ and throughout the West. In 2001 there were 87,835 applications for mule deer or any antlered deer hunts in Arizona. Permits issued for these hunts generated \$2,210,832 in resident license fees, and \$317,119 in nonresident fees in Arizona this year. Millions more dollars are generated in Arizona each year from deer hunting-related purchases.

The decline of mule deer in the West has coincided with the general increase in forest canopy closure, fire suppression, and the reduction of understory

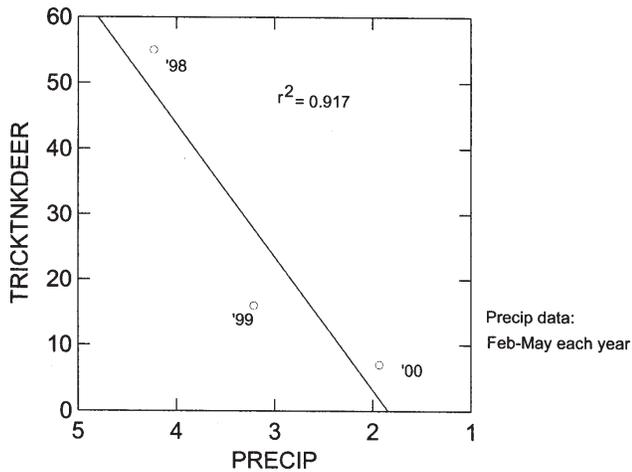
vegetation. The deer-habitat-human interaction factors listed above demonstrate how mule deer population

trends and habitat use patterns can be an effective indicator of forest health and a useful monitoring tool. The Kachina block treatments have potential to enhance deer habitat quality. The Kachina Block treatment prescription will produce a different ratio of open forest for forage production and dense patches for hiding than that produced at Mt. Trumbull. Learning the responses of mule deer to different ratios of open forest/dense patches will enhance our ability to manage for the benefit of mule deer populations in Arizona.

### **Gaps in Knowledge of Mule Deer - Restored Forest Habitat Relationships**

AGFD research at Mt. Trumbull provides the only information we are aware of to date documenting mule deer responses to ponderosa pine forest restoration treatments. This research has demonstrated a need to combine open-canopied forest to improve forage vegetation with patches of dense vegetation to meet bedding and fawning cover needs. Threshold ratios of these habitat components are not yet known, nor do we know how far from escape/hiding cover mule deer will forage in treated forests.

AGFD has also documented that mule deer use of the Trick Tank Unit at Mt. Trumbull, the first large unit to be completed, has shown a marked decline over the 3 years (1998 – 2000) since treatment (Fig. 1). Figure 1 correlates spring precipitation with mule deer summer use of this unit. In this figure we use spring precipitation as a proxy variable for ground cover vegetation since we have noted a strong correlation between spring rains and vegetation growth in treated units. We have not identified the specific factor(s) responsible for decreased mule deer use of this area. Possibilities include: short-term site fidelity is being replaced by avoidance of treated areas; deer are responding directly to varying levels of ground cover vegetation (associated with spring precipitation); forage quality has decreased each year since treatment for reasons not related to precipitation; or, the combination of habitat openness and intense human presence in the area has caused an avoidance response. These types of questions must be answered before we apply forest restoration treatments over broad expanses of forest landscape.



**Figure 1. Mule Deer Use of Trick Tank Unit, Mt. Trumbull, During 3 Years Since Treatment, 1998-2000**

The Kachina Village Forest Health Project is the second of 10 proposed ~4,000 ha planning units within the Flagstaff Wildland-Urban Interface (WUI), as part of the Grand Canyon Forests Partnership (USDA Forest Service 2000, 2001). This 4,217 ha project is located on the Mormon Lake and Peaks Ranger Districts, is located 6 km south of Flagstaff, includes the communities of Kachina Village and Forest Highlands, and will extend between Highways 89A and I-17 southward to the rim above Oak Creek Canyon.

Multiple thinning prescriptions are proposed in various treatment units in the Proposed Action for this project. While each prescription proposed has unique wildlife value and is therefore of research/monitoring interest, we propose to focus on two prescriptions which are extensive enough to ensure adequate samples may be generated, and which most closely represent WUI prescriptions likely to be applied throughout the west: “Thinning from Below – North of Kelly Canyon and Lower 89A Corridor” (hereafter TBN), and “Thinning from Below – South of Kelly Canyon” (hereafter TBS).

TBN will occur on 779 ha (1,923 ac) and will focus on reducing wildfire risk by both reducing ladder fuels and disconnecting the present continuous crown canopy. Post-treatment target tree densities range from 40-120 ft.<sup>2</sup> basal area, canopy closure reduced to 40 to 50 percent, and mid-story canopy base height raised to an average of 15 ft. Small trees will be thinned around existing clumps of larger trees, maintaining existing spatial structures. Approximately 10 percent of the area will be man-

aged as grassy openings located in areas where they were likely to have occurred in the past. Gambel oaks will not be cut.

TBS will occur on 674 ha (1,665 ac) south of Kelly Canyon and in the Mexican Pocket area. This area will be thinned with the objective of reducing wildfire risk in a manner similar to TBN but will also retain dense cover patches meant to enhance post-treatment wildlife value. Up to 25 percent of this area will be retained in dense clumps of understory trees with each clump exceeding 35 trees/clump, and clumps ranging in size from 0.04-0.4 ha (1/10<sup>th</sup> to 1 acre). Clumps will retain closed canopies with interlocking limbs and foliage. The forest surrounding clumps will be thinned to 40-100 ft.<sup>2</sup> basal area. The combination of closed and open forest types proposed for TBS is expected to enhance wildlife value for species requiring dense patches of cover and those associated with ponderosa savannahs. Grassy openings and Gambel oaks will be managed in the same manner as in TBN.

**Study Objectives**

Our primary objective is to use mule deer as an indicator of the effects of two different thinning prescriptions (TBN, TBS) within the Kachina Village Forest Health Project. We will do so by collecting statistically reliable data comparing mule deer use of specific areas both pre- and post-treatment. The data collected will describe mule deer responses to thinning treatments, and will provide detailed and useful information which will help to guide future habitat management both locally and throughout the Southwest.

**Objective 1: Collect baseline pre-treatment data on mule deer habitat use and selection in both TBN and TBS Kachina Village Forest Health Project treatment areas.**

**Procedure 1.1 - Pre-treatment data collection**

In spring 2002, we will outfit up to 16 mule deer with telemetry collars with Global Positioning System (GPS) capabilities. Animals will be captured throughout the study area using a variety of proven methods, with 8 captured north and 8 south of Kelly canyon. Sixteen animals is a minimal number, to reduce cost, based on the recommendations (>20 animals) by Alldredge and Ratti (1986) and Leban (1999) for statistically powerful analyses.

GPS collars have several advantages over standard VHF telemetry collars:

After deploying the collars on animals, collection of location data is automated, requiring little effort in the field. Only periodic monitoring for mortality signals is required. Also, by eliminating presence of people in the field, the bias introduced by human disturbance from monitoring is eliminated.

Because of the automated nature of the collars, location data can be collected more frequently than with conventional collars, and the number of locations achievable (>1000/animal/year) far exceeds the capabilities of VHF collars. Data will be collected year-round, even when field conditions would prohibit standard VHF monitoring.

The locations produced by GPS collars are quite accurate (15m average). Acquiring locations this accurate with standard collars would require extensive and costly field technician labor.

Although initial cost of the collars is higher, overall cost per location is greatly reduced (<\$2) because field technician labor time is effectively eliminated.

Collars will be configured to record a GPS fix every 7 hours, and retrieved when batteries are depleted or animal mortality is indicated. Collars will be configured to last 2 years and, therefore, provide up to 2 years of pre-treatment data depending on treatment implementation schedule.

Prior to scheduled collar expiration we will retrieve all collars while simultaneously placing new collars on the same deer. If we are unable to recapture deer, the collars will be removed from the animal via an automatic release buckle. The collar can then be retrieved on foot. We will then download collars into an AGFD GIS database, and prepare data for analysis of pre-treatment habitat selection preferences.

Because of the potential confounding effects of human disturbance, mostly within the TBN study area, vibration sensors will be installed along roadways at all boundaries of TBN and TBS treatments to index levels of human disturbance. Vibration sensors will be checked twice per week, separating weekdays and weekends. The relationship between deer location distance from roads and the level of human activity on roads will be examined graphically to determine a disturbance threshold. If a significant relationship is found, roadways exceeding the disturbance threshold will be buffered in the GIS to the threshold distance, and this area will not be considered available habitat.

**Objective 2.** *Collect post-treatment data on mule deer habitat use and selection in both TBN and TBS Kachina Village Forest Health Project treatment areas.*

### **Procedure 2.1 - Post-treatment data collection**

The first spring after treatments have been fully completed (we anticipate 2005) we will outfit up to 16 mule deer with telemetry collars with Global Positioning System (GPS) capabilities. Collar configurations, data collection procedures, and data retrieval/downloading will be the same as described for pre-treatment above. *\*Note: Completing treatments in the shortest possible timeframe is important to minimize the degree of external influence on animals.*

Levels of human activity in post-treatment areas will be indexed and habitat availability buffered in the same manner as described for pre-treatment data collection, above.

An intern will be hired for one field season to help map the boundaries of all dense cover patches of trees retained after treatments with a GPS receiver.

**Objective 3.** *Compare selection preferences of mule deer for TBN and TBS habitats between pre- and post-treatment periods.*

### **Procedure 3.1 - Selection preference analysis**

Four habitat types will be considered in this study: TBN, TBS, canyons (untreated), and other.

Total availability of each habitat type will be measured directly from GIS maps of the study area (generated by the Coconino N.F.). Using minimum convex polygons, home ranges as well as habitat availability for each animal will be identified.

Habitat use will be determined for each deer by comparing the proportional distribution of GPS locations to that available within each habitat type.

The *expected* number of locations for each habitat type will be the proportional equivalents of each available habitat.

Habitat selection analysis (Neu et al. 1974) will be used to test the following null hypothesis:

$H_0$ : Habitat use (GPS locations) occurs in equal proportion to habitat availability.

Additionally, we will employ Bonferroni confidence intervals (Neu et al. 1974, Byers et al. 1984) to determine which habitats are selected or avoided and the strength of each demonstrated selection. These determinations will be made both pre- and post-treatment.

We will use Johnson' (1980) use-availability ranking method to index selection strength demonstrated by deer for each habitat type both pre- and post-treatment.

Finally, we will use a Mann-Whitney *U* test (Zar 1999) to test for differences in the selection ranking of each habitat type between pre- and post-treatment, under the null hypothesis:

$H_0$ : Selection preferences displayed by mule deer for each habitat type do not differ between pre- and post-treatment.

In this regard it would be optimal to have the same deer telemetered both pre- and post-treatment. We do not anticipate that this is logistically possible, however, and will have a similar number of deer telemetered in each area during each study phase.

Finally, mule deer locations will be correlated with stand information on average dense cover patch size and patch density to determine whether a relationship exists for deer use of various stand types as defined by dense cover patches.

### ***Benefits to Adaptive Management***

While wildlife concerns continue to dominate professional and legal debates concerning WUI fire risk reduction and forest restoration, information on effects of treatments on wildlife remains extremely limited. Furthermore, true adaptive forest management cannot proceed in an informed manner without wildlife effects information. The information we propose to generate will directly address this problem. The results of this study will allow us to make better-informed management decisions regarding forest restoration and mule deer populations by providing information on TBN and TBS treatment prescriptions and mule deer use. This study will also provide additional information on ratios of foraging:bedding habitat suitable for mule deer, and ultimately will be of great value in guiding the placement of various treatment prescriptions on forest landscapes in WUI's and elsewhere.

**Project Partners:** Partners include the Coconino National Forest, Grand Canyon Trust, Arizona Game and Fish Department, and other members of the Grand Canyon Forests Partnership.

## **Budget**

### ***Year 1 (pre-treatment):***

GS 20 Spec. III	1/12 time	\$4,326.92
GS 19 Spec. II	1/2 time	\$20,891.00
(develop study plan, initiate project)		
Overhead		\$4,320.00
		<hr/>
		\$(29,537.92)
Initial deer capture		\$12,800.00
Vehicle		\$6,000.00
Equipment:	GPS collars	\$50,000.00
	vibration sensors	\$1,200.00
	computer supplies	\$5,850.00
AOO (field supplies)		\$2,000.00
		<hr/>
Year 1 Total		\$107,387.92

### ***Year 2 (pre-treatment):***

GS 19 Spec. II	1/2 time	\$20,891.00
(analysis and reporting of pre-data)		
Overhead		\$3,760.38
		<hr/>
		\$(24,651.38)
Vehicle		\$6,000.00
AOO (field supplies)		\$1,000.00
		<hr/>
Year 2 Total		\$31,651.38

### ***Year 3 (1<sup>st</sup> year post-treatment):***

Ps/ere		
GS 19 Spec. II	1/2 time	\$20,891.00
(GPS cover patches)		
Intern		\$3,214.00
(GPS cover patches)		
Overhead		\$4,335.43
		<hr/>
		\$(28,440.43)
Refurbish GPS collars		\$3,200.00
Replace GPS collars		\$12,800
Vehicle		\$6,000.00
AOO (field supplies)		\$1,000.00
		<hr/>
Year 3 Total		\$51,440.43

**Year 4 (post-treatment):**

Ps/ere

GS 20 Spec. III	1/12 time	\$4,326.92
GS 19 Spec. II	1/2 time	\$20,891.00
(final analysis & reporting)		
Overhead		\$4,535.60
		<hr/>
		\$(29,753.52)
Vehicle		\$6,000.00
AOO (pub/pres costs)		\$3,000.00
		<hr/>
Year 4 Total		<b>\$38,753.52</b>

**Literature Cited**

- Belsky, A. J., and D. M. Blumenthal. 1997. Effects of livestock grazing on stand dynamics and soils of upland forests of the interior West. *Conservation Biology* 11:315-327.
- Byers, C.R., R.K. Steinhorst, and P.R. Krausman. 1984. Clarification of a technique for analysis of utilization-availability data. *Journal of Wildlife Management* 48(3):1050-1053.
- Carlson, P.C., G.W. Tanner, J.M. Wood, and S.R. Humphrey. 1993. Fire in key deer habitat improves browse, prevents succession, and preserves endemic herbs. *Journal of Wildlife Management* 57(4):914-928.
- Cooper, C.F. 1960. Changes in vegetation, structure, and growth of southwestern pine forests since white settlement. *Ecological Monographs* 30:129-164.
- Covington, W.W. and M.M. Moore. 1994. Southwestern ponderosa pine forest structure: Changes since Euro-American settlement. *Journal of Forestry* 92:39-47.
- Fox, K.V., and P.R. Krausman. 1994. Fawning habitat of desert mule deer. *Southwestern Naturalist* 39(3):269-275.
- Freddy, D.J., W.M. Bronaugh, and M.C. Fowler. 1986. Responses of mule deer to disturbance by persons afoot and snowmobiles. *Wildlife Society Bulletin* 14:63-68.
- Gerlach, T.P., and M.R. Vaughan. 1991. Mule deer fawn bed site selection on the pinon canyon maneuver site, Colorado. *Southwestern Naturalist* 36(2):255-258.
- Germaine, S.S. 1998. Short-term effects of ponderosa pine forest restoration on wildlife at Mount Trumbull, Arizona: 1997 & 1998 data. Arizona Game and Fish Department Research Branch Report. 43 pp.
- Germaine, H.L. and S.S. Germaine. 1999. Short-term wildlife responses to ponderosa pine forest restoration treatments in the Mount Trumbull area, Arizona. Arizona Game and Fish Department Annual Progress Report. 20 pp.
- Hobbs, N.T., and R.A. Spowart. 1984. Effects of prescribed fire on nutrition of mountain sheep and mule deer during winter and spring. *Journal of Wildlife Management* 48(2):551-560.
- Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. *Ecology* 61(1):65-71.
- Kie, J.G. 1984. Deer habitat use after prescribed burning in northern California. Pacific Southwest forest and range experiment station. USDA Forest Service research note PSW-369.
- Kufeld, R.C., D.C. Bowden, and D.L. Schrupp. 1988. Habitat selection and activity patterns of female mule deer in the Front Range, Colorado. *Journal of Range Management* 41(6):515-522.
- Mast, J.N., P.Z. Fule, M.M. Moore, W.W. Covington, and A.E.M. Waltz. 1999. Restoration of presettlement age structure of an Arizona ponderosa pine forest. *Ecological Applications* 9:228-239.
- Neu, C.W., C.R. Byers, and J.M. Peek. 1974. A technique for analysis of utilization-availability data. *Journal of Wildlife Management* 38(3):541-545.
- Parker, K.L. and M.P. Gillingham. 1990. Estimates of critical thermal environments for mule deer. *Journal of Range Management* 43(1):73-81.
- Smith, H.D., M.C. Oveson, and C.L. Pritchett. 1986. Characteristics of mule deer beds. *Great Basin Naturalist* 46(3):542-546.

*Appendix B • Research Proposals*

Stager, D.W., and D.A. Klebenow. 1987. Mule deer response to wildfire in Great Basin pinyon-juniper woodland. United States Forest Service General Technical Report INT No. 215:572-579.

Thomas, J.W., H. Black, Jr., R.J. Sherzinger, and R.J. Pedersen. 1979. Deer and elk.

In *Wildlife Habitats In Managed Forests: the Blue Mountains of Oregon and Washington*. J.W. Thomas, editor. USDA Agricultural handbook No.533. 104-127.

USDA Forest Service. 2000. Fort Valley ecosystem restoration project environmental assessment. Coconino National Forest Supervisor's Office, Flagstaff, Arizona, USA.

Yarmoloy, C., M. Bayer, and V. Geist. 1988. Behavior responses and reproduction of mule deer, *Odocoileus hemionus*, does following experimental harassment with an all-terrain vehicle. *Canadian Field Naturalist* 102:425-429.

Zar, J.H. 1999. *Biostatistical analysis*. 4th edition. Prentice Hall. Upper Saddle River, NJ, U.S.A.

# EVALUATING PONDEROSA PINE FOREST RESTORATION EFFECTS ON FOREST SONGBIRDS - A Monitoring Proposal - Emphasizing the Kachina Village Forest Health Restoration Project - Mormon Lake Ranger District, Coconino National Forest

Arizona Game and Fish Department  
Research Branch  
2221 W. Greenway Road  
Phoenix, AZ 85023

September 1, 2001

## Introduction

Logging, fire suppression, grazing activities, and climate changes over the past 150 years have drastically modified distribution, species composition and stand ages in ponderosa pine forests, resulting in general declines in forest health (Covington and Moore 1994). A proliferation of younger age class trees dominate forests today (Johnson 1994, Mast et al. 1999) with increased potential for catastrophic fire, disease, and decreased health of the ponderosa pine ecosystem (Covington and Moore 1994, Covington et al. 1997). These problems have spawned forest health restoration initiatives (Moore et al. 1999, Wagner et al. 2000) that advocate restoring ecosystem structure and function, using aggressive thinning of forests to improve tree growth, increase incidence of prescribed fire, and promote old-growth forest conditions (Covington and Moore 1994, Covington et al. 1997). The current threat of catastrophic fire to human safety and property in the Wildland-Urban Interface (hereafter WUI)—where homes and other human development interface with wildland vegetation—are of high concern to land managers, fire service personnel, property owners, and others.

However, sharp debate and controversy exist due to lack of knowledge of both effectiveness of WUI wildfire reduction treatments and their corresponding effects on wildlife. The primary subjects of controversy surrounding the Grand Canyon Forests Partnership fire risk reduction/forest ecosystem health treatments are the efficacy of treatments and the effects of such treatments on wildlife.

To address existing concerns, a suite of restoration prescriptions have been proposed for reducing wildfire risk in the WUI in the greater Flagstaff vicinity. While individual prescriptions to date have been derived from professional interpretations of historic pre-settlement forest conditions, each varies with respect to post-treatment densities of ponderosas and understory trees retained. These features will influence how well fire risk is reduced in the WUI and what type of wildlife species are supported in treated areas.

Wildlife response data are extremely limited to help formulate treatment prescriptions that support greater wildlife species diversity. To achieve success in implementing fire risk reduction projects in the WUI, we must be able to demonstrate both the effectiveness of fuels reduction treatments and maintain viable breeding populations of all native wildlife.

## **Justification and Need for Wildlife Monitoring and Research**

Debate and controversy abounds due to lack of knowledge of the effectiveness of WUI catastrophic wildfire reduction treatments and their corresponding effects on wildlife. The primary subjects of controversy surrounding the Grand Canyon Forests Partnership fire risk reduction/forest health restoration treatments, as demonstrated in 6 administrative appeals and 1 lawsuit, are the efficacy of treatments and the effects of such treatments on wildlife. Larger-scale environmental opposition to fire risk reduction treatments in the urban interface is

demonstrated by the recent filing of a Notice of Intent by the Center for Biological Diversity to sue over urban interface projects and their perceived effects on threatened and endangered species.

To optimize success in implementing fire risk reduction/forest health projects in the urban interface, we must be able to demonstrate both the effectiveness of fuels reduction treatments and the corresponding retention of native wildlife. Limited wildlife response data are available to help inform optimal fire risk reduction/forest health treatment prescriptions; these have come primarily from the Mt. Trumbull restoration project. While fire-risk reduction treatments planned for north of Kelly Canyon in the Kachina Village Restoration Block appear similar to that applied at Mt. Trumbull, the majority of treatments planned for south of Kelly Canyon are dissimilar due to the retention of patches of understory trees, and leaving buffers of untreated forest along canyon rims.

Wildlife species are expected to respond differently to each treatment prescription, and only by evaluating the relationships of key wildlife to various treatments can we inform the adaptive restoration process. Hard information on the effects of various restoration treatments on wildlife are needed to guide the discussion of the most desirable prescription or blend of prescriptions to restore WUI forests. We (Research Branch, Arizona Game and Fish Department [AGFD], as partners in the Grand Canyon Forest Partnership) propose to monitor expected fire risk reduction treatments in two prescription types in the Kachina Village forest health and fire risk reduction block.

### ***Forest Songbirds as Monitoring and Indicator Species***

Songbirds are powerful management indicators because many individual species are highly habitat and structure-specific (McArthur and McArthur 1961, James 1971, Rosenstock 1998). Songbirds are in decline throughout the Western Hemisphere, primarily due to habitat degradation on breeding, migration, and wintering grounds (Terborg 1989a). Restoration treatments may drastically alter forest structure in a short time, and are expected to increase prey abundance for songbirds at ground level, and to decrease amounts of foraging and nesting substrate in the mid- and over-story canopy. These changes to forest structure have great potential to alter songbird community composition and habitat availability. Therefore, it is essential to

identify species retained in areas receiving different treatment prescriptions so we can best manage for viable breeding populations of all native songbird species on forest landscapes.

Forest songbirds are well suited for indicating effects of forest restoration treatments, for comparing responses among different treatment prescriptions, and for informing the adaptive management process, because:

- Many species of forest songbirds are obligates of pine and mixed conifer forests and of distinct structural (VSS) stages (Szaro and Balda 1986, Rosenstock 1996, Moir et al. 1997). Songbird species partition habitat from ground level through overstory canopy, and these habitat relationships may change during breeding, migration, and winter seasons. Because of the high level of structural specificity of many songbird species during different seasons, forest songbirds make excellent indicators of habitat structural diversity.
- Forest songbirds are highly responsive to changes in ponderosa forest structure and composition, with several species demonstrating marked population changes as ponderosa forests have been altered since circa 1910 (reviewed by Scurlock and Finch 1997).
- Songbird populations are influenced by factors at the micro-habitat, stand, and landscape scales.
- Many species of forest songbirds are abundant and widespread in ponderosa forests, making collection of robust data sets relatively inexpensive and efficient. This allows analytically powerful comparisons among habitat types, treatment prescriptions, and of pre- and post-treatment effects.
- Once collected, bird community data can be easily parsed into examinations of individual species responses, responses of select indicator species, as guilds defined by nesting or foraging habitat-use traits, or as entire communities.
- A broad base of published knowledge exists on the effects of various logging practices and of fire on songbird populations (Finch et al. 1997), affording predictions to be formulated and tested

about responses of individual songbird species to specific prescriptions. Testing *a-priori* predictions has many advantages over conducting purely descriptive or comparative studies, the foremost being clearer understanding of implications of specific management actions.

### **Existing Forest Songbird Research and Implications to Forest Restoration**

Forest changes over the past 150 years have undoubtedly resulted in geographic scale shifts in abundance for many species of forest songbirds. Scurlock and Finch (1997) reviewed songbird surveys from 1911, 1928, and 1961 and report numerous species have either increased or decreased in abundance and distribution during this time. They attribute this to changes in forest structure associated with human activity since before Euro-American settlement of the region.

Responses of songbirds to restoration treatments are generally expected to reflect a shift back toward pre-settlement community composition. However, treated forests won't have pre-settlement old-growth characteristics for decades or longer, and appropriate habitat structure must be retained on the landscape to ensure retention of viable populations of all songbirds until treated areas attain old-growth characteristics. Furthermore, identification of particular habitat structures (e.g. snags, thickets) required to retain various songbird species in restoration-treated settings is necessary to inform the adaptive management process for forest restoration.

We are aware of only three studies (Beier 1998, Germaine 1999, Gillihan 2000) that have examined songbird communities in the context of ponderosa forest restoration in the Southwest. However, other studies have examined responses of breeding and non-breeding songbirds to common silvicultural prescriptions and among ponderosa age, size, and vegetative structural stage classes in the Southwest. Data from these studies are valuable for predicting responses of various species and guilds to ponderosa forest restoration treatments.

- Beier (1998) collected 3 years' data on breeding bird abundance in ponderosa forest preceding restoration treatments at Mt. Trumbull, Arizona. He reported white-breasted nuthatch, grace's warbler, mountain chickadee, pygmy nuthatch, and

western tanager as the five most abundant species during the breeding season, and noted brown-headed cowbirds as rare but present. Beier (1998) also noted a preference by cavity nesters for snags, and six bird species that demonstrated a preference for nesting in the largest trees available.

- Germaine (1998) and Germaine and Germaine (1999, 2000) also worked at Mt. Trumbull, and collected 2-years' pre-treatment data on birds during the spring ('98-'99) and fall ('99-'00) migration periods. The most abundant birds recorded during spring migration were mountain chickadee, yellow-rumped warbler, Grace's warbler, Steller's jay, white-breasted nuthatch, western tanager, and dark-eyed junco; the most abundant birds during fall migration were Steller's jay, white-breasted nuthatch, mountain chickadee, dark-eyed junco, and western bluebird. Germaine (1998) noted that sagebrush openings and pinyon-juniper stands appeared to support the lowest abundance of migrants, while areas containing deciduous trees supported the highest abundance and diversity of migrants. Germaine (unpub. Data) also noted that overall bird abundance appeared higher during fall than in spring.
- Gillihan (2000) examined short-term responses of breeding birds to small (~ 40 ha) restoration plots on the San Juan National Forest in southwestern Colorado. He noted birds that were only found in untreated forest (mourning dove, brown creeper, hermit thrush, black-headed grosbeak, band-tailed pigeon, northern flicker, olive-sided flycatcher), while others (northern goshawk, downy woodpecker, ruby-crowned kinglet, plumbeous vireo, orange-crowned warbler) were only found in treated areas.
- All three studies noted the presence of brown-headed cowbirds, and Germaine (unpub. Data) and Gillihan (2000) both noted higher abundances of cowbirds in natural openings and treated areas than in untreated forest. These observations are important because nest parasitism by cowbirds has caused significant declines in some host species (Terborg 1989b).

Some general trends were noted in these and other studies:

- Bird diversity was higher in ponderosa forests that had a deciduous component, usually Gambel oak or aspen (Mannan and Seigel 1988, Rosenstock 1998, Gillihan 2000).
- Bird community composition differed between dense and more open forest stands (whether natural or silviculturally derived), with increases in ground foraging and open area birds (chipping sparrows, Cassin's finches, western bluebirds and several flycatchers) and decreases in dense canopy or bark substrate foragers and nesters (western flycatcher, pygmy nuthatch, hermit thrush, black-headed grosbeak, red-faced and Grace's warblers) as forests became more open (Szaro and Balda 1979, 1986, Blake 1982, Mannan and Seigel 1988, Gillihan 2000). In general open forests had increased abundances of granivores and open-aerial foragers and decreases in coniferous mid and overstory nesters and canopy and bark foragers.
- Bird density peaked in lightly thinned stands and was lower both in uncut areas and areas opened to the extent planned for restoration treatments in the WUI (Szaro and Balda 1979, 1986).
- Several forest bird species demonstrated preferences for trees with old-growth characteristics, if available (Mannan and Seigel 1988, Beier 1998).
- Several forest bird species were less abundant or absent from forest stands that had been silviculturally thinned or burned and contained no large trees demonstrating old-growth characteristics (Mannan and Seigel 1988, Szaro and Balda 1979, 1986, Blake 1982).

### **Gaps in Knowledge of Forest Songbirds and Restored Forest Habitat Relationships**

Limited information exists to date on songbird responses specifically to ponderosa restoration treatments. Existing studies in ponderosa forests have demonstrated that birds respond to forest thinning at both the population and community levels, and suggest that forest restoration will affect

birds during the breeding, migration, and winter seasons. Different restoration prescriptions will retain different habitat features (e.g. varying ponderosa tree densities and diameters, volume of midstory coniferous canopy, etc.), and will, therefore, likely retain songbird species in different abundances. Songbird species diversity is highly dependent on habitat structural diversity (MacArthur and MacArthur 1961), and restoration prescriptions that homogenize landscapes are likely to support fewer species than those that strive for structural heterogeneity. Therefore, gaining and integrating information from a wide spectrum of restoration treatments and seasons is vital to our ability to manage for viable forest songbird populations in restored forest settings.

### **Breeding Songbirds**

Breeding songbirds have specific habitat requirements for nesting and feeding (Szaro and Balda 1986, Rosenstock 1996) and are highly mobile, making them good indicators of habitat quality. However, it is not known where thresholds in appropriate habitat exist, and beyond which some species may not be retained. This is an important consideration because existing restoration prescriptions will alter forest habitats drastically and in a short period of time. Treatment prescriptions that aggressively open forest canopies may replace forest-interior birds species with ground foraging and aerial flycatching species, but consideration to volume and clumpiness of post-treatment coniferous canopy may cause more forest-interior species to be retained. Therefore, it is important to identify breeding bird species retained in each treatment prescription so that future prescriptions may be applied in a coordinated manner allowing retention of all breeding birds on our forest landscapes.

### **Migrating and Wintering Songbirds**

Habitat requirements of passerine birds during spring and fall migration are poorly understood, but are known to include sites that afford high quality foraging, predation avoidance, and roosting habitats (Rappole 1995). Most long distance migrants require highly specific types of stopover habitat, with a large number of species using forested habitats (Rappole 1995). Different restoration treatment prescriptions are expected to vary in amounts of insects, seeds, and fruits available and in amount and type of foraging substrates retained in the lower, mid, and over-story canopy. These changes in prey base and forest structure have a great potential to

alter the community composition and habitat use of both wintering and spring and fall migrant bird assemblages, but we do not yet know the relationship between different prescriptions and songbird assemblages in these seasons.

### ***Kachina Village Forest Health Project***

The Kachina Village Forest Health Project is the second of 10 proposed ~4,000 ha planning units within the Flagstaff Wildland-Urban Interface (WUI), as part of the Grand Canyon Forests Partnership (USDA Forest Service 2000, 2001). This 4,217 ha project is located on the Mormon Lake and Peaks Ranger Districts, is located 6 km south of Flagstaff, includes the communities of Kachina Village and Forest Highlands, and will extend between Highways 89A and I-17 southward to the rim above Oak Creek Canyon.

Multiple thinning prescriptions are proposed in various treatment units in the Proposed Action for this project. While each prescription proposed has unique wildlife value and is therefore of monitoring interest, we propose to focus on two prescriptions which are extensive enough to ensure adequate samples may be generated, and which most closely represent WUI prescriptions likely to be applied throughout the West: “Thinning from Below – North of Kelly Canyon and Lower 89A Corridor” (hereafter TBN), and “Thinning from Below – South of Kelly Canyon” (hereafter TBS).

TBN will occur on 779 ha (1,923 ac) and will focus on reducing wildfire risk by both reducing ladder fuels and disconnecting the present continuous crown canopy. Post-treatment target tree densities range from 40-120 ft<sup>2</sup> basal area, canopy closure reduced to 40 to 50 percent, and mid-story canopy base height raised to an average of 15 feet. Small trees will be thinned around existing clumps of larger trees, maintaining existing spatial structures. Approximately 10 percent of the area will be managed as grassy openings located in areas where they were likely to have occurred in the past. Gambel oaks will not be cut.

TBS will occur on 674 ha (1,665 ac) south of Kelly Canyon and in the Mexican Pocket area. This area will be thinned with the objective of reducing wildfire risk in a manner similar to TBN but will also retain dense cover patches meant to enhance post-treatment wildlife value. Up to 25 percent of this area will be retained in dense clumps of understory trees with each clump exceeding 35 trees/clump, and clumps ranging in size from 0.04-0.4 ha (1/10<sup>th</sup> to 1 ac). Clumps will retain closed canopies with inter-

locking limbs and foliage. The forest surrounding clumps will be thinned to 40-100 ft<sup>2</sup> basal area. The combination of closed and open forest types proposed for TBS is expected to enhance wildlife value for species requiring dense patches of cover and those associated with ponderosa savannahs. Grassy openings and Gambel oaks will be managed in the same manner as in TBN.

### ***Objectives of this Proposal***

The Proposed Action for the Kachina Village Forest Health Project includes a *Purpose and Need* to “research and demonstrate key ecological....dimensions of forest health improvement efforts” (page 10) and *Administrative and Strategic Direction* to “encourage research and monitoring....to evaluate the effects of the project” (USDA Forest Service 2001; page 3). We have described why forest songbirds are an excellent choice for evaluating the effects of restoration treatments planned for the Kachina Village Block, and propose to collect reliable data with which to demonstrate songbird responses to restoration and with which to compare effects of this treatment prescription to other existing prescriptions (e.g. those at Mt. Trumbull, Fort Valley, etc.). Our objectives are to monitor breeding and non-breeding songbirds in each treatment prescription to identify the ability of songbird species to persist among various treatment types. This monitoring will result in reliable information and recommendations for restoration applications within the Flagstaff WUI and elsewhere in ponderosa forests in the Southwest.

### ***Specific Objectives:***

- To compare pre- and post-treatment songbird communities among areas:
  - scheduled to receive thinning-from-below restoration treatments that do not retain dense cover patches (TBN);
  - scheduled to receive thinning-from-below restoration treatments that retain dense cover patches (TBS, as described above);
  - adjacent areas of similar vegetation to serve as controls;
  - near (< 150 m) and far (>250 m) from untreated canyon forest habitat; and,
  - containing low (< 25 percent of expected range) and high (>75 percent of expected range) percent composition of Gambel oak presence.

## **Design and Procedures**

**Objective 1:** *To survey songbird communities in pre-treatment and control areas during winter, migration, and breeding periods.*

### **Procedure 1.1 - Pre-treatment songbird data collection**

- a. We will conduct modified point counts (area-constrained surveys) at 150 points distributed evenly among TBN, TBS, and Control (CTRL) forest habitat during spring migration (April-early May), breeding season (late May-early July), and winter (Jan-Feb) of 2002-2003, contingent upon project implementation scheduling and available funding. Survey points will be separated by  $\geq 200$  m, will be  $>100$  m from the treatment edges (other than canyons, described below), and will be surveyed between 0530 and 1000 hours for breeding birds, and 0630 and 1200 hours for migrating and wintering birds, on days with minimal wind and no precipitation. Three visits of 8 minutes duration each will be made to each point during each survey period, with recorded survey data constrained to within 75 m of each point.
- b. Species of, and distance to each individual bird detected visually or aurally will be recorded during surveys by field technicians experienced in bird censusing. Abundance values for each species at each point in each season will be the highest number of individuals recorded during any of the three visits/season.
- c. Data will be summarized within each seasonal survey period, and will consist of evenness within guilds, with guilds defined by foraging and nesting substrate use. Both guild and indicator species analysis suffer the possibility of misrepresenting member species. Therefore, intra-guild membership and relative abundance of each species will be tracked among CTRL, TBN, and TBS.
- d. In each forest type (TBN, TBS, CTRL), survey points will be distributed such that 25 points fall within 150 m of canyon edges and 25 points fall beyond 250 m from canyon edges. Contingent upon our ability to find areas having a Gambel oak basal area  $>10$  and areas having no oak within each distance class (near and far

from canyons), survey points will be distributed such that 12-13 in each distance class are in stands containing Gambel oak and 12-13 points in areas containing no Gambel oak. All points will be placed to avoid the influence of pre-existing meadow openings.

**Objective 2:** *To describe habitat characteristics among pre-treatment forest types.*

### **Procedure 2.1 - Measure pre-treatment habitat characteristics**

- a. To determine pre-treatment forest structural conditions influential to forest songbirds we will measure forest structural characteristics on all treatment and control survey plots in 0.1 ha (.25 ac) plots centered on survey points. We will measure diameter at breast height (dbh) of all trees  $>2.5$  cm dbh in two 6 m wide belts running N-S and E-W across plots. We will record percent deciduous, coniferous, midstory, and overstory canopy closure at 40 points distributed about the plot, and will index ground cover vegetation density  $\leq 2.5$  m in height using a density board. These measurements will be made for describing pre-existing differences among treatment and control areas, and will not be used in analyses of bird variables among treatment/control areas.

**Objective 3:** *To survey songbird communities in post-treatment and control areas during winter, migration, and breeding periods.*

### **Procedure 3.1 - Post-treatment songbird data collection**

- a. Bird survey and vegetative data will be collected during the first 2 years post-treatment at the same points and in the same manner as described in Procedure 1.1.

**Objective 4:** *To describe post-treatment habitat characteristics among treatment types.*

### **Procedure 4.1 - Measure post-treatment habitat characteristics**

- a. To determine post-treatment forest structural conditions pertinent to forest songbirds we will measure forest structural characteristics on all treatment and control survey plots in the same manner as

described in Procedure 2.1. Again, these measurements will be made for describing differences among post-treatment and control areas, and will not be used in analyses of bird variables among treatment/control areas.

**Objective 5:** *To compare effects of TBN and TBS restoration treatments to control areas.*

Procedure 5.1 – Assess effects of restoration treatments on TBN, TBS, and CTRL areas.

- a. For bird guilds, the difference between TBS pre-treatment – TBS post-treatment, TBN pre-treatment – TBN post-treatment, and CTRL pre-treatment – CTRL post-treatment will be examined in an ANOVA modification of the B-A-C-I-P (Stewart-Oaten et al. 1992) design. The ANOVA will include tests for interaction effects among treatment type x distance from untreated canyon habitat and treatment type x oak composition, under:
  - a. Ho1: the difference between pre- and post-treatment songbird guild membership is equal among TBN, TBS, and CTRL areas; and,
  - b. Ho2: no interaction effects among treatment type, distance from canyon habitat, or oak composition.

**Benefits to Adaptive Management**

While wildlife concerns continue to dominate professional and legal debates concerning WUI fire risk reduction and forest restoration, information on effects of treatments on wildlife is presently extremely limited. The information we propose to generate will directly address this problem. Further, true adaptive forest management cannot proceed in an informed manner without wildlife effects information. The information we propose to generate will enlighten debates on compatibilities and incompatibilities between individual treatment prescriptions and numerous response groups of wildlife, will identify wildlife species warranting concern in future treatments, and ultimately will be of great value in guiding the placement of various treatment prescriptions on forest landscapes, in WUI's and elsewhere.

Project Partners: Partners include the Coconino National Forest, Grand Canyon Trust, Arizona Game and Fish Department, and other members of the Grand Canyon Forests Partnership.

**Budget**

While we feel it is important to collect songbird information during the three seasons described in this document, we present funding options for including 1, 2, or all 3 proposed survey seasons.

**Funding Alternatives**

<b>Year 1</b>	Breeding	Breed & Spring	Breed, Spring, Winter
GS 20 Spec. III	\$3,784.86	\$3,784.86	\$3,784.86
GS 19 Spec. II	\$15,078.00	\$23,694.00	\$30,874.00
GS 16 Technician	\$3,727.50	\$7,455.00	\$8,520.00
Overhead	\$3,000.05	\$4,639.29	\$5,734.24
Vehicle	\$4,000.00	\$5,000.00	\$6,000.00
AOO	\$2,000.00	\$2,000.00	\$2,000.00
Equipment	\$5,850.00	\$5,850.00	\$5,850.00
<b>Year 1 Total:</b>	<b>\$37,440.36</b>	<b>\$52,423.15</b>	<b>\$62,763.10</b>
<b>Years 2 &amp; 3</b>			
GS 20 Spec. III	\$3,784.86	\$3,784.86	\$3,784.86
GS 19 Spec. II	\$15,078.00	\$23,694.00	\$30,874.00
GS 16 Technician	\$3,727.50	\$7,455.00	\$8,520.00
Overhead	\$3000.05	\$4,639.29	\$5,734.24
Vehicle	\$4,000.00	\$5,000.00	\$6,000.00
AOO	\$2,000.00	\$2,000.00	\$2,000.00
<b>Year 2:</b>	<b>\$31,590.41</b>	<b>\$46,573.15</b>	<b>\$56,913.10</b>
<b>Year 3:</b>	<b>\$31,590.41</b>	<b>\$46,573.15</b>	<b>\$56,913.10</b>
<b>Year 4</b>			
GS 20 Spec. III	\$3,784.86	\$3,784.86	\$3,784.86
GS 19 Spec. II	\$37,336.00	\$37,336.00	\$37,336.00
GS 16 Technician	\$3,727.50	\$7,455.00	\$8,520.00
Overhead	\$5,955.96	\$6,450.98	\$6,592.41
Vehicle	\$4,000.00	\$5,000.00	\$6,000.00
AOO	\$3,500.00	\$3,500.00	\$3,500.00
<b>Total:</b>	<b>\$58,304.32</b>	<b>\$63,526.84</b>	<b>\$65,733.27</b>

\* We are investigating the possibility of using Northern Arizona Audubon members to assist in bird surveys, at a cost reduction of up to \$10,000/yr. However, we are weighing savings versus scientific data collection quality tradeoffs.

## Literature Cited

- Beier, P. 1998. Bird abundance and diversity prior to restoration treatments for old-growth ponderosa pine. Final Report – Arizona Game and Fish Department Heritage grant 196008.
- Blake, J.G. 1982. Influence of fire and logging on nonbreeding bird communities of ponderosa pine forests. *Journal of Wildlife Management* 46:404-415.
- Covington, W.W. and M.M. Moore. 1994. Southwestern ponderosa pine forest structure: Changes since Euro-American settlement. *Journal of Forestry* 92:39-47.
- \_\_\_\_\_, P.Z. Fule, M.M. Moore, S.C. Hart, T.E. Kolb, J.N. Mast, S.S. Sacket, and M.R. Wagner. 1997. Restoring ecosystem health in ponderosa pine forests of the Southwest. *Journal of Forestry* 95:23-29.
- Finch, D.M., J.L. Ganey, W. Yong, R.T. Kimball, and R. Sallabanks. 1997. Effects and interactions of fire, logging, and grazing. Pages 103-136 *in* Block, W.M. and D.M. Finch eds., *Songbird ecology in southwestern ponderosa pine forests: A literature review*. Rocky Mountain Forest and Range Experimental Station General Technical Report RM-GTR-292. Fort Collins, CO.
- Germaine, S.S. 1998. Short-term wildlife responses to ponderosa pine forest restoration treatments in the Mount Trumbull area, Arizona. Annual Progress Report, Arizona Game and Fish Department. Phoenix, AZ. 30 pp.
- Germaine, H.L. and S.S. Germaine. 1999. Short-term wildlife responses to ponderosa pine forest restoration treatments in the Mount Trumbull area, Arizona. Annual Progress Report, Arizona Game and Fish Department. Phoenix, AZ. 20 pp.
- \_\_\_\_\_. 2000. Short-term wildlife responses to ponderosa pine forest restoration treatments in the Mount Trumbull area, Arizona. Annual Progress Report, Arizona Game and Fish Department. Phoenix, AZ. 21 pp.
- Gillihan, S.W. 2000. Avian responses to ponderosa pine ecosystem restoration. Final report to the Southwestern Colorado Wildlife Research Committee and the Colorado Natural Areas Program.
- James, F.C. 1971. Ordination of habitat relationships among breeding birds. *Wilson Bulletin* 83:215-236.
- Johnson, M. A. 1994. Changes in southwestern forests: stewardship implications. *Journal of Forestry* 92:16-19.
- MacArthur, R.H. and J.W. MacArthur. 1961. On bird species diversity. *Ecology* 42:594-598.
- Mannan, R.W. and J.J. Seigel. 1988. Bird populations and vegetation characteristics in immature and old-growth ponderosa pine forests, northern Arizona. Final Report, Reference G500016, School of Renewable Natural Resources, University of Arizona, Tucson, AZ.
- Mast, J.N., P.Z. Fule, M.M. Moore, W.W. Covington, and A.E.M. Waltz. 1999. Restoration of presettlement age structure of an Arizona ponderosa pine forest. *Ecological Applications* 9:228-239.
- Moir, W.H., B.W. Geils, M.A. Benoit, and D. Scurlock. 1997. Ecology of southwestern ponderosa pine forests. Pages 3-27 *in* Block, W.M. and D.M. Finch eds., *Songbird ecology in southwestern ponderosa pine forests: A literature review*. Rocky Mountain Forest and Range Experimental Station General Technical Report RM-GTR-292. Fort Collins, CO.
- Moore, M.M., W.W. Covington, and P.Z. Fule. 1999. Reference conditions and ecological restoration: A southwestern ponderosa pine perspective. *Ecological Applications* 9:1266-1277.
- Rappole, J.H. 1995. *The Ecology of Migrant Birds: A Neotropical Perspective*. Smithsonian Institution Press, Washington D.C.
- Rosenstock, S.S. 1996. Habitat relationships of breeding birds in northern Arizona ponderosa pine and pine-oak forests. Arizona Game and Fish Dept. Technical Report 23, Phoenix.
- \_\_\_\_\_. 1998. Influence of Gambel oak on breeding birds in ponderosa pine forests of northern Arizona. *Condor* 100:485-492.

- Scurlock, D. and D.M. Finch. 1997. A historical overview. Pages 43-68 *in* Block, W.M. and D.M. Finch eds., *Songbird ecology in southwestern ponderosa pine forests: A literature review*. Rocky Mountain Forest and Range Experimental Station General Technical Report RM-GTR-292. Fort Collins, CO.
- Stewart-Oaten, A. J.R. Bence, and C.W. Osenberg. 1992. Assessing effects of unreplicated perturbations: no simple solutions. *Ecology* 73:1396-1404.
- Szaro, R.C. and R.P. Balda. 1986. Relationships among weather, habitat structure, and ponderosa pine forest birds. *Journal of Wildlife Management* 50:253-260.
- \_\_\_\_\_ and R.P. Balda. 1979. Effects of harvesting ponderosa pine on nongame bird populations. USDA Forest Service Research Paper RM-212, Rocky Mountain Forest and Range Experimental Station, Flagstaff, AZ.
- Terborg, J. 1989a. *Where have all the birds gone?* Princeton: Princeton University Press. Princeton, NJ.
- Terborg, J. 1989b. Perspectives on the conservation of neotropical migrant landbirds. Pages 7-12 *in* J.M. Hagan III and D.W. Johnson, eds., *Ecology and conservation of neotropical migrant landbirds*. Smithsonian Institution Press, Washington, D.C.
- USDA Forest Service. 2000. Fort Valley ecosystem restoration project environmental assessment. Coconino National Forest Supervisor's Office, Flagstaff, Arizona, USA.
- Wagner, M.R., W.M. Block, B.W. Geils, and K.F. Wenger. 2000. Restoration ecology: A new forest management paradigm, or another merit badge for foresters? *Journal of Forestry* 22-27.

