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

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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 Greater Flagstaff 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 Biological 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 reseeding (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 mots, 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 expediture 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.

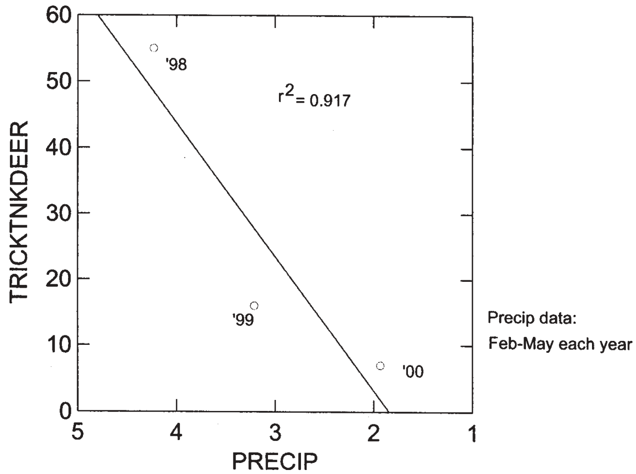

Figure 1. Mule Deer Use of Trick Tank Unit, Mt. Trumbull, During 3 Years Since Treatment, 1998-2000

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 Greater Flagstaff 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 $ft.^2$ basal area, canopy closure reduced to 40 to 50 precent, 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 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 ($1/10^{th}$ to 1 acre). Clumps will retain closed canopies with interlocking limbs and foliage. The forest surrounding clumps will be thinned to 40-100 $ft.^2$ 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 Greater Flagstaff Forests Partnership.

Budget

Year 1 (pre-treatment):

GS 20 Spec. III	1/12 time	$4,326.92
GS 19 Spec. II (develop study plan, initiate project)	1/2 time	$20,891.00
Overhead		$4,320.00
		$(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
Year 1 Total		$107,387.92

Year 2 (pre-treatment):

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

Year 3 (1st year post-treatment):

Ps/ere

GS 19 Spec. II (GPS cover patches)	1/2 time	$20,891.00
Intern (GPS cover patches)		$3,214.00
Overhead		$4,335.43
		$(28,440.43)
Refurbish GPS collars		$3,200.00
Replace GPS collars		$12,800
Vehicle		$6,000.00
AOO (field supplies)		$1,000.00
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 (final analysis & reporting)	1/2 time	$20,891.00
Overhead		$4,535.60
		$(29,753.52)
Vehicle		$6,000.00
AOO (pub/pres costs)		$3,000.00
Year 4 Total		$38,753.52

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 Mangement 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.

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

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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 Greater Flagstaff 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 Greater Flagstaff 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, Gilihan 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 know where thresholds in appropriate habitat exist, and beyond which some species may not be retained. This is an important considersation 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 Greater Flagstaff 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^2 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 (1/10th to 1 ac). Clumps will retain closed canopies with interlocking limbs and foliage. The forest surrounding clumps will be thinned to 40-100 ft^2 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 ≥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 ≤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 Greater Flagstaff 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

Year 1	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
Year 1 Total:	$37,440.36	$52,423.15	$62,763.10
Years 2 & 3			
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
Year 2:	**$31,590.41**	**$46,573.15**	**$56,913.10**
Year 3:	**$31,590.41**	**$46,573.15**	**$56,913.10**
Year 4			
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
Total:	$58,304.32	$63,526.84	$65,733.27

* 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.

The Tassel-Eared Squirrel as an Indicator Species for Evaluating Ponderosa Pine Forest Restoration Effects on Wildlife

A Comprehensive Research and Monitoring Proposal Emphasizing the Kachina Village Forest Health Project Mormon Lake Ranger District, Coconino National Forest

Arizona Game and Fish Department
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September 5, 2001

Introduction

Timber harvest, long-term fire suppression, and livestock grazing have contributed to substantial changes in southwestern ponderosa pine (*Pinus ponderosa*) forest structure since European settlement, as presettlement forests were more open and park-like (Cooper 1960, Covington and Moore 1992, 1994; Belsky and Blumenthal 1997, Mast et al. 1999). A proliferation of younger age class trees dominate forests today (Johnson 1994, Mast 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 the incidence of prescribed fire, and promote old-growth forest conditions (Covington and Moore 1994, Covington et al. 1997).

To date, the most intensive application of forest restoration principals has been ongoing since 1995 at Mount Trumbull, north of the Grand Canyon. Here, sufficient treatments have been implemented to result in modification of prescriptions through the adaptive management process (Covington 2000). Elsewhere, forest restoration activities have largely been limited to demonstration-type projects, including at the north rim of the Grand Canyon National Park, at Fort Valley near Flagstaff, and the Blue Ridge Demonstration Project on the Apache-Sitgreaves National Forest. Until recently, the most ambitious and extensive application of forest restoration was planned for the Flagstaff Urban Wildland Interface as part of the Grand Canyon Forests Partnership. Here, the Forest Service will attempt to conduct planning on approximately 4000 ha per year over 10 years (UDSA Forest Service 2000). The Fort Valley Ecosystem Restoration Project represents the first of these units, with treatment of “Phase I” scheduled for summer 2001 (USDA Forest Service 2000). The Kachina Village Forest Health Project, the next unit being planned within the Flagstaff Urban Wildland Interface has progressed to the point of issuance of a Proposed Action (USDA Forest Service 2001).

Ponderosa pine forest restoration activities throughout the Southwest are anticipated to escalate dramatically over present levels, particularly along forest-urban interfaces exhibiting greatest risk for catastrophic wildfire impact. Current proposals target restoration activities on 81,000 ha annually in Arizona and New Mexico over the next 10 years (Anonymous 2001). The prevailing restoration emphasis is on quantitative reconstruction of presettlement forest structure (Covington et al. 1997, Fule et al. 1997, Mast et al. 1999). Treatments emulating reference density structure have resulted in large reductions in tree density, up to 98%, with resultant densities of 60 trees/ha or less (Mast et al. 1999). A biological opinion was recently issued for proposed catastrophic wildfire reduction on 752,000 ha in Arizona and New Mexico in 283 wildland/urban interface areas, allowing treatments to reduce basal areas to as low as 9 m^2/ha (40 ft^2/ac).

Justification and Need for Wildlife Monitoring and Research

Considerable concern exists relative to the potential effects of forest restoration on a multitude of forest wildlife, particularly when done over large, contiguous areas. Over 400 species of vertebrate wildlife inhabit Arizona's ponderosa pine forests, all with different habitat requirements and potential short- and long-term response to forest restoration activities. The most comprehensive evaluations of wildlife response to forest restoration activities have been ongoing at Mount Trumbull since 1996 (Covington 2000). However, after years of pre-treatment data collection on a wide range of wildlife taxa, planned restoration treatments have not occurred, greatly limiting post-treatment evaluations (Covington 2000). As such, even the most comprehensive assessments to date have added only limited definitive insights into wildlife relationships to forest restoration. And still, forest restoration activities elsewhere in Arizona are accelerating while many questions regarding wildlife effects remain unanswered. Additionally, there is concern that restoration treatments may further add to cumulative effects of intensive even-aged forest management on wildlife since 1980 (Dodd and Adams 1989, Arizona Game and Fish Department 1993).

Wildlife concerns associated with forest restoration range from the potential "keyhole" effect on some species which may not persist on the on the landscape for some time following restoration treatment, to short-term disruption of forest function and processes associated with reduced tree densities and canopy closure and increased soil temperatures and drying. Forest restoration has the potential to impact forest structure and horizontal and vertical diversity at multiple scales, particularly for sensitive species exhibiting narrow habitat requirements. Appropriate forest matrices to sustain all wildlife species on both short- and long-term timeframes are currently unknown, as are guidelines for maintaining effective movement corridors. The impact of non-native and invasive plant and animal species following restoration activities, as well as associated increased road densities, soil erosion, and slash disposal are also of concern.

A key element of forest ecosystem restoration is the effective application of adaptive management principals (Covington 2000). Adaptive management is integral to the continuous refinement and modification of restoration prescriptions and applications based on monitoring and evaluation of the effects of previous treatments. Effective and equitable application of adaptive management principals to addressing concerns for all forest resources is critical to the success of forest restoration, especially as treatments are accelerated in the future. However, to date, funding for monitoring of forest restoration effects on wildlife has lagged behind other resources and must be increased to address the multitude of concerns associated with wildlife.

With the wide range of wildlife concerns, coupled with the multitude of affected species, the task of monitoring and research is potentially immense. Yet, monitoring and research realistically cannot occur on all species and therefore efforts must be prioritized to best utilize limited agency resources as well as focusing on "indicator" species that provide the best insights into forest restoration relationships. One such species that appears well suited for serving as a valuable tool for monitoring and researching forest restoration treatments at all scales is the tassel-eared squirrel (*Sciurus aberti*).

The Tassel-Eared Squirrel as a Monitoring and Research Indicator Species

The tassel-eared squirrel is a near-ideal species in which to monitor and research forest restoration treatments and provide much needed feedback through adaptive management. This ubiquitous species is an obligate of our extensive ponderosa pine forests and may serve as an effective indicator species and surrogate for other forest wildlife species for several reasons, including:

- The tassel-eared squirrel is numerous and widespread enough throughout the ponderosa pine ecosystem (Brown 1984, Dodd et al. 1998) to ensure that statistically reliable population data can be collected, facilitating comparison between areas, treatments, or making pre- and post-treatment evaluations. Mean densities in excess of 1 squirrel/ha have been recorded (Dodd et al. 1998, Dodd 1999).
- Tree squirrels in general are relatively sensitive to forest structural habitat modification, and as such serve as excellent indicators of forest condition (Carey 2000). A large body of past research and literature coupled with ongoing research by Arizona Game and Fish Department since 1995 has established squirrel population and habitat relationships (Dodd

et al. 1989, Dodd et al. 2003). Squirrels are particularly sensitive to reduced tree densities, basal area, and canopy closure, all which result after forest restoration treatment.

- Techniques to efficiently and reliably assess tassel-eared squirrel population response to forest structural modification already exist. The Arizona Game and Fish Department invested considerable effort to develop and validate techniques to accurately estimate squirrel density, utilizing feeding sign and prepared track count indices (Dodd et al. 1998). Further, we have identified juvenile squirrel recruitment as a key population response variable and have also refined techniques to reliably estimate this parameter (Dodd et al. 1998, Dodd 1999).
- Current research into landscape-scale forest habitat relationships to tassel-eared squirrel populations (Dodd 1999) have yielded valuable insights into forest restoration effects, particularly the importance of high quality habitat patches that serve as population source areas for squirrels (Van Horne 1983, Pulliam 1988). Further research in this arena is vital to obtaining a clearer understanding of landscape-scale habitat relationships.
- Tassel-eared squirrels play a key role in nutrient and water exchange cycles within the ponderosa pine ecosystem (States and Gaud 1997, States and Wettstein 1998). They are integral to ponderosa pine ecosystem function as part of a highly evolved symbiotic relationship among squirrels, fungi, and ponderosa pine (Maser and Maser 1988, States and Gaud 1997). Mycorrhizal fungi are integral to the energy flow and nutrient cycles as symbionts with conifers including ponderosa pine (Vogt et al. 1981), facilitate seedling establishment and survival (Heidmann and Cornett 1986, Riffle 1989), and enhance resilience to environmental stress (Perry et al. 1989). Mycophagy by tassel-eared squirrels is essential for recruitment and survival (Dodd et al. 2003), especially in highly variable environments; fungi are dependent on squirrels to serve as agents of spore dispersal (States and Wettstein 1998). Short-term disruptions to the essential ecosystem functions served by squirrels and hypogeous fungi associated with forest restoration treatments may persist for decades.
- The tassel-eared squirrel is an economically important species and constitutes a popular small game species in Arizona, hunted since 1953. Annual harvest the past 20 years (1981-2000) has averaged 82,370 squirrels, with an average of 42,170 hunter days of recreation accrued. This activity annual has an economic impact of over $1,900,000 in direct sales of sporting equipment, and a multiplier effect to the state's economy of $3,378,000, using figures from the International Association of Fish and Wildlife Agencies (1996). Squirrels are also a popular watchable species, often present in and around homeowner's yards and forest campgrounds.
- The tassel-eared squirrel is a primary prey species for the northern goshawk (*Accipiter gentilis*), a controversial Forest Service sensitive species (Reynolds et al. 1992). Squirrels are particularly important to goshawks during winter when many other prey species have either hibernated or migrated (Dodd et al. 1998).
- The tassel-eared squirrel has been utilized as a management indicator species in all Arizona national forest land and resource management plans.

All these factors combined make the tassel-eared squirrel biologically, logistically, and politically well suited for forest ecosystem restoration monitoring and research. Such monitoring and research can provide both short- and long-term insights into forest restoration treatments, particularly useful in applying adaptive management.

Tassel-Eared Squirrel Research and Implications to Forest Restoration

Since 1995, the Arizona Game and Fish Department's Research Branch has been conducting intensive tassel-eared squirrel research addressing relationships to habitat at multiple scales: 1) tree clump, 2) stand or habitat patch, and 3) landscape scales.

Tree Clump Level

At the tree clump level, we assessed squirrel habitat selection at 2 study sites on the Coconino National

Forest utilizing radio telemetry. Based on tracking of 25 different squirrels during 1996-1997, and comparing 835 use versus 787 random plots (0.04 ha), we discovered the following (Dodd and Lema *In prep*.):

- Squirrels "selected" for several structural components at the clump level. They exhibited strongest selection relative to availability for:
  - — canopy closure (use sites had 16% higher canopy closure on average),
  - — mature and old growth vegetation structural stage (VSS; Reynolds et al. 1992) 5 and 6 trees (use sites had 80% more per plot),
  - — basal area (use sites were 35% higher), and
  - — stand density index (SDI; use sites were 31% higher.
- Preliminary results also indicate that squirrel home range size varied as a function of these parameters.

Stand or Patch Level

At the stand or habitat patch scale, we studied squirrels at 8 - 60 ha study sites on the Coconino National Forest from 1995-1997. Our study sites crossed a wide gradient of habitat condition. Though the focus of this research was to develop techniques to reliably estimate tassel-eared squirrel density (Dodd et al. 1998), we were able to gain insights into seasonal squirrel population dynamics and relationships to habitat condition and diet, including:

- Most study sites exhibited large seasonal fluctuations in squirrel density between spring and fall periods, with average increases in density of 182% noted. These large increases in density at sites that exhibited poor structural habitat characteristics were attributed to seasonal availability of pinecone seed in heavily thinned areas adjacent to high quality habitats. Squirrels moved to adjacent higher quality habitats during winter. Thus, squirrels benefited from seasonal use of open, thinned habitats within mosaics with higher quality habitats by exploiting food sources.
- Study sites exhibited characteristics of either "source" or "sink" habitats (Lidicker 1975, Van Horne 1983). Sink habitats were those where recruitment was limited and insufficient to offset mortality, but where populations were apparently maintained by immigration from more stable and productive source areas (Pulliam 1988). Dodd et al. (1998) found that higher quality source habitats were relatively rare compared to sink habitats, as widespread past even-aged management has reduced forest stand, patch, and landscape diversity (Patton 1992), and eliminated many optimum tassel-eared squirrel habitats (Patton 1984).
- Squirrel population performance was related to structural habitat condition (Dodd et al. 1998) and squirrel dietary use of hypogeous fungi (Dodd et al. 2003):
  - — Juvenile squirrel recruitment was related to both the number of interlocking canopy trees and summer fungal content in fecal samples, pointing to the importance of both habitat and diet. Study sites with at least average levels of recruitment had a minimum of 22 patches/ha of >5 interlocking canopy trees. Patton (1975) reported that 92% of squirrel nests occurred in groups, with 75% having ≥ 3 interlocking trees. We found that summer fungal content in the squirrel diet was related to stand basal area, similar to the findings of States and Gaud (1997) where hypogeous fungi production was strongly related to basal area.
  - — Winter squirrel survival (significantly lower than other periods) was correlated to to winter fungal diversity in the diet.
  - — Overall mean squirrel density was related to fecal fungi diversity.
  - — Mean fluctuations in squirrel density between spring and fall were related to ponderosa pine quadratic mean diameter. Patton et al. (1985) reported that larger trees were particularly important to tassel-eared squirrels for food and cover, and Larson and Schubert (1970) found that pinecone production and crop frequency were positively related to tree diameter.

Landscape Level

Since 1999, we have been investigating landscape-scale forest habitat relationships to tassel-eared squirrel population dynamics at 9 – 500 ha study sites on the Coconino National Forest (Dodd 1999). Study sites were oriented along a gradient of ratio of optimal to marginal patch area (ROMPA; Lidicker 1988, Krohne 1997). This study focused on evaluating the relationships of the proportion of suitable habitat or ROMPA to squirrel population dynamics, and identifying thresholds where or if they exist. This approach is warranted based on studies were landscape-scale thresholds have been shown to exist (Andren 1994, Kareiva and Wennergren 1995, Bowers and Matter 1997, Krohne 1997), and where ROMPA appears to be more important in describing wildlife response than patch area and spatial pattern, at least above threshold levels. The description and quantification of squirrel population “source” and “sink” habitats by Dodd et al. (1998) greatly facilitated landscape-scale habitat assessment under a island biogeographic approach (MacArthur and Wilson 1967) and using ROMPA. Areas characterized as population “source” habitats function as patch islands (or “mainlands”), constituting the “optimum” habitat under an approach using ROMPA. These optimum habitats are surrounded by relatively unsuitable (e.g., for recruitment) “sink”, or “marginal” (under ROMPA) habitats (Dodd et al. 1998). Focusing on landscapes comprised of such optimum and marginal patch extremes provides us a basis to investigate ROMPA relationships under a island biogreaphic approach. The intensively thinned units of ongoing forest restoration projects are structurally similar to our “marginal” habitat areas subjected to past timber harvest practices that emphasized even-aged management systems. These practices have been demonstrated as being detrimental to tassel-eared squirrel populations (Pederson et al. 1976, 1987; Patton 1984; Patton et al. 1985; Patton et al. 1985; Arizona Game and Fish Department 1993; Dodd et al. 1998). Based on our research conducted to date, our findings indicate:

- Mean study site squirrel density estimated during spring 1999 and 2000 exhibited a dramatic threshold, dropping sharply at approximately 35% ROMPA. Above this threshold, mean density remained relatively consistent. Within “optimum” habitat sampling plots only, highest densities were recorded at sites with ROMPA between 40 and 50%, indicating a benefit from edge effect and habitat mosaic.
- Mean study site juvenile squirrel recruitment estimated during fall 1999 also exhibited a threshold, dropping sharply between 35 and 40% ROMPA. Even in “optimum” habitat sampling plots, juvenile recruitment dropped off sharply below 30% ROMPA. Highest mean recruitment was noted between 40 and 45% ROMPA, again suggesting a benefit from edge effect and habitat mosaic.
- These preliminary results point to the importance of maintaining sufficient amounts of high quality source habitats in maintaining squirrel densities and recruitment at the landscape scale. They also point to the potential benefit of limited intensive thinning with the creation of mosaics exhibiting high edge effect, presumably where squirrels are able to seasonally exploit different food sources, as described by Dodd et al. (1998).

Gaps in Our Knowledge of Tassel-Eared Squirrel and Habitat Relationships

Though we have added substantially to our knowledge of tassel-eared squirrel relationships to ponderosa pine habitat, large gaps remain in of understanding, particularly relating to forest restoration. These gaps in our knowledge and needs to effectively integrate squirrel and other wildlife habitat requirements into future forest restoration activities include:

- Given the preliminary establishment of squirrel density and juvenile recruitment thresholds at approximately 35% ROMPA, we need to now what size and arrangement of source habitat blocks at or above the threshold provides the best habitat for squirrels. An assessment of patch size requirements is essential under intensive forest restoration and wildfire risk reduction programs to address squirrel needs for “single-large or several-small” (SLOSS; Simberloff 1988) optimum habitat patches (or a mix) arranged on the landscape.
- Evaluation of tassel-eared squirrel population response to a range of forest restoration prescriptions applied at varying scales, and what prescriptions may optimize squirrel density, recruitment, and survival. We need to know what level of clumpiness and other structural habitat attributes are needed to maintain adequate recruitment and density.
- Further investigation of the relationships among squirrel population dynamics, seasonal food (e.g., hypogeous fungi,

ponderosa pine cone) availability, and a forest restoration prescriptions.

- What landscape matrix combining source habitat blocks and a range of restoration treatment forest structural conditions will optimize tassel-eared squirrel density, recruitment, and survival.

Opportunities to Assess Tassel-Eared Squirrel Response to Forest Restoration

Three distinct opportunities are available to us to monitor and research the effects of forest restoration practices on tassel-eared squirrel populations, to fulfill the need for adaptive management information, and to fill our remaining gaps in knowledge. These opportunities include: 1) utilize existing areas exhibiting structural characteristics similar to forest restoration treatments, 2) evaluate current and future forest restoration treatments at multiple scales, and 3) pursue experimentally designed treatments and mosaics for intensive evaluation as part of future forest restoration projects.

Utilize Existing Areas

Vast portions of Arizona national forest were subjected to intensive even-aged management practices during the period from the late 1970s to early 1990s. Much of these areas exhibit structural conditions similar to those resulting from forest restoration treatment, and therefore may be used as "surrogate" habitat to make inferences regarding forest restoration treatments. There currently exists a near infinite range of forest mosaics across the landscape, as well as tools such as Geographic Information System (GIS) databases and LANDSAT imagery to facilitate this approach. The shortcoming of this approach is that it does not directly evaluate the effects of forest restoration.

Evaluate Current and Future Restoration Treatments

Under such an approach, we can attempt to overlay experimental evaluation designs on restoration projects once they have been planned and/or potentially implemented. This approach is particularly effective were we can achieve replications of treatments and utilize control areas, though this may not be possible, making it difficult to adequately control for all treatment effects. Nonetheless, each and every project should be evaluated for opportunities for monitoring, research and adaptive management evaluation.

Integrate Research Experimental Designs into Future Restoration Projects

This is our ultimate approach to evaluating and understanding forest restoration effects on wildlife and squirrels in particular. Here, we desire to actively participate in the planning process for applicable restoration projects to implement various prescriptions and treatment mosaics in an experimentally designed manner with replications and controls, and ability to account for treatment effects. While doing such, we recognize and desire to integrate the needs of other resources to achieve multiple objectives under any given project. Given the large areas proposed for evaluation in the near future, and ability to utilize multiple adjacent projects to achieve desired experimental designs, this approach would appear feasible. It certainly has the potential to yield the most applicable and scientifically valid results to be applied under adaptive management.

Kachina Village Forest Health Project

As previously mentioned, the Kachina Village Forest Health Project represents the second of 10 approximately 4000 ha planning units within the Flagstaff Urban Wildland Interface, as part of the Grand Canyon Forests Partnership (USDA Forest Service 2000, 2001). This 4217 ha project area is located 6 km south of Flagstaff, adjacent to the communities of Kachina Village and Forest Highlands.

The proposed action for this project was issued on June 27, 2001, and includes various forest health and fire risk reduction treatments on portions of the 3127 ha of Forest Service land (USDA Forest Service 2001). The proposed action reflects the Coconino National Forest's commitment to adaptive management, applying insights gained from Fort Valley and elsewhere, leading to a range of proposed restoration and fire risk reduction prescriptions. These prescriptions incorporate "special design features into the management plan to continue to provide habitat" for tassel-eared squirrels and other species (USDA Forest Service 2001; page 10). These proposed prescriptions include:

- Thinning from below north of Kelly Canyon and lower Highway 89A corridor on 778 ha (1923 ac), with clumpy variable thinning densities and residual basal areas ranging from 40 – 120 ft^2 basal area.

- Thinning from below south of Kelly Canyon and within the Mexican Pocket area on 674 ha (1665 ac), with clumps retained ranging from 0.04 – 0.4 ha (0.1 – 1.0 ac) in size
- Thinning from below to improve tree longevity and Gambel oak habitat on 170 ha (418 ac)
- Thinning from below within Mexican spotted owl protected activity centers (PACs) on 180 ha (446 ac)
- Thinning from below for dense canopy retention for improving forest resiliency of northern goshawk habitat on 50 ha (124 ac)
- Thinning from below within the Griffiths Spring drainage on 33 ha (81 ac)
- Prescribed burning on 3127 ha (7725 ac)

Opportunities to Assess Tassel-Eared Squirrel Response on the Kachina Village Project

The proposed prescriptions for implementation on the Kachina Village Project, especially those that focus on retention/enhancement of clumpy forest structural characteristics provide an excellent opportunity to assess the population response by tassel-eared squirrels. With the demonstrated importance of canopy clumpiness and interlocking crowns to tassel-eared squirrels (Dodd et al. 1998), this project would address one of the aforementioned major gaps in our knowledge relating to understanding squirrel relationships to various forest restoration prescriptions. The Kachina Village project affords us the opportunity to determine what level of clumpiness and other structural attributes are needed by squirrels to maintain adequate juvenile recruitment and density. Further, such an evaluation would provide the Forest Service justification for future application of prescriptions that are more costly to implement and depart from the presettlement referenced-based restoration model (Covington et al. 1997, Fule et al. 1997). The range of prescriptions and area sufficient to provide for multiple sample plots/replications and treatment controls makes an assessment of tassel-eared squirrel population relationships at Kachina Village particularly attractive.

The focus of this proposal is to evaluate tassel-eared squirrel response to the 2 predominate thinning prescriptions on the Kachina Village project exhibiting special design features to maintain wildlife habitat values:

- Thinning from below north of Kelly Canyon with variable thinning densities and residual basal areas ranging from 40-120 ft^2 basal area on 778 ha (1923 ac), or the **"wildland-urban interface thinning without clumps prescription"**, and
- Thinning from below south of Kelly Canyon and within Mexican Pocket area with clumps retained from 0.04 – 0.4 ha (0.1 – 1.0 ac) in size on 674 ha (1665 ac), or the **"wildland-urban interface thinning with clumps prescription**".

Monitoring Objectives

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.Ö.to evaluate the effects of the project" (USDA Forest Service 2001; page 3). Our goal is to utilize the tassel-eared squirrel as a monitoring indicator species to evaluate the effects of intensive forest thinning treatments at Kachina Village, collecting statistically reliable information to help address the project purpose and need and administrative and strategic direction. This monitoring will provide much needed feedback through the adaptive management process to determine baseline effects information, and to identify which prescriptions optimize squirrel population response with treatments to improve forest health and reduce fire risk. This monitoring will yield reliable information and recommendations for application elsewhere within the Flagstaff Urban Wildland Interface and throughout the Southwest.

Specific objectives and procedures for monitoring tassel-eared squirrel population response to forest restoration activities associated with the Kachina Village project include:

Objective 1

Conduct pre-treatment monitoring of tassel-eared squirrel populations to establish baseline density in areas where the 2 predominate forest health prescriptions with special design measures (wildland-urban interface thinning with and without clumps) will be implemented at the Kachina Village Forest Health Project.

Objective 2

Conduct post-treatment monitoring of tassel-eared squirrel population response to the 2 predominate forest health prescriptions with special design measures (wildland-urban interface thinning with and without clumps) to be implemented at the Kachina Village Forest Health Project, comparing pre-treatment baseline to post-treatment and control area density, as well as squirrel response to thinning with clumps and thinning without clumps

Objective 3

Assess relative winter squirrel use by differential clump size [0.04 – 0.4 ha (0.1 – 1.0 ac)] within the wildland-urban interface thinning with clumps prescription to determine optimum clump size supporting winter squirrel use.

Objective 4

Analyze all data and prepare a final project report.

Monitoring Procedures

The specific procedures to be employed for each monitoring objective detailed above are as follows:

Objective 1. Conduct pre-treatment monitoring of tassel-eared squirrel populations to establish baseline density in areas where the 2 predominate forest health prescriptions with special design measures (wildland-urban interface thinning with and without clumps) will be implemented at the Kachina Village Forest Health Project.

Procedure 1.1 – Establish monitoring plots within treatment areas and adjacent controls.

a. Within each of the 2 predominate prescriptions, wildland-urban interface thinning with and without clumps, locate 12 - 24 ha sampling plots each (24 total), referencing each plot starting point using a Global Positional System (GPS) receiver.

b. Associated with each of the 2 predominate prescriptions, situate 3 – 24 ha control plots (6 total) in adjacent forest of similar pre-treatment structural condition. Reference each control plot starting point using a GPS receiver.

Procedure 1.2 - Estimate tassel-eared squirrel density

a. We will utilize the feeding sign index technique reported by Dodd et al. (1998) to estimate squirrel density at all treatment and control plots during Spring (April-May). Density estimates derived during the spring period were found to be an excellent measure of yearlong, mean squirrel density (Dodd et al. 1998). This technique will employ 256 – 1 m^2 plots spaced over 24 ha (60 ac) on which squirrel feeding sign will be noted as present or absent. This data (percentage of plots exhibiting feeding sign) will be entered into a regression model to yield statistically reliable estimates of density and 90% prediction intervals, as per Dodd et al. (1998).

b. Pre-treatment feeding sign index monitoring will occur on all 30 plots during spring 2002-2003, yielding 2 years of pre-treatment monitoring information contingent upon project implementation scheduling.

Objective 2. Conduct post-treatment monitoring of tassel-eared squirrel population response to the 2 predominate forest health prescriptions with special design measures (wildland-urban interface thinning with and without clumps) to be implemented at the Kachina Village Forest Health Project, comparing pre-treatment baseline to post-treatment and control area density, as well as squirrel response to thinning with clumps and thinning without clumps

Procedure 2.1 - Estimate tassel-eared squirrel density

a. We will utilize the same procedures detailed in Procedure 1.1 above at all 30 plots.

b. The feeding sign index monitoring will occur during spring 2004-2005, yielding 2 years of post-treatment monitoring information contingent upon project implementation scheduling.

Procedure 2.2 - Assess relationships of squirrel response variables to treatments.

a. We will compare squirrel density information obtained during pre-treatment monitoring to that collected post-treatment for each prescription. Changes between pre- and post-treatment squirrel population response for each prescription will also be compared to control plots, allowing for comparisons of relative magnitude of change over time. We will also compare squirrel density on plots thinned with clumps to plots thinned without clumps to determine population response by squirrels.

b. As Dodd et al. (1998) found that squirrel use of thinned (“sink”) habitats was partly a function of proximity to quality (“source”) habitats, we will measure the mean distance of each plot (plot center) to the nearest unthinned forest patch. This information will be used to assess interactions between treatment prescription and distance to unthinned forest, utilizing Analysis of Covariance (ANCOVA) techniques.

Objective 3. Assess relative winter squirrel use by differential clump size [0.04 – 0.4 ha (0.1 – 1.0 ac)] within the wildland-urban interface thinning with clumps prescription to determine optimum clump size supporting winter squirrel use.

Procedure 3.1 – Determine relative winter/early spring squirrel use by differential clump size.

a. At the same time that post-treatment feeding index counts are conducted within the 12 wildland-urban interface thinning with clumps prescription plots, we will determine relative squirrel use the proceeding winter/early spring by differential clump size. The winter period accounts for the greatest source of squirrel mortality (Dodd et al. 1998) and the period where home ranges are most restricted (Lema 2001); this period is considered as a limiting period for squirrels (Dodd et al. 1998). To determine the role of clump size in influencing winter squirrel use, we will measure relative feeding sign occurring within various clump size categories.

As discernable clumps are encountered along the feeding sign index transects, they will be assigned within one of the following clump size categories:

<0.04 ha	(<0.10 ac)
0.04 – 0.08 ha	(0.10 – 0.20 ac)
0.81 – 0.12 ha	(0.21 – 0.30 ac)
0.13 – 0.20 ha	(0.31 – 0.50 ac)
0.21 – 0.30 ha	(0.51 – 0.75 ac)
0.31 – 0.40 ha	(0.76 – 1.00 ac)
>0.40 ha	(>1.00 ac)

Within each clump encountered and classified, we will also categorize tassel-eared squirrel use, reflected as a function of feeding sign abundance. An estimate of feeding sign abundance will be made for each clump, assigned to one of the following categories:

No use	(no evidence of squirrel use noted)
Very light use	(1 – 25 terminal clippings per 0.1 ac)
Light use	(26 – 150 terminal clippings per 0.1 ac)
Moderate use	(151 – 500 terminal clippings per 0.1 ac)
Heavy use	(501 – 1000 terminal clippings per 0.1 ac)
Very heavy use	(>1000 terminal clippings per 0.1 ac)

b. A log-linear model analysis will be employed to explore associations between winter squirrel use, clump size, and distance of each plot to the nearest unthinned forest patch. The latter parameter will utilize the information obtained under Procedure 2.2.b.

Monitoring Budget

Table 1 depicts the 4-year budget for tassel-eared squirrel monitoring activities at the Kachina Village Forest Health Project, broken down by year. The amount requested for pre-treatment monitoring (Objective 1) is $16,100 for year 1 and $10,400 for year 2, for a total of $26,500. The request for post-treatment monitoring (Objectives 2 and 3) is $27,020 for year 3 and $25,250 for year 4, totaling $52,270. Along with the amount to prepare a final report in year 4 of $8,850, the total requested budget is **$87,620** for the 4 years.

Literature Cited

Andren, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. Oikos. 71:355-366.

Anonymous. 2001. Proposed ten year federal/state/tribal/local partnership programs for restoration of Arizona/New Mexico urban interface and wildland forest areas. Proposal prepared for Western Governor’s Association.

Arizona Game and Fish Department. 1993. Review of the U.S. Forest Service strategy for managing northern goshawk habitat in the southwestern United States. Phoenix, Arizona, USA.

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.

Bowers, M. A., and S. F. Matter. 1997. Landscape ecology of mammals: relationships between density and patch size. Journal of Mammalogy. 78:999-1013.

Brown, D. E. 1984. Arizona's tree squirrels. Arizona Game and Fish Department, Phoenix, Arizona, USA.

Carey, A. B. 2000. Effects of new forest management strategies on squirrel populations. Ecological Applications 10:248-257.

Cooper, C. F. 1960. Changes in vegetation, structure and growth of Southwest pine forests since white settlement. Ecological Monographs 30:126-164.

Covington, W. W. 2000. Restoration of ecosystem health in southwestern forests. Comprehensive report submitted to USDI Bureau of Land Management. Ecological Restoration Institute, Northern Arizona University, Flagstaff, Arizona, USA.

, and M. M. Moore. 1994. Southwestern ponderosa forest structure and resource conditions: 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. Sackett, and M. R. Eagner. 1997. Restoration of ecosystem health and southwestern ponderosa pine forests. Journal of Forestry 95:23-29.

Dodd, N. L. 1999. Landscape-scale forest habitat relationships to tassel-eared squirrel population dynamics in northcentral Arizona: Research study plan 1999-2002. Arizona Game and Fish Department, Phoenix, Arizona, USA.

, and S. L. Adams. 1989. Integrating wildlife needs into national forest timber sale planning: a state agency perspective. Pages 131-140 *in* A. Tecle, W. W. Covington, and R. H. Hamre, technical coordinators. Proceedings of multiresource management of ponderosa pine forests. US Forest Service General Technical Report RM-185.

, S. S. Rosenstock, C. R. Miller, and R. E. Schweinsburg. 1998. Tassel-eared squirrel population dynamics in Arizona: index techniques and relationships to habitat condition. Arizona Game and Fish Department Technical Report 27, Phoenix, Arizona, USA.

, J. S. States, and S. S. Rosenstock. 2003. Tassel-eared squirrel population, habitat condition, and dietary relationships in northcentral Arizona. Journal of Wildlife Management. *In press*.

Edminster, C.B., and W. K. Olsen. 1996. Thinning as a tool for restoration and maintaining stand structure in stands of southwestern ponderosa pine. Pages 61-67. *In* Conference on adaptive ecosystem restoration and management: restoration of cordelleran conifer landscapes in North America. US Forest Service General Technical Report RM-GTR-278.

Farentinos, R. C. Observations on the ecology of the tassel-eared squirrel. Journal of Wildlife Management 36:1234-1239.

Fule, P. Z., W. W. Covington, and M. M. Moore. 1997. Determining reference conditions for ecosystem management of southwestern ponderosa pine forests. Ecological Applications 7:895-908.

Heidmann, L. J., and Z. J. Coronett. 1986. Effects of various regimes and ectomycorrhizal inoculations on field survival and growth of ponderosa pine container seedlings in Arizona. Tree Planters Notes 37:15-19.

International Association of Fish and Wildlife Agencies. 1996. The economic importance of hunting. Washington, D.C., USA.

Johnson, M. A. 1994. Changes in southwestern forests: stewardship implications. Journal of Forestry 92:16-19.

Karieva, P., and U. Wennergren. 1995. Connecting landscape patterns to ecosystem and population processes. Nature. 373:299-301.

Krohne, D. T. 1997. Dynamics of metapopulations of small mammals. Journal of Mammalogy. 78:1014-1026.

Lema, M. 2001. Dynamics of Abert squirrel populations: home range, seasonal movements, survivorship, habitat use, and sociality. Thesis, Northern Arizona University, Flagstaff, Arizona, USA.

Lidicker, W. Z., Jr. 1975. The role of dispersal in the demography of small mammals. Pages 103-128

in F. B. Golley, K. Petuswewicz, and L. Ryskowski, editors. Small mammals: their productivity and population dynamics. Cambridge University Press, New York, New York, USA.

MacArthur, R.H., and E. O. Wilson. 1967. The theory of island biogeography. Princeton University Press, Princeton.

Maser, C., and Z. Maser. 1988. Interactions among squirrels, mycorrhizal fungi, and coniferous forests in Oregon. Great Basin Naturalist 48:358-369.

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.

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.

Patton, D.R. 1992. Wildlife habitat relationships in forested ecosystems. Timber Press, Inc. Portland, Oregon, USA.

_____. 1984. A model to evaluate Abert squirrel habitat in uneven-aged ponderosa pine. Wildlife Society Bulletin. 12:408-413.

_____. 1975. Nest use and home range of three Abert squirrels as determined by radio tracking. US Forest Service Research Note RM-281.

_____., R.L. Wadleigh, and H.G. Hudak. 1985. The effects of timber harvest on the Kaibab squirrel. Journal of Wildlife Management. 49:14-19.

Pederson, J. C., R.C. Farentinos, and V.M. Littlefield. 1987. Effects of logging on habitat quality and feeding patterns of Abert squirrels. Great Basin Naturalist. 47:252-258.

_____., R.N. Haysenyager, and A.W. Hegen. 1976. Habitat requirements of the Abert squirrel (*Sciurus aberti navajo*) on the Monticello District, Manti-La Sal National Forest. Utah State Division Wildlife Resources Publication 76-9, Salt Lake City, Utah, USA.

Pollock, K.H. 1982. A capture-recapture design robust to unequal probability of capture. Journal of Wildlife Management. 46:752-757.

Pulliam, H.R. 1988. Sources, sinks, and population regulation. The American Naturalist. 132:652-661.

Reynolds, R. T., R. T. Graham, M. H. Reiser, R. L. Bassett, P. L. Kennedy, D. A. Boyce, Jr., G. Goodwin, R. Smith, and E. L. Fisher. 1992. Management recommendations for the northern goshawk in the southwestern United States. US Forest Service General Technical Report RM-217.

Simberloff, D. 1988. The contribution of population and community biology to conservation science. Annual Review of Ecology and Systematics. 19:473-511.

Southwest Forest Alliance. 1996. Forests Forever! A plan to restore ecological and economic integrity to the Southwest's National Forests and forest-dependent communities. Flagstaff, Arizona, USA.

States, J. S., and W. S. Gaud. 1997. Ecology of hypogeous fungi associated with ponderosa pine. I. Patterns of distribution and sporocarp production in some Arizona forests. Mycologia 89:712-721.

, and P. J. Wettstein. 1998. Food habits and evolutionary relationships of the tassel-eared squirrel (*Sciurus aberti*). Pages 185-194 *in*: M. A. Steele, J. F. Merritt, and D. A. Zegers, editors. Ecology and evolutionary biology of tree squirrels. Virginia Museum Natural History Special Publication 6.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management. 47:893-901.

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

. 2001. Kachina Village forest health project proposed action. Coconino National Forest Supervisor's Office, Flagstaff, Arizona, USA.

Vogt, K. A., R. L. Edmonds, and C. C. Grier. 1981. Biomass and nutrient concentrations of sporocarps produced by mycorrhyzal and decomposer fungi in *Abies amabilis* stands. Oecologia 50:170-175.

Wagner, M. R., W. M. Block, B. W. Geils, and K. F. Wenger. 2000. Restoration ecology: a new forest paradigm or another merit badge for foresters? Journal of Forestry 98:22-27.