Forest Plan Monitoring

and

Evaluation Report

Santa Fe National Forest

Fiscal Years 2006 and 2007

FOREST SUPERVISOR'S CERTIFICATION

The Santa Fe National Forest Plan (Forest Plan) was originally approved in July of 1987. This annual monitoring and evaluation report is based on the Monitoring Plan contained in Chapter 5 of the Forest Plan and the regulatory requirements in 36 CFR 219.11(f).

I have reviewed the annual Monitoring and Evaluation Report for the Santa Fe National Forest for fiscal years 2006 and 2007.

Amendments or revisions to the Forest Plan are not likely to be made as a result of this report. Instead, information from this report will be used in the planning and design of the Santa Fe Forest Planning process.

This Monitoring and Evaluation Report meets regulatory requirements in 36 CFR 219.11(f)) for completing an annual report.

May 30, 2008

DANIEL J. JIRON
Forest Supervisor

Date

EXECUTIVE SUMMARY

The Forest Plan Monitoring and Evaluation Report for fiscal years 2006 and 2007 is written to inform the Forest Supervisor and the public of information collected on the National Forest System lands and resources of the Santa Fe National Forest, as well as progress toward achieving the goals, objectives and desired future conditions as stated in the Santa Fe National Forest Plan. Table 1. FY 2006-2007 Monitoring Activities catalogues and summarizes the results of monitoring preformed on the Santa Fe National Forest in fiscal years 2006 and 2007. Chapter 5 of the Forest Plan, titled Monitoring Plan, is provided for comparison with the monitoring conducted in FY 2006-2007.

The FY 2006-2007 report also includes the following reports on project-specific monitoring conducted in the Santa Fe Municipal Watershed and Monument Canyon Research Natural Area.

- Santa Fe Watershed Fuels Reduction Project, Wildlife Monitoring Progress Report and Summary, March 2008

- Monument Canyon Forest Restoration Project: Final Report, June 2007

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ABBREVIATIONS, ACRONYMS AND INITIALS

BLM	Bureau of Land Management
BMP	Water quality best management practices
CCF	100 cubic feet
CFRP	Collaborative Forest Restoration Program
GIS	Geographic Information System
GPS	Global Positioning System
INFRA	Infrastructure Database for integrated inventory of and financial data for its constructed features, including buildings, dams, bridges, water systems, roads, trails, developed recreation, range facilities, administrative sites, heritage sites, and other improvements.
MIS	Management Indicator Species
NEPA	National Environmental Policy Act
NRIS	Natural Resource Information System
RD	Ranger District Office
RO	Southwestern Regional Office
SHPO	State Historic Preservation Officer
SO	Forest Supervisor’s Office
TAG	Santa Fe Watershed Technical Advisory Group comprised of independent scientists and researchers
TES	Endangered Species Act listed/proposed Threatened & Endangered, and Forest Service Sensitive wildlife and plant species
TIM	Timber Information Manager
WFRP	Wildlife, Fish, and Rare Plants

SECTION 1 – PURPOSE AND RELEVANCE

The purpose of this annual monitoring report is to inform the Forest Supervisor and the public of the progress toward achieving the desired conditions, goals, objectives, and standards and guidelines of the Santa Fe National Forest Plan. Monitoring data gathered at the Forest and Ranger District levels is analyzed to determine whether management actions and practices are attaining or making progress toward attainment of Forest desired conditions, goals, and objectives, and if monitoring measures and methods are useful in making these determinations.

PROGRESS TOWARD DESIRED CONDITIONS

In FY2006-2007 the Santa Fe National Forest continued to make progress toward achieving desired conditions in the following areas:

	FY 2006	FY 2007
Access Management		
Roads maintained	420 mi.	525 mi.
Roads decommissioned	10 mi.	18 mi.
Fire and Fuels		
WUI (Wildland Urban Interface) acres treated	11,432 ac.	4,859 ac.
Non-WUI acres treated	1,779 ac.	10,717 ac.
Heritage Resources		
New heritage sites inventoried	146 sites	56 sites
Acres surveyed	1,905 ac.	2,849 ac.
NRHP listed and eligible sites managed	21 sites	22 sites
Acres managed	486,602	489,531
Range Management		
New grazing allotment management plans	6 AMPs	18 AMPs
Allotments managed under AMP[1]	73 allots	73 allots
Range vegetation improved	738 ac.	12,440 ac.
Invasive plants (noxious weeds) treated	616 ac.	121 ac.
Recreation		
Recreation sites maintained to standard	41	41
Campgrounds reconstructed	0	2
Trails maintained to standard	108 miles	42 miles
Wilderness Education Plan (4 wilderness areas)	1	0

[1] 73 active allots, 3 vacant allots, 5 closed allots, 4 horse & burro allots

	FY 2006	FY 2007
Soil and Water		
Watershed conditions improved	850 ac.	639 ac.
Vegetation		
Forest vegetation improved	601 ac.	1,800 ac.
Special forest products (latillas, vigas, posts, poles)	4,100 ccf	3,761 ccf
Firewood (charge and free use)	21,785 cords	24,400 cords
Reforestation	0	190 ac.
Christmas tree permits sold	4,764	5,235
Wildlife and Fish		
Terrestrial habitat improved	1,870 ac.	2,009 ac.
Aquatic/riparian (stream) habitat improved	22 mi.	7 mi.

FOREST PLAN BACKGROUND & AMENDMENTS

The Forest Plan and Final Environmental Impact Statement were first published as drafts in 1982, as finals in 1983, and then were withdrawn in order to address appeal issues regarding timber harvesting and wild and scenic rivers. Once appeal issues were resolved, these documents were approved and published in final form in July of 1987.

Preliminary Forest staff recommendations for updating the Forest Plan were developed in 1996-98 and are contained in the fiscal year1999 Monitoring & Evaluation Report. Those recommendations are still valid, although additional amendments have been made or may be necessary to incorporate evolving agency policies and direction. Following is the list of Forest Plan amendments:

- Amendment #1- Changed timber sale schedule (8/88)
- Amendment #2- Added management direction for recommended Wild and Scenic Rivers (1/89)
- Amendment #3- Changed timber sale schedule (5/89)
- Amendment #4- Added Pajarito Peak electronic site (2/90)
- Amendment #5- Adjusted management area boundaries between area "C" and "Q" (10/92)
- Amendment #6- Incorporated Region-wide amendment for managing Mexican spotted owl habitat, northern goshawk habitat, old growth and livestock grazing (5/96)
- Amendment #7- Allowed deviation from visual quality requirements for El Cajate Mine (12/96)
- Amendment #8- Modified Management Area J direction for Gallinas Municipal Watershed (10/97)
- Amendment #9- Added new management area and associated direction for managing the East Fork of Jemez Wild and Scenic River corridor (08/02)
- Amendment #10- Added new management area and associated direction for managing the Jemez National Recreation Area (01/03)

- Amendment #11- Pecos Wild and Scenic River: new standards, guidelines, Management Plan (07/03)
- Amendment #12- Managing Special Species Habitat (12/04)

Forest Plan Revision Schedule

Revision of the Forest Plan will proceed according to the National Forest System Land Management Planning Final Rule, commonly referred to as the 2008 Planning Rule. The Final Rule, 36 CFR 219, Federal Register/ Vol. 73, No. 77/Monday, April 21, 2008/ Rules and Regulations, can be accessed on-line at:
http://www.fs.fed.us/emc/nfma/includes/planning_rule/08_planning_rule.pdf

Highlights of the Final Rule and responses to Frequently Asked Questions about the Final Rule can be accessed on-line at:
http://www.fs.fed.us/emc/nfma/2008_planning_rule.html

The Santa Fe National Forest is currently scheduled to initiate Revision in Fiscal Year 2010.

Section 2 – Data Collection and Analysis

Monitoring for the Santa Fe National Forest occurs for different purposes and at different scales. It is important for the reader to understand that many different methods of data collection occur, because this has a direct effect on how that information is conveyed, analyzed, and what it can tell us about Forest land and resource conditions.

Types of Monitoring & Data Collection

There are four primary types of monitoring and data collection that are considered when monitoring under the Forest Plan. Often times, all four types of data are collected to help us plan and understand the impacts of management actions for a specific resource. The four monitoring types include the following:

Implementation Monitoring: Considers information and measurements to determine if projects and plans are implemented as designed. Most implementation monitoring occurs at the project level, and includes general information about the final results of the project.

Effectiveness Monitoring: Tells us whether or not plans, projects, or activities have results that help meet stated goals and objectives. Effectiveness monitoring is one of the key principles behind adaptive management, and is focused on the 'on-the-ground' result of a specific action. Effectiveness monitoring is the primary monitoring type used in this report.

Validation Monitoring: Helps determine if the initial data, assumptions, and parameters used in the development of the plan are correct, or if there is a better way to meet established Goals and Objectives and Desired Conditions.

Resource Condition Monitoring: Provides information that assists in the determination of existing social, ecological, and economic resource conditions and trends.

In addition to the four types of data collected, there are also two scales that can be distinguished at which data collection occurs.

Project-level Monitoring: Much of the monitoring on for the Santa Fe National Forest completed is specifically focused on project implementation. This type of monitoring often focuses on answering questions such as,

- "Has the project been completed to established standards?"
- "Have the objectives of the project been met?"
- "Was the project effective toward meeting established resource and management goals?"
- "What was the project cost?"

Much of the monitoring data is collected on a project-by-project basis. As a result, it can be difficult to extrapolate to the Forest Plan level and answer questions regarding progress toward achievement of Forest Plan desired conditions and the Forest's contribution toward achieving applicable outcomes of the Forest Service national strategic plan (36 CFR 219.12(f)(2)(i)(ii)).

Resource Monitoring: Resource monitoring is not necessarily project-based and commonly occurs at a scale much larger than the project level. However, it may include data collection in an area as small as a short stream segment to data collection for a specific resource that occurs at a landscape or watershed scale. Inventories are a common type of resource monitoring.

These monitoring types and scales are all essential for us to understand the impacts of management activities, projects, and actions taken. Furthermore, they are essential for providing the basic understandings that enable us to work with the public to address management concerns and progress toward the agency's mission of social, economic, and ecological sustainability.

INVENTORIES AND ASSESSMENTS

Mid-Scale Existing Vegetation Mapping Project

The Mid-Scale Existing Vegetation Mapping Project was initiated by the USDA Forest Service Southwestern Region, Regional Inventory and Monitoring Program in 2002 for the primary purpose of supporting Forest Plan Revision as well as on-the-ground, project-level land and resource planning and management activities.

The Mid-scale Existing Vegetation Mapping Project will produce a spatially continuous and consistent corporate GIS layer and tabular database, consistent with Agency Existing Vegetation Mapping Standards and Protocols. Specifically, the Project will generate GIS data and layers necessary for the production of maps that depict the extent and spatial distribution of existing vegetation, in terms of:

- Vegetation Cover Types:

    - Lifeform (e.g. tree or shrub); and
    - Dominant species
- Canopy Cover:
    - Tree and shrub canopy cover categories
- Vegetation Structure (size class)

The Project consists of several discrete steps, including field data collection, and desk-top modeling exercises. The collection of “training” and accuracy assessment data was initiated on the Santa Fe National Forest in 2006 and will conclude in 2008. In subsequent years, the “training” data set will be used to generate a model of existing vegetation, and the accuracy assessment data will be used to evaluate and validate the model. The Region and Forest anticipate delivery of GIS data and layers, reference data, maps, and an accuracy assessment by 2010, prior to the initiation of Forest Plan Revision.

Geographical Information Systems

During fiscal years 2006 and 2007, the Santa Fe National Forest Resource Information Group continued to build and update the Geographic Information System (GIS) databases and associated tabular databases for resource planning and analysis. GIS data for heritage resources, vegetation treatments, invasive species, fire history, fire management, roads, trails, dispersed and developed recreation, range allotments/pastures and improvements, sensitive species, lands acquisitions and boundary adjustments were generally updated on a project-by-project basis or periodically.

For each of these layers, the Forest is continuously working to reduce error in its GIS data by reviewing check plots and updating the data accordingly for increased precision and accuracy. Additionally, the Forest has conformed our data to meet regional and national data dictionary standardization.

The IWeb INFRA database continued to be updated and linked with existing GIS databases including roads, trails, developed recreation sites, administrative sites, and range features. Inventory continued on deferred maintenance inspections and costs for those items listed in the previous sentence plus buildings, dams, water, waste water, bridges, major culverts, and archaeological sites. The Forest also migrated the Natural Resources Information System (NRIS) invasive species spatial and tabular data to the National Data Center.

The Resource Information Group has also provided trainings in GIS and GPS to field users to assist with streamlining inventory and monitoring processes in the field.

Appendix 3 provides a current list of GIS layers.

SECTION 3 – FY 2006-2007 MONITORING

EVALUATION OF MONITORING RESULTS

This section includes a compilation of responses by Forest staff and resource specialists to questions formulated to find out what has been learned from monitoring. Their comments will help improve management of Forest lands and resources and the Forest Plan monitoring program.

General Questions pertinent to Forest Plan monitoring

The following questions were asked of Forest and Ranger District program managers and resource specialist.

1. What did you learn from monitoring your resource area(s)?
2. What changes have you made in managing your resource area(s) as a result of monitoring?
3. What methods and techniques have you found to be most effective for monitoring your resource area(s)?
4. What progress have you made toward achieving desired conditions in your resource area(s)?
5. What methods and techniques have you found to be most effective for monitoring your resource area(s)?
6. What methods and techniques have you changed or improved as a result of monitoring your resource area(s)?
7. What monitoring methods and techniques would you like to add, change, improve or discontinue?
8. Do you have any specific research needs related to monitoring?
9. What public involvement in monitoring and evaluation worked or didn't work?
10. How can we better inform and involve the public about monitoring and evaluation?

1. What did you learn from monitoring your resource area(s)?

- Monitoring water developments in areas with cattle grazing validated that in some cases fencing around the developments was unnecessary to protect water quality (Range – Sierra Mosca)
- When there is no fuel reduction large-scale fires are more likely and can be costly. (Range/Fire)
- Monitoring after Molina & Borrego Fires showed positive affects on range (grass recovery) & watershed (long-term stream stability) conditions when livestock were temporarily deferred (June-July for first 2 years post-fire). (Range)
- An increase in habitat fragmentation is occurring as a result of landowner turnover and changes to historical land uses (i.e., permittees who ranch to land owners with vacation homes). (Range) See Alice McSweeny & Carol Raish (Rocky Mountain Research Station) – studies on this topic
- Monitoring is an important and necessary tool, especially for areas used under special-use permits (i.e., during movie filming). Pre-inspection and establishing a baseline is needed as part of monitoring these resources over the course of the permit. (Rec)

- The predominant types of recreation at campsites changes over time (i.e., overnight hikers to day hikers at Puerto Nambe). (Rec)
- Site stewards are an effective presence for monitoring against potential vandalisms at heritage sites. (Arch)
- Increased use of OHVs can have negative effects on wildlife habitat (i.e., destroys forage base, destroys previously undisturbed habitat). (Wildlife)
- Modifying motor vehicle use on roads (i.e., closing to OHVs, creating non-motorized areas - El Invierno) resulted in better use of wildlife habitat over time. (Wildlife)
- Thinning and burning treatments (Santa Fe Watershed) did not have a negative effect on wildlife and had a positive effect on many species (see RMRS 2006 report on SFWS). (Wildlife)
- Mowing sage-brush can result in an increase in cheat grass (i.e., can have impacts on fire regime and soil matrix). Season of mowing, range condition, or community vegetation composition might also have impacts (i.e., Cuba Mesa mowed in fall and little crested wheat grass and cheat grass enhanced; Lagunas Simon mowed in winter and had crested wheat grass but cheat grass not enhanced).
- End products need to be specified to have flexibility so that jobs can be done without interference from conflicting contractual and prescriptive requirements. (Veg)
- DBH cutting restrictions (from Goshawk and MSO guidelines, NEPA and public pressure to preserve old-growth and snags) has resulted in poor age-class distribution of trees (i.e., skewed towards large trees).
- Monitoring may show that current practices (meeting targets as opposed to meeting objectives) may not be effective land management.
- Mechanical removal of musk thistle reduces populations. (Range)
- Application of fire to carefully thin stands (i.e., Goshawk guidelines) can have negative impacts on silviculture achievements (caused by flame lengths, ambient heat, etc.) for various reasons (i.e., tight crown spacing) (FR18). Objectives of silviculture can be negated by burning that is not specifically planned to accommodate other resources. (Fire/Fuels)
- It is possible to manage for different resources (i.e., Goshawk and fire management) even though they seem to have conflicting management guidelines (i.e., clumped vs. open canopies).
- Implementation of mitigation measures and water quality BMPs assures that effects to soil and watershed are minimal. (Soil and Water)
- Monitoring is crucial to hit targets for adaptive management of resources or areas.
- Range and wildlife water developments are deteriorating and require funding and manpower for maintenance and reconstruction. More frequent monitoring is necessary during times of uncharacteristic weather patterns which can accelerate the deterioration of earthen dams.
- Monitoring to meet stubble height guidelines using force account with the range improvement task force is still being used to determine whether stubble height guidelines are met.
- Mechanical treatment of Russian Knapweed is not effective (rhizomes).
- Film production can not be allowed in sensitive areas (i.e., wildlife, water) because filming has an inherent need for flexibility and their requirements and needs are constantly changing (Las Conchas film site).
- Construction costs for film production should include funding for multiple years of post-filming revegetation and reclamation rehab projects.
- More cost-recovery training is needed because line is not trained and cost-recovery is not permitted without training.

- Film production needs an on-site monitor (i.e., resource and public relations) at all times. In addition, a liaison at the ranger district office is needed during all hours of film production to help process requests from the on-site monitor(s).
- For special use activities, safety requirements need to be stated prior to granting of permits and mechanisms need to be in place to ensure follow through.
- Individual assessment is needed to design the monitoring of each special project (i.e., film production) based on size of project, number of people involved, etc.
- More coordination between planning and implementation is needed for timber (i.e., removal of insect infested trees), fuels, and recreation (i.e., camp ground construction) contracts.
- Monitoring has helped to identify areas with problems and areas that have improved (FR 376, Guadalupe corridor). (Respect the Rio)
- Monitoring with adaptive management has helped areas recover quicker after long-term drought. (Range)

2. What changes have you made in managing your resource area(s) as a result of monitoring?

- Monitoring reports are used to adaptively manage range resources (i.e., timing, duration, intensity) (Range)
- Decisions for areas that are managed for multiple resources (i.e., silviculture and fire) need to be integrated so that goals and objectives of both objectives are accommodated simultaneously. (see fire/silviculture example Q1)
- Trail maintenance projects are based on monitoring (i.e., conditions of dead fall, erosion problems, etc.) (Rec)
- Support for thinning and burning to enhance wildlife habitat and diversity. (Wildlife)
- Time, funding, and personnel needed for monitoring are being usurped by office work (i.e., AgLearn, Empower HR, etc.).
- Incorporating reclamation that has proven effective into future reclamation plans. (Min & Geol)
- Reduced total cattle numbers during drought years, changed distribution strategies, changed grazing management on certain allotments based on site-specific carrying capacities (i.e., moved from deferred rotation to rest rotation). (Range)
- Monitoring resulted in abolishing an MSO PAC after it was determined that there were located in an unfavorable habitat. (Wildlife)
- Monitoring certain allotments has shown a downward trend in range condition and therefore management is being altered to a deferred rotation and/or rest rotation strategy.
- Monitoring on Mesa Poleo I has shown that more hiding cover is needed for wildlife. This change was reflected in managing the remaining portion of Mesa Poleo I and all of Mesa Poleo II.
- Resource management (i.e., timing, duration, intensity) undergo adaptive management based on monitoring reports (Range)
- Decisions for areas that are managed for multiple resources (i.e., silviculture and fire) need to be integrated to accommodate the goals and objectives of both resources simultaneously. (see fire/silviculture example Q1)
- Utilized adaptive management more in grazing strategies. (Range)
- Water earthen dams were maintained with Bentonite after monitoring found them to be impaired. (Wildlife and Range)

3. **Does monitoring show your resource area(s) to be moving toward the desired conditions?**

- Yes (Range, Heritage, Wildlife, Recreation)
- Proper Functioning Condition surveys done on riparian areas show they are being managed properly and moving towards desired condition. (Range)
- System trails maintenance is not moving towards desired condition because the districts do not have time or money to clear trails. (Rec).
- In some wilderness campsites monitoring can be enough for the area to move towards the desired condition. (Rec)
- Overall trend has shown that adaptive management of range resources has been effective over the past 5 years. (Range)
- The querencias (continuous use grazing) management strategy is not helping meet desired standards and guidelines of forage use.
- Informal monitoring of road closure and decommissioning, forest health, and prescribed fire projects indicates these areas are moving towards desired future conditions.
- Monitoring water developments shows that they are functioning as an important wildlife resource (i.e., presence of animal tracks). (Wildlife)
- Development of upland water sources has led to a better distribution of cattle and less cattle dependence of riparian areas. (Range)

4. **What progress have you made toward achieving desired conditions in your resource area(s)?**

- Annual monitoring has provided information to make effective decisions and adjustments of livestock numbers and seasons of use based on past, current, and predicted climate conditions and range conditions. (Range)
- Wildlife habitat acres have been improved through thinning, burning, and road closures.
- Site stewards and signing has added enforcement, helping to protect existing heritage sites. (Heritage)
- Recreation sites are steadily maintained despite increased use. (Rec)
- Rough-scale ocular monitoring of fire treatments showed them to be very effective.
- Through the Allotment Management Plan for Capulin Allotment, we have seen indications of a healthier riparian area (i.e., various stages of regeneration of cottonwoods). (Range)
- Thinning, use of heavy equipment and prescribed fires are helping us meet management goals for WUIs and forest health projects.
- Cattle exclosures on riparian areas have helped them move towards desired conditions (i.e., increased willow regeneration and beaver rehabilitation).
- Buck and pole fences, education (contact ranger program), and restoration activities have helped move towards the desired condition (NMED impaired streams) of reducing sediments and controlling temperature in the streams (i.e., Rio Guadalupe, Rio Cebolla, Jemez River, East Fork Jemez River, and Rio de las Vacas). (Respect the Rio)
- Monitoring of Cebolla/San Antonio allotments has resulted in a change in management (combined herds and increased deferment) which has helped it move towards desired conditions. (Range)
- Monitoring of water earthen dams/trick tanks found them to be impaired (i.e., filled with silt, inadequate Bentonite volume, or not working), resulting in grant applications

(SIKES and Rocky Mountain Elk Foundation) to obtain funding for maintenance and repair. (Wildlife and Range)

5. **What methods and techniques have you found to be most effective for monitoring your resource area(s)?**

- Range/Readiness monitoring allows for the assessment of range resources and implementation of management decisions identified in AOIs or NEPA decisions. (Range)
- Pre- and post-event monitoring is important for areas used heavily for special events (i.e., films). (Rec)
- Cooperation of monitoring mining and mineral activities by other agencies (i.e., BLM and State). Mining operators tend to respond better to these other agencies than to the forest service, perhaps because of their authority; State can shut-down operations. (Geology)
- PFC, stubble heights, and ocular utilization estimates are rapid and efficient assessments that give decent snapshots of an area's desired condition. (Range)
- Range readiness evaluation timing is dependent upon the timing of the permit; early entry dates or late with high elevation. (Range)
- On the ground field time is the most effective way to monitor resource areas.
- Quantitative measurements are more effective than qualitative.
- Education has been important; the public is becoming more aware of reasons for agency management decisions through the Respect the Rio program.
- Photo-point monitoring is effective at monitoring and documenting violations (incident reports and violations) and directing management actions (El Puente Blanco).
- Monitoring of restoration activities (i.e., vegetation planting, adding large woody debris) such as cross-sections and stream profiles have helped improve stream quality and move away from the NMED impaired classification.
- Stream survey data is needed to assess stream conditions and develop actions to move streams towards desired conditions.
- Photo monitoring and on-site observations of pellet, scat, and tracks helps monitor wildlife use. (Wildlife)
- Taped call-backs can be efficient to monitor wildlife occupancy (i.e., MSO PACs). (Wildlife)

6. **What methods and techniques have you changed or improved as a result of monitoring your resource area(s)?**

- Cost recovery is now a part of the process for special use areas (i.e., film). (Rec)
- Developed adapted monitoring protocols (less expensive equipment) for use with the public through the CFRP program.
- Management directions need to be more specific for activities involved in film production (i.e., filming accommodated but construction is not).
- Adding a new position (targeted at recreation, education and enforcement) has helped add a new enforcement dimension to monitor dispersed recreation areas along the river.

7. **What monitoring methods and techniques would you like to add, change, improve or discontinue?**

- Change or improvement of the interface between handheld/field electronics (PDA/IPAQ) and office computers is needed to make electronic records efficient. (Range, Heritage)

- Remote cameras and GPS collaring for wildlife is effective and can provide essential and new information, but is cost prohibitive for the agency. (Wildlife)
- Frequency based monitoring would be an effective addition to obtaining a more complete picture in monitoring range conditions. (Range)
- New monitoring techniques might not be as effective as discontinued techniques (P-U). (Range)
- Fuels need more field techniques (i.e., fire range condition class) to help monitor site conditions. (Fire/Fuels)
- Historically, monitoring was more quantitative whereas now it is more qualitative. Quantitative on-site measurements might help with public response and should be made a priority.
- Current range monitoring practices are primarily quantitative but more qualitative monitoring can be useful to describe a broader range of characteristics. (Range)
- Volunteers are an important resource to monitoring trails and areas that staff doesn't have time to visit. (Rec)
- Tools exist that allow for effective monitoring of fire fuels and conditions, but more skills (training), time, and less personnel turnover is needed to have the funding and manpower to do this.
- Effectiveness monitoring is an important component to land management and needs to be budgeted for (time and funding) and incorporated into goals in addition to meeting targets.
- More staff would increase the capacity of the volunteer work, thereby increasing the monitoring that could be done on the district.
- Respect the Rio and its contact ranger program has been extremely effective but is currently funded by grants that will end in 2011. Monitoring activities associated with the program are valuable and continued should continue to be funded.
- Funding is needed to increase staff (wildlife technicians) to monitor past occupied sites of TES species. (Wildlife)
- Law enforcement/Security (not necessarily Forest Service) needs to monitor the crew through the entire film production process (i.e., through clean-up).

8. Do you have any specific research needs related to monitoring?

- More species and site-specific research on newly listed sensitive species is needed because very little information is known about them. (Wildlife)
- Long-term plots are needed to monitor the effects of mastication on soil conditions and vegetation response. In addition, plots that help differentiate the effects of fire and mastication and the combined effects of these treatments are needed. (Fire)
- Research on different types of burns (pile vs. broadcast vs. chip) is needed to determine their effects on noxious weeds.
- Need more efficient ways to conduct site-specific monitoring (quantitative) in the field.
- Need to be able to identify and prioritize the relative importance of maintenance areas within districts and across the entire forest.
- Need mid-level water quality monitoring (less strict and less time intensive than EPA standards) that can be conducted at regular, more frequent time intervals and for more areas is needed so that site-specific data can be obtained.
- Migratory bird surveys would help us meet migratory bird act requirements and monitor TES species.

- Establishing long-term data sets for prescribed fires (i.e., stand conditions, fuel characteristics, and effectiveness of maintenance burns) in WUI areas would help monitor their condition and validate management objectives.
- Collaborative research on water quality with the Surface Water Quality Bureau in the New Mexico Environment Department can contribute to a greater breadth of data.
- Bat mist nets and ANABATS to monitor visitation to water tanks and other habitat areas would be effective. (Wildlife)
- Camera sensory traps to monitor wildlife traffic around hot spots would be effective. (Wildlife)

9. What public involvement in monitoring and evaluation worked or didn't work?

- Collaborative monitoring with permittees is frequently employed and effective. (Range)
- Held a monitoring workshop for permittees at Ghost Ranch Conference Center in collaboration with Game and Fish. (Range)
- Site stewards for heritage sites are an effective presence and provide more consistent monitoring that would otherwise not be completed. (Heritage)
- Partnerships with Forest Guild (YCC) to monitor fires and fuels (hand or mechanical thinning), weeds, and range utilization have been effective and also an important public education tool. (Fire, Range)
- Range permittees are taking an increasingly larger role in monitoring (i.e., stubble height) their allotments and have taken these skills to also monitor their own private lands. (Range)
- Involved communities (Deer Lake) can be willing to spearhead monitoring projects in their areas, especially when there is a history of successful relationships between the public and the Forest Service.
- Game & Fish monitoring of wildlife populations on the forest is effective but limited to species with hunting interest. (Wildlife)
- CDT volunteer groups are important at monitoring and maintaining trails. (Rec – ask David Allen)
- Effective relationship to collaborate with OSE to monitor water impoundments.
- Casual reports from recreationists (sportsmen/hunters) are helpful in monitoring resource damage and site conditions.
- University researchers often utilize and monitor the forest through research activities but do not necessarily convey that information to the Forest Service.
- A greater effort needs to be made to collaborate with the other agencies (i.e., State) to document monitoring results from clean-up efforts (i.e., Meth lab dumping clean-up).
- Volunteers are a valuable resource for helping to maintain trails and identify problem areas but can be time consuming to manage. (Rec)
- Collaborative Forest Restoration Program multi-party monitoring work-days with public and stakeholder participation can be an effective and large work force.
- CFRP projects with Coronado High School to quantitatively monitor road closure projects and forest health projects have been an effective resource.
- Range meets with permittees several times a year to participate with them in active monitoring of status of range readiness, stubble height, and year end monitoring.
- Tips from the public can be helpful but need to be validated or from reliable sources. (Wildlife)

10. How can we better inform and involve the public about monitoring and evaluation?

- Increasing public involvement in monitoring in addition to showing monitoring results has increased understanding and acceptance of management strategies by permittees. (Range)
- Hands-on involvement that gives the public a large role will empower them and give them responsibility for the process.
- Public education to inform the public of the complexity of the process will be a valuable tool.
- The public has many questions about Forest Service activities that are currently primarily addressed through informal activities. More formal presentations or questions and answer sessions would help keep the public informed on Forest Service activities. However, public meetings and open houses are poorly attended because of their misconception that by not attending they are sending a message that they do not support the activity.
- On-site presence of Forest Service employees and a consistency in their monitoring and message to the public is an important educational tool.

TABLE 1. FY 2006 –2007 MONITORING ACTIVITIES

The following list of resource-specific questions was used in the development of Table 1. Not all resource areas had monitoring activities responsive to the questions. Unless specifically noted, monitoring activities apply to both FY2006 and FY2007.

1. **Air Quality**
   - Was air quality of the Class I air sheds being maintained in FY 2006-07?
2. **Fire-Fuels**
   - Are fuel treatments (mechanical and burning) effective?
   - How many acres of hazardous fuels reduction activities within the Wildland-Urban Interface and other high risk areas were accomplished in FY 2006-07?
   - How many acres of wildland fire use were used to mimic natural processes, maintain/improve vegetative conditions, and/or restore natural processes and functions to ecosystems in FY 2006-07?
3. **Forestry**
   - How many acres of timber management (thinnings, harvest, etc) were accomplished in FY 2006-07?
   - How many acres of reforestation occurred in FY 2006 and are harvested lands being adequately restocked within five years?
   - Are forestry practices maintaining or restoring natural forest types, and encouraging healthier, more resilient and sustainable forest types?
   - How many acres of vegetative communities were treated to move them towards their desired condition in FY 2006-07?
4. **Heritage**
   - How many acres of surveys and clearances were accomplished in FY 2006-07?
   - Are project avoidance or mitigation measures being followed and effective at protecting heritage resources?
   - Are heritage resources being affected in non-project areas and if so, for what reasons?
5. **Insect & Disease**
   - How many acres of survey for insect and disease infestations were accomplished in FY 2006-07?
   - Are insect and disease populations compatible with objectives for restoring or maintaining healthy forest conditions?
6. **Lands**
   - How many right-of-way easements were acquired in FY 2006-07?
   - Were non-recreation commercial, utility and other land use permits/authorizations in compliance with Forest Plan and agency direction in FY 2006-07?
7. **Minerals**
   - How many and of what kind of mining activities and operations were active on the Forest in FY 2006-07?

- o Were all mining operations in compliance with their plans of operation?
- o Are minerals and energy (oil and gas) exploration and development project mitigation measures and lease stipulations effective and being followed?
- o Where applicable, are reclamation plans for staged reclamation and completed mining operations being met?

8. Recreation

- o Did potable drinking water sources provided by the Forest meet water quality standards in FY 2006-07?
- o Are Forest recreation sites and facilities, inc. trails, meeting health, safety, accessibility, and maintenance requirements and achieving resource / social objectives?
- o How many illegal motorized entries into wilderness areas occurred in FY 2006-07?
- o How many miles of trails were maintained to standard in FY 2006-07?

9. Range

How many acres of noxious or non-native invasive species were inventoried and how many acres were treated in FY 2006-07?
How many allotments / acres were administered in compliance with AMPs in FY 2006-07?
How many allotments / acres were put under new AMPs in FY 2006-07?

10. Soil & Water

To what extent did Forest management activities affect water quality / quantity, and aquatic, riparian, and wetland ecosystems in FY 2006-07?
How many miles of stream aquatic / riparian treatments, including the addition woody debris, were accomplished in FY 2006-07?
Are project mitigation measures, inc. BMPs being followed and effective at protecting soil / water resources?
Are the effects of Forest management, including prescriptions, resulting in significant changes in land productivity?

11. Wildlife

How many acres are providing for the conservation of and moving toward desired habitat conditions for:

- o FS sensitive species?
- o T&E species?
- o MIS?
- o neo-tropical migratory birds?

12. Volunteer Programs

- o How many and what kinds of volunteer programs took place on the Forest in FY 2006.

13. Facilities

- o Were Forest administrative facilities maintained to appropriate health and safety standards in FY 2006-07?
- o How many miles of road have been closed or decommissioned? Are decommissionings effective
- o Are closures and decommissioning effective in preventing motorized access?

14. Law Enforcement

- o How many and what kinds of illegal activities cases were handled in FY 2006.

TABLE 1. FY 2006 –2007 MONITORING ACTIVITIES

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Access Management				
Road closure & decommissioning	Effectiveness of road decommissioning for spur of FR 264	Cuba	RD Fisheries program	Project-based
Road condition	Road sign monitoring and inventory	Cuba	RD, Road files	Annually
Road condition	Assess condition of Level 2 and 3 roads (FRs 113, 636, 263, 18, 83, 86, 92, 375,324, 223, and 85)	Pecos-Las Vegas	RD and SO Files	Annually (list changes)

Air Quality & Climate				
Class I air quality	Air quality monitoring in the San Pedro Parks Wilderness	Coyote, Cuba	http://vista.cira.colostate.edu/views/Web/Sitebrowser/Sitebrowser.aspx?SiteID=34	Weekly
Class I air quality	Air quality monitoring in the Pecos Wilderness	Española, Pecos-Las Vegas	http://vista.cira.colostate.edu/views/Web/Sitebrowser/Sitebrowser.aspx?SiteID=35	Weekly
Particulate matter	Santa Fe Watershed baseline monitoring (pm 2.5)	Santa Fe watershed	NM Environment Dept	Fall / Winter, & during Rx burning
Prescribed burn air quality	Smoke concentration compliance monitoring	Forest-wide per project	RD Fire project files	Project-based
Climate	Climate monitoring at 8 Zone Remote Automated Weather Stations (RAWS) – collects temperature, precipitation, relative humidity, winds, and fuel moistures	Zone-wide (BIA, State, FS, & NPS lands)	Fire and Aviation Management database	Daily 24/7
Particulate Matter	Reynolds Bldg, Santa Fe, baseline air quality monitoring (pm 2.5)	Santa Fe / Canyon Road	NM Environment Dept	Daily 24/7
Precipitation	Precipitation monitoring	Coyote	RD files	Daily 24/7
Precipitation	SNOTEL snow pack measurement	Cuba, Pecos-Las Vegas	http://www.wcc.nrcs.usda.gov/snotel/snotel.pl?sitenum=922&state=nm	Daily 24/7
Precipitation	Measuring snow pack; water content	Española	NRCS: Lakewood, CO and Albuquerque offices	Winter months per USGS guidelines

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Fire & Fuels				
Fire Closures / Restrictions	Fire closure compliance monitoring	Forest-wide	SO, Fire files and closure orders	Depends on compliance w/ closure orders
Fire research / fuels monitoring	CFRP thinning (Monument Canyon)	Jemez	University of Arizona, Tucson	Project-based
Fire research / fuels monitoring	Fire surrogate plots implementation monitoring (Virgin and Tusas)	Jemez, Cuba	Andy Vigil	Project-based
Fuel condition assessments	Fuel moistures (dead and live)	Forest-wide	SO and RO, Fire files	Seasonally, select ed locations
Fuel condition assessments	Fuels moisture sampling (part of RAWS station)	Forest-wide	SO, Fire files	Daily during fire season
Fuel condition assessments	Data collection on Fire Regime Condition Class on a project level basis; Jemez – CFRP NAU Ecological Restoration Institute data collection (203 acres)	Forest-wide	SO project files	Project-based
Fuel condition assessments	San Diego & Stable Prescribe burn fuel moistures (dead and live)	Jemez	SO and RO, Fire files	Project based
Fuel condition assessments	RAWS sampling (temp, RH, wind speed/direction, fuel moistures)	Coyote, Cuba & Jemez	RD, Fire files	Daily during fire season
Fuel condition assessments	Fuels moisture sampling for fire severity funding and prior to Prescribed burning for Gallina and Mesa Alta	Coyote	RO, Fire files	Project-based
Fuels monitoring	Jemez Ranger District fuels moisture sample collections to justify Fire Severity funding (2006)	Jemez, Cuba	RD Fire files	Twice/week different sites Mar - Oct
Fuels treatment	Acres treated – measure for both mechanical and prescribed burn treatments and according to WUI or non-WUI areas (2006)	Forest-wide, Sylvia V.	NFPORS	Annually
Fuels treatment	Acres treated – measure for both mechanical and prescribed burn treatments and according to WUI or non-WUI areas (2007)	Forest-wide, Sylvia V.	NFPORS	Annually
Fuels treatment	Mesa Poleo, 91 acres pre-commercial thinning (SPFH)	Coyote	FACTS, RO Forest Management files	Project-based
Fuels treatment	Implementation monitoring for Gallina WUI Phase I (200 acres burned, 150 acres mechanical)	Coyote	RD, Fire files; NFPORS	Project-based

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Fire & Fuels (cont.)				
Fuels Treatment	2007 - Chaparral, 130 acres thinned and slash lopped/scattered	Cuba	FACTS, RO, Forest Management files	Project-based
Fuels treatment	FR 531 mechanical fuel break (90 acres)	Cuba	RD-Fuels files	Project-based
Fuels treatment	Project implementation monitoring for Chaparral WUI prescribe burn. South Ojitos	Cuba	RD-Fuels files	Project-based
Fuels treatment	Force account thinning 50 acres in the Chaparral WUI (Ranch Bales-Water Tank)	Cuba	RD-Fuels files	Project-based
Fuels treatment	Implementation monitoring for Chaparral WUI prescribed burn and mechanical treatment project (Middle Fork, Matt Reidy & O'Neill, – 1,500 acres)	Cuba	RD, Fire files	Project-based
Fuels treatment	Show-me trip w NMF&G of San Diego Rx to find out if burn met F&G wildlife objectives (7,400 acres burned, 1,900 met G&F objectives, monitored smoke in Cañones and Gilman areas, RAWS station monitored burn)	Jemez	RD project files	Project-based
Fuels treatment	Jemez Corridor WUI (Lions site) mechanical thinning and chipping (137 acres) implementation monitoring	Jemez	RD, Fire files and Timber contract files	Project-based 95%completed as of 3/2006
Fuels treatment	Jemez 4 WUI project: Sierra los Piños WUI area and Thompson Ridge site chipping and pile burning (170 acres) implementation monitoring	Jemez	RD, Fire files and Timber contract files	Project-based
Fuels treatment	Stable Mesa prescribed fire treatment implementation monitoring (4,800 acres of 6,500 acres)	Jemez	NFPORS	Project-based
Fuels treatment	Stable Mesa prescribed fire treatment implementation monitoring (1,700 + 4,800 from 2006 = 6,500 total acres)	Jemez	NFPORS	Project-based
Fuels treatment	Thompson Ridge - Mastication 270 acres + 50 acres cut/pile (inmate crew) Monitoring by COR ever other day	Jemez	NFPORS	Project-based
Fuels treatment	COR monitored Cochiti thinning/piling completed, 300 total acres	Jemez	NFPORS	Project-based
Fuels treatment	2006 - Mesa Poleo Phase I, 91 acres thinned and masticated (contract) Mesa Poleo Phase II, 386 acres hand thinning, slash lopped & scattered	Coyote	FACTS, RO, Forest Management files	Project-based
Fuels treatment	Resource condition monitoring in the Lakes Rx Project – fuels and timber data collection and assessment	Jemez	NFPORS	Project-based

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Fire & Fuels (cont.)				
Fuels treatment	2007 - Mesa Poleo Phase I, 192 acres thinned and masticated (contract) Mesa Poleo Phase II, 300 acres thinned and slash lopped/ scattered, and 300 acres of previous year's thinned area masticated (contractor)	Coyote	FACTS, RO, Forest Management files	Project-based
Fuels Treatment	La Cueva - 102 acres pre-commercial thinning (SPS4 funded)	Pecos/Las Vegas	FACTS, RO Forest Management files	Project-based
Fuels treatment	Chaperito Ridge prescribed burn implementation monitoring.	Pecos-Las Vegas	RD, Burn Files	Project-based
Fuels treatment	La Cueva prescribed burn; FUTA developed fuels transects and burn plans in upper Mora	Pecos-Las Vegas	RD, Project files	Project-based
Prevention	WUI analysis; prioritization of WUI areas	Forest-wide	SO-Fire files	Annually
Prevention	FireWise participation: meetings and information	Forest-wide	FireWise meeting notes; SO FireWise program files	Ongoing
Prevention	Rancho de Chaparral Girl Scout Camp, WUI defensible space monitoring	Cuba	RD-Fire files & NM Forestry Dept Bernalillo District-files	Twice a year, Annual Meeting
Prevention	WUI defensible space fire hazard monitoring – summer home inspections	Pecos-Las Vegas	RD, Recreation files and Fire files	Annually

Heritage Resources				
Effects monitoring	NRHP listed/eligible sites, no discovered/reported disturbances	Forest-wide	RD/SO Heritage files	On-going
Effects monitoring	Effectiveness of road maintenance protocols Coyote & Española– Number of roads have decreased and protocol is working (mtnc level 3 & 4 roads)	Coyote, Española	RD Heritage files	Project based
Effects monitoring	Heritage priority assets review, Headquarters Well, will require heritage evaluation in 2008	Española	RD Heritage file	Heritage priority
Effects monitoring	Mitigation effectiveness & site protection monitoring for: Santa Fe Municipal Watershed hand thinning project (3 sites) - Completed	Española	RD Heritage files	Project-based
Effects monitoring	Site testing (6 NR-eligible sites) on FR 416V for San Ildefonso land transfer. Completed testing and report is due to SHPO end of calendar year 2007	Española	RD Heritage files	Land claim-based
Inventories	Heritage resource inventories (5,506 acres)	Forest-wide	SO, Heritage files	Annually

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Heritage (cont.)				
Project Clearances	Project clearance and site marking (195,186 acres)	Forest-wide	SO, Heritage files	Annually
Research	PhD student research on Jicarilla-Apache heritage sites: settlement and land use information Completed Rio del Oso Apache project (2006)	Española	RD/SO Heritage files	Research completed
Research	Grad Student (UNM) research on Polvadera Obsidian quarries (research started 2005)	Española	RD/SO Heritage files	Ongoing
Site condition assessment	Site condition/disturbance monitoring: 5 National Register eligible sites, and 1 National Register listed site (Guaje Ridge ruins) in Cerro Grande fire area; Guaje Ridge Ruin (NRHP) monitored, no disturbances	Española	RD Heritage files	National Register sites assessed annually
Site condition assessment	Site condition monitoring of 10 sites in the Caja del Rio and the Polvadera Mesa area and Garcia Canyon Completed	Española	RD Heritage files	Done by Site Stewards
Site condition assessment	Heritage resource site condition monitoring of Glorieta Baldy Lookout National Register site	Pecos-Las Vegas	RD/SO-Heritage Resource files	Monthly (Apr-Oct)
Site condition assessment	Heritage resource site condition monitoring of the Hacienda, Glorieta Mesa Rock Art, La Cueva East Rock Shelter, La Cueva West Rock Shelter, Commissary Creek Rock Shelter, Glorieta Mesa Rock Shelters, Anton Chico Stone Structures, and Anton Chico Rock Shelters by Site Stewards	Pecos-Las Vegas	RD/SO-Heritage Resource files	Monthly depending on accessibility
Site condition assessment	Historical data recording/monitoring and stabilization of the Anton Chico Hacienda, by Passport-in-Time volunteers	Pecos-Las Vegas	SO/RD-Heritage Resource files	Annually
Site condition assessment	Monitoring of 2 sites for the Forest Road 63L (Lawson Road) road maintenance	Pecos-Las Vegas	RD/SO-Heritage Resource files	Project based
Site condition assessment	Monitoring of 4 sites for the Tres Lagunas Pasture Tree Falling - Site Intrusions and Out-of-Compliance Undertakings	Pecos-Las Vegas	RD/SO-Heritage Resource files	Project based
Site condition assessment	Implementation monitoring on 2 sites for the Upper Mora Centennial Fence Project	Pecos-Las Vegas	RD/SO-Heritage Resource files	Project based
Site condition assessment	Implementation monitoring of one site for rebuilding of the Geary recreation residence in Gallinas Canyon	Pecos-Las Vegas	RD/SO-Heritage Resource files	Project based
Site condition assessment	Fire effects monitoring of 7 sites in the Sebadilla Prescribed Burn area (Phase II implementation)	Pecos-Las Vegas	RD/SO-Heritage Resource files	Project based

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Insect & Disease Management				
Evaluation	Regional Forest Health Manager monitored completed forest health projects	Coyote, Cuba, Jemez	RO, Forest Management files	Project-based
Evaluation	Pre-treatment insect and disease vulnerability evaluation for the Rendija Canyon thinning project	Española	RO, Forest Management files	Project-based
Evaluation	Post-treatment evaluation to determine the level of mortality among the standing (leave) trees and bark beetle prevention in the Santa Fe municipal watershed	Española	RO, Forest Management files	Project-based
Evaluation	Jemez Falls bark beetle prevention project implementation monitoring	Jemez	RO, Forest Management files	Project-based
Evaluation	2006 - Post-treatment evaluation of bark beetle prevention spraying at Paliza family and group campgrounds	Jemez	RO, Forest Management files	Project-based
Implementation	2006 - Mesa Poleo Phase I, 91 acres thinned and masticated (contract) Mesa Poleo Phase II, 386 acres hand thinning, slash lopped & scattered	Coyote	FACTS, RO, Forest Management files	Project-based
Implementation	2007 - Mesa Poleo Phase I, 192 acres thinned and masticated (contract) Mesa Poleo Phase II, 300 acres thinned and slash lopped/ scattered, and 300 acres of previous year's thinned area masticated (contractor)	Coyote	FACTS, RO, Forest Management files	Project-based
Implementation	386 acres special cut and lop/scatter	Coyote	FACTS, RO Forest Management files	Project-based
Implementation	2007 - Chaparral, 130 acres thinned and slash lopped/scattered	Cuba	FACTS, RO, Forest Management files	Project-based
Vegetation treatments	2006- Jemez Falls Campground Stewardship project: 217 acres contractor thinning and mastication	Jemez	FACTS, RO Forest Management files	Project-based
Inventory	Insect/disease activity monitoring and inventory – aerial detection survey for insect damage, with aerial survey map and report	Forest-wide	RO and SO GIS files	Annually
Inventory	2006- Campgrounds surveyed for gypsy moth infestation	Forest-wide	RO and SO GIS files	One-time
Treatment	Piñabetosa mechanical dwarf mistletoe control (197 acres) project implementation and survey	Coyote	SILVA	Project-based
Treatment	Paliza and Redondo campgrounds stewardship contract bark beetle control implementation monitoring (146acres)	Jemez	SILVA database	Project-based

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Law Enforcement				
Illegal activities	Monitoring of illegal trash dumping and illegal outfitters	Coyote	SO, Law Enforcement files	Ongoing

Minerals				
Abandon mines	Canyon de San Diego (Jemez) and Nacimiento Mine (Cuba)	Jemez - Cuba	Cuba RD, Mineral files	Annually
Mine reclamation	Surface inspection of 2 closed mines, Las Conchas, and Utility Block reclaimed mine site	Forest-wide	Cuba RD, Mineral files	Annually
Mine reclamation	Mine reclamation effectiveness and water quality monitoring: Nacimiento and Las Conchas mines	Cuba, Jemez	Cuba RD, Mineral files	Annually
Permit compliance	Monitoring/inspections of 12 active mines and 56 O&G wells	Forest-wide	Cuba RD, Mineral files	Annually and Quarterly
Saleable minerals	Rock collection site permit sales monitoring	Forest-wide	RD, Minerals files and INFRA database	Annually

Non-Recreation Facilities				
Infrastructure	Real property inspections (includes wastewater); condition surveys for maintenance needs; Safety inspection (selected high-risk work areas)	Forest-wide	INFRA database	Annually
Infrastructure	Inspections & facility condition/maintenance surveys of 44 facilities inc. recreation and administrative sites, and water systems (Forest total 274 agency, 5 lease)	Forest-wide	INFRA database	Annually
Infrastructure	Deadman and redtop fire tower inspections	Cuba	RD, Fire files	Annually
Infrastructure	Deadman, Redtop Cerro Pelado, Barillas, & Encino Fire Lookout Tower inspections	Coyote , Cuba, Jemez, Pecos-Las Vegas	RD- Fire, SO-Safety files	Annually

Non-Recreation Special Uses				
Road easements & special uses	Condition and permit compliance for FR 10 Copar and Utility Block haul permits	Jemez	SO, Roads files	Annually
Special Uses	2007- Permit compliance monitoring of installation of ponderosa water line	Jemez	RD, SUP files	Project-driven

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Non-Recreation Special Uses (cont.)				
Utilities	Permit compliance for Tesuque Radio Company	Española	RD, Recreation files	Annually
Utilities	Los Alamos water tank construction and SU permit compliance monitoring	Española	RD, Recreation files	Project-based
Utilities	SU permit compliance for powerlines and electric utility structures: Tesuque Radio Company and State structures	Española	RD, Recreation files	Annually
Range				
Grazing permit compliance	Ranger District / 2006 allots / 2007 allots Coyote / 11 / 11 Cuba / 19 / 19 Española / 9 / 9 Jemez / 8 / 9 Pecos-Las Vegas / 20 / 20 Monitoring includes: pasture rotation, authorized dates, class of animal, confirmation / livestock numbers, updated brand cards and ear tags, and brand checks on livestock	Forest-wide	INFRA and RD, Range Files	Annually
Grazing permit compliance	Unauthorized livestock monitoring: Coyote RD - 2 allot's, Cuba RD - 6 allot's, Española RD - 5 allot's, Pecos-LV RD - 5 allot's	Cuba, Coyote, Española	INFRA and RD, Range files	Annually
Grazing permit compliance	Grazing standard compliance monitoring in Jemez Natural Recreation Area (San Diego allotment)	Jemez	RD, Range files and INFRA	Twice a year
Grazing permit compliance	Watering systems conditions after drought: Barbero, Springs, Valle Grande, and El Pueblo	Pecos-Las Vegas	INFRA and RD, Range file	Annually
Elk use, selected allotments	Utilization cages to measure elk utilization prior to turn-out on Chicoma, Oso Vallecitos, and Polvadera allotments	Española	NM Dept. of Game & Fish, RD Range files	Wildlife habitat / use Annually

Monitoring Item	Monitoring Description			Area	Data/report Location	Monitoring Frequency
Range (cont.)						
Key use area condition	Ranger District	2006 allots	2007 allots	Forest-wide	INFRA and RD, Range files	Annually on selected allotments
	Coyote	10	10			
	Cuba	17	17			
	Española	9	9			
	Jemez	8	9			
	Pecos-Las Vegas	20	20			
	Monitoring of pre- and post-grazing utilization stubble height of forage species					
Range condition	Ranger District	2006 allots	2007 allots	Forest-wide	INFRA database and RD Range files	Annually
	Coyote	2 / yr	2 / yr			
	Cuba	11	11			
	Española	9	9			
	Jemez	8	9			
	Pecos-Las Vegas	18	18			
Range facilities	Condition inspections: 10 miles of fencing, 5 stock tanks, and 7 riparian exclosure fences			Coyote	INFRA and RD, Range files	100% monitored in 2004, 20% on annual basis
Range facilities	2007 - Deferred maintenance inventory and inspection of 10 facilities: fences, stock tanks, corrals, and spring developments			Coyote	INFRA, Range files	Periodic
Range facilities	Riparian exclosure fences: Coyote RD - 7, Cuba - 2, Española - 2 (Oso Vallecitos, Polvadera allots)			Coyote, Cuba, Española	INFRA and RD, Range files	Annually
Range facilities	Riparian exclosure fence monitoring: 7 exclosures on Cuba, 6 on Coyote			Coyote, Cuba, Española	INFRA and RD, Range files	Annually
Range facilities	Implementation/effectiveness, Coyote RD, 1 trick tank; Española RD, Sierra Mosca Allot trick tank			Coyote, Española	INFRA and RD, 2230 Range files	Project-based
Range facilities	Deferred maintenance inventory on Jemez – 20% of range improvements (fences, stock tanks, corrals, spring developments), Coyote – 10 improvement			Coyote, Jemez	INFRA, Range files	Periodic
Range facilities	Water facilities: monitoring of 7 livestock wells and 25+ springs			Cuba	INFRA and RD, Range files	Annually

<table>
<tr><th>Monitoring Item</th><th>Monitoring Description</th><th>Area</th><th>Data/report Location</th><th>Monitoring Frequency</th></tr>
<tr><td colspan="5">Range (cont.)</td></tr>
<tr><td>Range facilities</td><td>Stock tank condition monitoring (~180 stock tanks) – mapping, photo recording, and function analysis</td><td>Cuba</td><td>INFRA and RD, Range files</td><td>100% monitored in 2004, 20% on annual basis</td></tr>
<tr><td>Range facilities</td><td>Facility condition inspections: 25 miles of fence, 30 earth tanks, 1 riparian exclosure fences</td><td>Pecos-Las Vegas</td><td>INFRA and RD, Range files</td><td>Selected sites monitored annually</td></tr>
<tr><td>Range facilities</td><td>Stock drinkers and pipeline condition monitoring (~40 miles of pipeline and approximately 40 drinkers) – mapping, photo recording, and function analysis</td><td>Pecos-Las Vegas</td><td>INFRA and RD, Range files, NRCS EQUIP</td><td>Selected sites monitored annually</td></tr>
<tr><td>Range facilities</td><td>Inventory and inspection of 1.5 miles of new range fencing</td><td>Pecos-Las Vegas</td><td>INFRA and RD Range files</td><td>Selected sites monitored annually</td></tr>
<tr><td>Range facilities</td><td>Condition inspections 3 corrals</td><td>Pecos-Las Vegas</td><td>INFRA and RD, Range files</td><td>Selected sites monitored annually</td></tr>
<tr><td>Range facilities</td><td>Condition inspections 6 livestock water wells and 16 spring developments</td><td>Pecos-Las Vegas</td><td>INFRA and RD, Range files, NRCS EQUIP</td><td>Selected sites monitored annually</td></tr>
<tr><td>Range vegetation monitoring</td><td>2007- Cooperative range monitoring w/ Valles Caldera staff/volunteers on 15 Jemez RD sites</td><td>Jemez</td><td>Valles Caldera</td><td>Twice/year</td></tr>
<tr><td>Range readiness</td><td><table>
<tr><td>Ranger District</td><td>2006 allots</td><td>2007 allots</td></tr>
<tr><td>Coyote</td><td>10</td><td>10</td></tr>
<tr><td>Cuba</td><td>19</td><td>19</td></tr>
<tr><td>Española</td><td>9</td><td>9</td></tr>
<tr><td>Jemez</td><td>8</td><td>8</td></tr>
<tr><td>Pecos-Las Vegas</td><td>18</td><td>18</td></tr>
</table>Range soil and vegetative readiness for entry on 48 allotments</td><td>Forest-wide</td><td>INFRA, RD Range Files</td><td>Annually on selected allotments</td></tr>
<tr><td>Range surveys</td><td>2007- NEPA data collection & analysis for watershed, soils, wildlife, forage production-utilization, invasive plants for 1 allot, Cuba RD; 2 allots, Coyote RD: and V//, Vallecitos, and Ponderosa allots, Jemez RD</td><td>Coyote, Cuba, Jemez</td><td>NEPA Project files</td><td>Project-based</td></tr>
<tr><td>Range surveys</td><td>2007- Capacity analysis on Chicoma, Polvadera allots, Española RD; Alamo, Del Norte, Bear springs, Peralta, Bland allots, Jemez RD</td><td>Española, Jemez</td><td>RD Range Files</td><td>Project-based</td></tr>
</table>

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Range (cont.)				
Range surveys	Capacity analysis on Polvadera, Chicoma allots, Española RD; and V//, Vallecitos, and Ponderosa, Jemez RD	Española, Jemez	NEPA Project files	Project-based
Range surveys	Data collection & analysis: watershed, soils, wildlife, forage production-utilization, & invasive plants for NEPA on 14 allotments	Pecos-Las Vegas	NEPA Project files	Project-based
Range utilization	Valle Grande Grassbank monitoring with NMSU Extension Service	Pecos-Las Vegas	INFRA and RD, Range files	Annually
Vegetation condition	Range Improvement Task Force RAM monitoring on Mesa del Medio and Youngsville Allots, Coyote RD; and Peralta Allot, Jemez RD	Coyote, Jemez	RD, Range files	Project-based
Vegetation condition	2007 - Range Improvement Task Force RAM on Mesa del Medio, Youngsville allots	Coyote	RD, Range files	Project-based
Vegetation condition	NMSU Range Improvement Task Force, RAM monitoring on Barbero, Springs, Valle Grande, and El Pueblo (aka Grass Bank) allotments.	Pecos-Las Vegas	INFRA and RD Range files	Annually
Vegetation sampling	Ground cover and basal cover of grasses, forbs and shrubs on Rio De La Casa Allotment	Pecos-Las Vegas	NMSU, FS, LJEC	Project-based
Vegetation sampling	Ground cover and basal cover of grasses, forbs and shrubs on Rio De La Casa Allotment	Pecos-Las Vegas	NMSU, FS, LJEC	Project-based
Vegetation treatments	~100 ac Piñon-Juniper thinning on Caja del Rio Allotment	Española	INFRA and RD, 2230 Range files	Project-based
Vegetation treatments	~500 ac of thinning on Tecolote, El Solitario, Rio de la Casa, Barbero, and Valle Grande Grassbank allotments	Pecos-Las Vegas	INFRA and RD, 2230 Range files	Project-based

Recreation				
Facilities/sites	Campsite condition inventory and monitoring of Rio Chama Wild & Scenic River	Coyote	INFRA and RD recreation files	Annually
Facilities/site	Black Canyon Campground reconstruction project implementation monitoring	Española	RD Recreation files	Project-based
Facilities/sites	Condition inspection of recreation sites before opening	Española	RD Recreation files	Annually
Facilities/sites	Hazard tree monitoring at sites, facilities, and trails	Española	RD Recreation files (work logs)	Ongoing, summer season
Facilities/site	Paliza Campground phase 2 reconstruction project implementation monitoring	Jemez	RD Recreation files	Project-based

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Recreation (cont.)				
Facilities/sites	Rio Guadalupe watershed dispersed site inventory and use	Jemez	RD Recreation files	Ongoing, summer season
Rec Demo	Fee collection receipts	Forest-wide	RD Recreation files	Ongoing
Trails	Trail assessment and trail infrastructure condition monitoring, 195 trails, 912 miles:. Trail condition surveys ACS 14 mi.; Española, 11.2 mi.; Jemez, 1 mi.; Pecos-LV, 2 mi.)	Forest-wide	INFRA	20% annually
Trails	Condition inventory and assessment: trailheads, trail tread, drainage (culverts, water bars), and other infrastructure (10% of RD annually)	Coyote	INFRA, RD Recreation files	Annually
Trails	Daily trail crew activities maintenance logs	Española	RD Recreation work logs	Ongoing, summer season
Trails	Trail condition surveys and assessments	Española	RD Recreation files (work logs, photos)	Ongoing, summer season
Trails	Jemez National Recreation Area trail condition monitoring: Trail 137 & trail to Spence and San Antonio Hot Springs	Jemez	RD, Recreation files	Annually
Visitor Use	Use along Rio Chama Wild & Scenic River corridor: unauthorized new dispersed campsites (locations, how many per year)	Coyote	RD Recreation files	Summer months (5/30 - 9/30)
Visitor Use	Campground occupancy and use	Coyote	INFRA, RD Recreation files	Summer months (5/30 - 9/30)
Visitor Use	Use of popular dispersed camp sites by fire ring count and expansion of bare ground	Coyote	INFRA, RD Recreation files	Summer months
Visitor Use	Respect the Rio program dispersed campsite use and visitor satisfaction including vehicles, number of people, distance from stream	Cuba, Jemez	Respect the Rio annual report	Annually
Visitor Use	Assess OHV use and illegal dumping on Forest areas adjacent to Highway 84 (inc. El Invierno Allotment) closed in 2006; continual monitoring of gates, gate conditions, and El invierno cleanup after closure.	Española	RD-Recreation files	Incident basis
Visitor Use	Visitor Satisfaction of San Antonio Hot Springs management	Jemez	RD Recreation files	Annually

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Recreation (cont.)				
Visitor education	Develop Wilderness Education Plan for Pecos, San Pedro Parks, Chama River Canyon, and Dome wilderness areas	Forest-wide	SO/RD Recreation files	Project-based
Wilderness Use	Use of Chama and San Pedro Parks wilderness areas: campsites in wilderness areas: location, number, rehabilitation needs, and trespass	Coyote	RD Recreation files	Twice a year
Wilderness Use	Wilderness campsite monitoring: fire rings, vegetation impacts, trash, compliance with leave no trace principles	Española	RD Recreation files	Ongoing, summer season
Wilderness Use	Illegal OHV use in wilderness and non-wilderness areas, and impacts from use in designated areas	Española	RD Recreation files	Approx. twice a month
Wilderness Use	Dispersed recreation campsite inventory and site condition assessment of one high mountain lake in the Pecos Wilderness	Pecos-Las Vegas	RD Recreation files	Every 5 years
Trails	Trails rehabilitation project effectiveness monitoring, includes trails impacted by wildfires (Molina (2003) and Cerro Grande (2000).	Española	RD, Recreation work logs	Ongoing, summer season

Recreation Special Uses				
Special Uses	Outfitter-guide permit compliance - collect information on permittee actual use by trip, including number of clients, days, camps, fees, use conditions, etc. Española inc. Nordic Ski Club Challenge Cost Share Agreement	Coyote, Española, Jemez, Pecos-Las Vegas	RD SUP files	Ongoing
Special Uses	Permit compliance monitoring for the Santa Fe ski and associated areas including parking lot, lift line, and fences Ongoing in 2006, tree thinning, work projects, sculpting lift lines, monitoring out-of-bound skiing as per MOA, permit compliance monitoring. Millennium Lift construction finished (5/06) and life opened in 6/07	Española	RD-Special Use Permit files	Monitored weekly in winter; maintenance in summer
Special Uses	Special events and non-commercial group use permit compliance and effects monitoring (e.g. Caja del Rio Endurance Ride, Pajarito Punishment, Hyde Bike Race, Tesuque Peak run/Snowshoe race, etc.)	Española,	RD Recreation files	By event
Special Uses	2006 - permit compliance inspections on Wild Hogs, 3:10 to Yuma, and Comanche Moon	Española	RD SUP files	Project-driven

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Recreation Special Uses (cont.)				
Special Uses	Recreation residence permit (110 permits) compliance, inc., site condition and fire prevention inspections at Gallinas, Grass Mountain, Holy Ghost, and Winsor summer home areas	Pecos-Las Vegas	RD Recreation files	Annually

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Soil & Water				
Erosion	Santa Fe watershed soil erosion monitoring (part of paired watershed study)	Española	RD Watershed files	Project driven, SFWS TAG
Habitat condition / waterway function	Stream temperature monitoring: 78 miles & 7 streams	Forest-wide	SO Fisheries files	Temp measure at four hour intervals, June to October
Habitat condition / waterway function	Cecilia Creek, 2 stations, 5 miles: stream classification, substrate characterization and photo points	Coyote	RD Watershed files	3 yr interval w/ Jemez Mountain School
Habitat condition / waterway function	Rito Resumidero, 1 mile: stream classification, substrate characterization, stream function evaluation, and photo points	Coyote	RD Watershed and project files	Project-based
Habitat condition / waterway function	2006- Polvadera Creek aquatic / riparian habitat and fisheries inventory	Española	SO Fisheries files	Completed
Habitat condition / waterway function	Polvadera Creek restoration project implementation monitoring	Coyote	SO Fisheries files	Annually
HAZMAT remediation	2006- Asphalt emulsion spill in drainage near Santa Fe Ski Area, NMDOT chip seal project, remediation effectiveness monitoring 2007- inspection, soil catchments structures functioning properly	Española	SO Soil & Water files	Project-based
Potable water Quality	E. coli, total coliform and nitrate/nitrite sampling of 17 recreation sites; year-long sampling of Coyote RD administrative and Wells sites	Forest-wide	SO Engineering, NM Environment Department	Prior to opening & monthly
Road closure & decommission	Cecilia Cr. Watershed Restoration Project, Effectiveness monitoring, vegetation monitoring	Coyote	Coyote RD Watershed files	Project-driven

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Soil & Water (cont.)				
Road Closure, decommission, & fuelbreak thinning	WildEarth Guardians CFRP Road Closure & Decommissioning and Thinning Project: Establish permanent photo points, measure live/dead tree size, density, & canopy cover; surface fuels & understory vegetative cover, and soil-water infiltration rates	Coyote	WildEarth Guardians, Coyote RD Watershed files	Project-driven
Rehabilitation	2007 - Soil / vegetation rehabilitation followup inspection of the Las Conchas movie site	Jemez	RD Soil/ SUP files	Project-driven
Riparian condition	Riparian condition assessments: Youngsville, Mesa del Medio allotments; Española- Polvadera, Chicoma allotments	Coyote, Española	Coyote RD Watershed files	Project-driven
Soil condition	Soil condition inventory and compaction study, Resumadero campground (65 acres)	Coyote	RD Watershed files	Project-driven
Soil condition	Monitoring of soil moisture, compaction, and disturbance, Fuertes, Camino Corral, Gallina, and Mesa Poleo I projects	Coyote	RD Project files	Project-driven
Soil condition	Soil condition assessments on Ojitos, Pollywog, Gurule, Llaves, Chiquito allotments	Cuba	RD Range files	Project-driven
Soil condition	Soil condition assessments: Coyote- Youngsville, Mesa del Medio allotments; Española- Polvadera and Chicoma allotments	Coyote, Española	Coyote RD Watershed files	Project-driven
Stream survey	Channel stability assessments and Rosgen Stream Classification: Coyote- Cañones Cr, Chihuahuenos Cr, and Cañoncito Seco; Española- Polvadera Creek	Coyote, Española	Coyote RD Watershed files	Project-driven
Thinning monitoring	Velasquez CFRP Thinning Project: Establish permanent photo points, measure live/dead tree size, density, & canopy cover; surface fuels & understory vegetative cover	Coyote	Forest Guild or Coyote RD Watershed files	Project-driven
Water quantity	Stream flow and water quality data: Rio Grande, Chama and Jemez Rivers	Coyote, Española, Jemez	http://waterdata.usgs.gov/nm/nwis/nwis	Continuous
Water quality	Test well monitoring for uranium: Santa Fe municipal watershed, Buckman well field, Lower Santa Fe River, and Caja del Rio sites	Española	City of Santa Fe, Sangre de Cristo Water Division	Annually
Water quality	Water quality sampling study in the Santa Fe River to measure water quality parameters	Española	NM Environment Department (CWA 319 grant)	Monthly
Water quality	Paired watershed study: Water sampling for turbidity, non-organic and nutrient content, heavy metals, and runoff to determine impact of vegetation treatments on Santa Fe watershed	Española	RD, Santa Fe Watershed files	Project-based, City of Santa Fe and FS
Water quality	Santa Fe Municipal Watershed water intake	Española	City of Santa Fe, Sangre de Cristo Water Division	Monthly

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Soil & Water (cont.)				
Water quality	Jemez River gauging station	Jemez	http://waterdata.usgs.gov/usa/nwis/uv?site_no=08324000	Continuous
Water quality	Fenton Hill administrative site	Jemez	Los Alamos National Laboratory	Monthly
Water Quantity	Santa Fe sewage treatment plant effluent water use by Caja del Rio permittees livestock	Española	City of Santa Fe, NM Environment Department permit	Annually
Water Quality	Gallinas Municipal Watershed: sampling and data collection for total suspended solids	Pecos-Las Vegas	NMHU Department of Forestry and NS, RD, SO Watershed files	Annually

Vegetation Management

Invasive species	Mapped 12 populations of Russian Knapweed and implementation monitoring of 5 acres of mechanical control , both in the Rio Chama	Coyote	SO GIS corporate database	Annually
Invasive species	Effectiveness monitoring of mechanical treatments of invasive plants (noxious weeds) along Forest roads 144 and 103 and mapping in the Cerro Grande fire area (5,000 acres) along American Springs Road noxious weed mapping	Coyote, Española	RDs Range files, GIS corporate database	Project-based
Invasive species	Monitored for invasive species in Bear Paw fire line construction; 2007- Treated invasive species on 25 acres	Coyote	RD project files	Project-based
Invasive species	Treated 153 acres of invasive plant species including Russian Knapweed, Bull Thistle, Scotch Thistle, Musk Thistle, Toad Flax, Canadian Thistle, Cheat Grass, and Teasil	Cuba	RD project files	Annually
Invasive species	Inventoried and monitored 160 acres of new populations of invasive Russian Knapweed, Bull Thistle, Scotch Thistle, Musk Thistle, Toad Flax, Cheat Grass, Canadian Thistle, Spotted Knapweed, and Diffuse Knapweed	Cuba	RD project files	Annually
Invasive species	Mechanical control for 47 acres of musk thistle and implementation monitoring	Cuba	RD Project files	Annually
Invasive species	Noxious weed mapping and inventory: location and species information	Cuba	RD Range files, GIS Corporate database	Ongoing

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Vegetation Management (cont.)				
Invasive species	2006- 300 acres of mechanical control of salt cedar, Russian olive, and Siberian Elm 2007- Monitored effectiveness of salt cedar, Russian olive, and Siberian Elm treatments on 250 of 300 acres, 6 of 8 plots	Jemez	RD Project files	Bi-Annually
Invasive species	2006 - Mechanical control and implementation monitoring of 75 acres of musk thistle	Jemez	RD Project files	Annually
Invasive species	2007- Mechanical control and implementation monitoring of 25 acres of musk thistle	Jemez	RD Project files	Annually
Invasive species	Mechanical control and implementation monitoring of 25 acres of bull thistle	Pecos-Las Vegas	RD Range files, INFRA	Annually
Invasive species	Invasive weed population inventory on 18 of 26 allotments on the ranger district	Pecos-Las Vegas	RD Range files	Annually
Rehabilitation / restoration	Fuertes Meadow Restoration effectiveness monitoring (photos)	Coyote	Rd Project files	Project-based
Rehabilitation / restoration	2006- Cecilia Creek riparian thinning, 10 acres	Coyote	SO< Fisheries Files Coyote RD Hydro Files	Project-based
Rehabilitation / restoration	Ojitos sagebrush mowing implementation and effectiveness monitoring	Coyote	RD Project files	Annually
Rehabilitation / restoration	400 acres of sagebrush mowing	Cuba	RD	Project-based
Rehabilitation / restoration	200 acres of piñon-juniper thinning on Coyote Flats, Jemez RD and 50 acres of piñon-juniper thinning on the Cuba RD	Cuba, Jemez	FACTS, and RD, Range files	Project-based
Rehabilitation / restoration	Grass seeding effectiveness monitoring on the Molina fire and the Borrego fire: frequency plots to determine grass seedling success (Molina only)	Española	RD files, Molina Fire records	Annually
Rehabilitation / Restoration	2006 - CFRP (Collaborative Forest Restoration Project) identification of initial site conditions, canopy cover, presettlement trees, annual and forbs species list, and snag inventory 2007 - Monitoring of expected treatment impacts on trees/acre, canopy cover	Jemez	RD files	Cooperative project w/ FS, TNC & NAU Ecological Restoration Institute
Reforestation evaluation	First year plantation survival and stocking surveys on 72 acres of the BMG Fire	Cuba	FACTS, RD files	Project-based
Reforestation evaluation	First year ponderosa pine and Douglas-fir plantation survival on 404 acres of the Lakes Fire,	Jemez	FACTS, RD files	Project-based

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Vegetation Management (cont.)				
Reforestation evaluation	2006- First year plantation survival on 274 acres, Borrego Fire area	Española	FACTS, RD files	Project-based
Reforestation evaluation	2006- First year plantation survival on 443 acres, Cerro Grande Fire area	Española	FACTS, RD files	Project-based
Reforestation evaluation	First year plantation survival on 549 acres of the Viveash Fire	Pecos/Las Vegas	FACTS, RD files	Project-based
Special forest products	Removed and sold fuelwood, posts, poles, miscellaneous small roundwood, Christmas trees, and other small diameter products	Forest-wide	Timber Sale Accounting database	Annually
Special forest products	Collection permits- product price, terms of collection and products to be collected, dates of collection, date of issuance, issuing officer	Forest-wide	INFRA database	Annually, ongoing
Special forest products	2007 Reforestation cone collection	Coyote	TIM database	District wide
Special forest products	Firewood permits: 2006- 1,240 cords; 2007- 1,310 cords	Coyote	PTSAR database, Timber Sale Account database, INFRA	Annually
Special forest products	Collection permits: 2006- 0.867 MMBF (1,383 CCF); 2007- 1.968 MMBF (3,263 CCF) in FY2007	Coyote	PTSAR, TIM, and INFRA databases	Annually
Special forest products	Christmas trees: 2006- 332 permits; 2007- 184 permits	Coyote	TIM database	Annually
Special forest products	Monitored vegetative treatments in Mesa Paleo WUI	Coyote	RD, Project files	Project-based
Special forest products	Collection permit compliance- firewood, Christmas tree, boughs, vigas, latillas, and fence posts	Coyote	TIM, INFRA	Ongoing
Special forest products	Firewood permits: 2006- 1,522 cords; 2007- 1,160 cords	Cuba	PTSAR database, Timber Sale Account database, INFRA	Annually
Special forest products	Collection permits: 2006- 0.731 MMBF (1,155 CCF); 2007- 558 MMBF (883 CCF)	Cuba	PTSAR, TIMS, and INFRA databases	Annually
Special forest products	Christmas trees: 2006- 385 permits; 2007- 420 permits	Cuba	TIM	Annually
Special forest products	Collection permit compliance- firewood, Christmas tree, boughs, vigas, latillas, and fence posts	Cuba, Jemez	TIM, INFRA	Ongoing
Special forest products	Firewood permits: 5,620 Cords	Española	TIM	Ongoing

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Vegetation Management (cont.)				
Special forest products	Collection permits: 336 CCF	Española	PTSAR database, Timber Sale Account database, INFRA	Ongoing
Special forest products	Christmas trees: 335 permits	Española	TIM	Annually
Special forest products	Collection permit compliance- firewood, Christmas tree, boughs, vigas, latillas, and fence posts	Española	PTSAR database, Timber Sale Account database, INFRA	Ongoing
Special forest products	Firewood permits: 2006- 4,595 cords; 2007- 4,285	Jemez	PTSAR database, Timber Sale Account database, INFRA	Ongoing
Special forest products	Collection permits: 2006- 2.969 MMBF (5,283 CCF); 2007- 2.340 MMBF (3,688 CCF) in FY2007.	Jemez	PTSAR, TIMS, and INFRA databases	Annually
Special forest products	Christmas tree permits: 2006- 2,632 trees; 2007- 2,588 trees	Jemez	TIM	Annually
Special forest products	Collection permit compliance- firewood, Christmas tree, boughs, vigas, latillas, and fence posts	Jemez	TIM, INFRA	Ongoing
Special forest products	CFRP project implementation monitoring: Rowe Mesa II, Highlands, Tierra y Montes, and La Jicarita contracts	Pecos-Las Vegas	RD project files	Project-based
Special forest products	Collection permits: 1,809 CCF	Pecos-Las Vegas	TIMS and RD, Project files	Project-based
Special forest products	Firewood permits: 7,567 cords	Pecos-Las Vegas	TIMS and RD, Project files	Ongoing
Special forest products	Christmas trees: 1,080 permits	Pecos-Las Vegas	TIM	Annually
Special forest products	Collection permit compliance- firewood, Christmas tree, boughs, vigas, latillas, and fence posts	Pecos-Las Vegas	TIM, INFRA	Ongoing
Timber	Total timber products removed	Forest-wide	Timber Sale Accounting database	Annually
Timber	Commercial thinning: implementation monitoring of 680 acres on Camino Vigas and other sales	Coyote	FACTS and TSA databases	Project-based
Timber	Implementation and effectiveness monitoring Borrego Salvage sales	Española	TIM	Project-based
Timber	2006- Burnt Trail Salvage sale: 492 CCF sawtimber offered / sold	Española	PTSAR and TSA databases	Quarterly

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Vegetation Management (cont.)				
Timber	2007- Jemez Falls IRS project: 511 CCF (0.264 MMBF) sawtimber offered / sold	Jemez	PTSAR and TSA databases	Quarterly
Timber	Viveash salvage sale (5 sales): inspection and compliance monitoring of skid trails, landings, and rehabilitation on 842 acres	Pecos-Las Vegas	TIM and RD, Project files	Project-based
Vegetation treatments	Timber stand improvement thinning, Camino Corral: 2006- 443 acres; 2007- 175 acres	Coyote	FACTS, and District Ranger files	Project-based
Vegetation treatments	Timber stand improvement thinning, Eureka Mesa: 2006- 175 acres	Cuba	FACTS, and District Ranger files	Project-based
Vegetation treatments	Timber stand improvement thinning, Cochiti Mesa: 2006- 150 acres and Paliza: 2006- 25 acres	Jemez	FACTS, and District Ranger files	Project-based
Vegetation treatments	2006- Jemez Falls Campground Stewardship project: pre-commercial thinning and intermediate harvest (contractor thinning and mastication) implementation monitoring on 217 acres	Jemez	FACTS, RO Forest Management files	Project-based
Vegetation treatments	Redondo Stewardship contract: implementation monitoring on 100 acres	Jemez	RD and SO, Timber contract files	Project-based

Volunteer & Educational Programs				
Environmental Education	Monitoring volunteer / educational program participants, activities, public contacts, and participating schools and organizations	Forest-wide	SO, Fisheries files	Annually
Environmental Education	Leave no Trace: monitoring trainers / trainees, masters, courses, and contacts	Forest-wide	Coyote RD, Recreation files	Annually
Environmental Education	Respect the Rio Program (education component): campfire interpretive and contact ranger programs, and installation of interpretive signage Jemez only: Interpretive campfire and contact ranger programs 2007- Social surveys of campers and recreationists	Jemez, Cuba	SO, Fisheries files	Annually
Environmental Education	Collect and GPS map Guadalupe River dispersed camps	Jemez, Cuba	RD files	One time
Environmental Education	2007- develop bird walk for the Jemez Springs community bird walk in cooperation w/ Hawks Aloft, 14 participants	Jemez	RD files	Annually
Environmental Education	Earth Day Educational event: 450 children, 25 adults	Pecos-Las Vegas	RD Recreation files	Annually
Environmental Education	Classroom presentations	Pecos-Las Vegas	RD Recreation files	On-going

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Volunteer & Educational Programs (cont.)				
Special Events	Kids Fishing Day: 2006- 153 children, 75 adults, 12 educational booths; 2007- 133 children, 200 adults, 15 volunteers, 12 educational booths at Seven Springs fish hatchery	Forest-wide	Jemez RD files	Annually
Special Events	Culture Day with the Jemez Mountain School	Coyote	SO FireWise program files	Annually
Special Events	YCC education sessions including tour of Seven Springs fish hatchery, presentations on T&E and FS Sensitive species, bird and invasive plant identification, and GPS use	Jemez RD	RD files	Annually
Volunteer activities	Boy scout troop (~12 scouts and leaders) assisted for one day with a meadow restoration project	Jemez RD	RD files	Project-based
Volunteer activities	2007- Volunteers activities including assisting backcountry rangers with trail maintenance and trash collection	Pecos-Las Vegas	RD	Annually
Volunteer agreements	Maintaining volunteer agreement forms: cost data, work-time monitoring and accomplishments	Forest-wide	RD Recreation files	Annually

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Wildlife, Fish & Plants				
T&E / FS Sensitive Species	Rio Grande cutthroat trout: snorkel surveys for population counts at selected streams	Forest-wide	SO Fisheries files	Annually
T&E / FS Sensitive Species	Peregrine falcon: 3-6 sites monitored annually for breeding success by Terry Johnson	Forest-wide	NM Dept. of Game & Fish files	Annually
T&E / FS Sensitive Species	Mexican spotted owl: 2006- second year survey in the San Pedro Mountain Landscape Area	Coyote, Española	RD Wildlife files	Annually
T&E / FS Sensitive Species	Mexican spotted owl: monitoring grazing key use areas on five allotments	Cuba	RD Range files	Project-based
T&E / FS Sensitive Species	Northern goshawk suitable habitat population surveys	Cuba	SO Wildlife files	Annually
T&E / FS Sensitive Species	Mexican spotted owl: 2006 inventory 13 sites, ~20.000 acres; 2007- inventory eight sites, ~15,720 acres	Jemez	RD Wildlife files and WFRP files	Project-based

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Wildlife, Fish & Plants (cont.)				
T&E / FS Sensitive Species	Mexican spotted owl protected activity centers: 2006- eight PACs , ~4,800 acres; 2007- six PACs, ~3,600 acres	Jemez	RD Wildlife files	Approximately 3-6 MSO sites monitored per year
T&E / FS Sensitive Species	Mexican spotted owl breeding activity: 2006- Bear Canyon, ~600 acres; 2007-one site, 600 acres	Jemez	RD Wildlife files	Sites vary annually
T&E / FS Sensitive Species	NM meadow jumping mouse: survey of three locations, ~30 acres	Jemez	RD, Wildlife files and WFRP files	Annually
T&E / FS Sensitive Species	Northern goshawk surveys: 2006- four project areas, ~1,350 acres; 2007- four project areas, ~658 acres	Jemez	RD, Wildlife files and WFRP files	Project-based
T&E / FS Sensitive Species	Peregrine falcon: suitable breeding habitat, survey of one site, ~700 acres	Jemez	RD Wildlife files	Project-based; Annually
T&E / FS Sensitive Species	2007- Jemez Mountains salamander site inventory/monitoring: 2006- five sites, ~580 acres; 2007- three sites, ~159 acres	Jemez	RD Wildlife files	Project-based
T&E / FS Sensitive Species	E.F. Jemez River Trailhead monitoring noise levels and wildlife mitigations measures compliance with during filming of Wild Hogs movie	Jemez	RD Wildlife files	Project-based
T&E / FS Sensitive Species	Survey of Arizona willow and Rocky Mountain bristlecone pine	Pecos-Las Vegas	SO Fisheries files	Annually, Pecos Wilderness high lakes inventory
Non-sensitive species populations	Elk hunt: G&F Unit 6; effectiveness monitoring of hunter harvest survey in cooperation with NMG&F 2007 included population monitoring in the Valles Caldera and surrounding National Forest System lands	Coyote, Cuba, Española, Jemez	RD Wildlife files NM Dept. of Game & Fish	Annual
Non-sensitive species populations	NMG&F Black bear monitoring around national forest recreation sites	Cuba	NM Dept. of Game & Fish	Annually

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Wildlife, Fish & Plants (cont.)				
Non-sensitive species populations	NMG&F elk and deer population monitoring	Cuba	NM Dept. of Game & Fish	Annually
Non-sensitive species populations	2006-07 Breeding bird surveys along forest roads 376, 126 and 144	Jemez	RD, Wildlife files	Annually, S. Fettig, Bandelier NM and J. Fair, LANL
Non-sensitive species populations	Black swift: 2006- population monitoring; 2007- population monitoring and nest use	Jemez	RD, Wildlife files	Annually by H. Schwarz, Cibola NF
Non-sensitive species populations	2006-07 Bat mist netting survey on the E. F. Jemez River	Jemez	RD, Wildlife files and US Fish and Wildlife Service	Periodically by Lyle Lewis, FWS
Non-sensitive species populations	Nature Conservancy botanical surveys of the East Fork and Redondo CFRP project areas, ~314 acres	Jemez	RD, Wildlife files	Project-based
Non-sensitive species populations	2007- Effectiveness monitoring, use of black bear resistant trash containers at Jemez Falls Campground	Jemez	NM Dept. of Game & Fish	Problem-based
Non-sensitive species populations	Cooperative monitoring with Hawks Aloft of breeding bird populations along the lower Jemez River	Jemez	RD, Hawks Aloft files	Annual
Non-sensitive species populations	Herpetology survey along the lower Rio Cebolla	Jemez	RD Wildlife files	One-time
Non-sensitive species populations	Monitoring success of willow planting along the Rio Cebolla	Jemez	RD Wildlife files	Project based
Non-sensitive species populations	Bat mist netting survey on Cebollita Mesa to monitor bat use of range / wildlife water developments	Jemez	RD Wildlife files	One-time
Wildlife habitat/use	Stream mapping for fish composition and distribution, 78 miles of Polvadera Cr., Horsethief Cr., Panchuela Cr., Rio de las Vacas, Rito Anastacio, Rio Puerco, Cave Cr., and Rio Perro	Forest-wide	SO Fisheries files	Annually

Monitoring Item	Monitoring Description	Area	Data/report Location	Monitoring Frequency
Wildlife, Fish & Plants (cont.)				
Wildlife habitat/use	Experimental caged studies monitoring of elk use on selected grazing allotments	Coyote, Española, Jemez, Cuba	NM Dept. of Game & Fish and RD Range files	Annually
Wildlife habitat/use	Santa Fe Municipal Watershed: pre/post vegetation treatment effects monitoring on small mammals and birds	Española	Rocky Mountain Research Station	Project-based
Wildlife habitat/use	Elk salting effectiveness monitoring	Española	NM Dept. of Game & Fish	Annually
Wildlife habitat/use	Monitoring Keddy Lake and Jews Springs for NM jumping mouse habitat/use, elk use, and ORV use/damage	Jemez	RD, Wildlife files	Project based
Wildlife habitat/ watershed condition	Meadow restoration Las Conchas and Oat, Pony, and Hay Canyons, 2006- ~33 acres; 2007- ~2 acres	Jemez	RD Wildlife files	Project-based
Wildlife habitat/ watershed condition	Effectiveness monitoring of six earthen dams wildlife water sources	Jemez	RD Wildlife files	Project based
Wildlife habitat/use	Big horn sheep: population monitoring by NMG&F	Pecos-Las Vegas, Española	NM Dept. of Game & Fish	Annually by NM G&F
Wildlife habitat improvement	2007-Thinned 100 acres thinning in Cañada Tusas	Coyote	RD Wildlife files	Project-based
Wildlife habitat improvement	2007- Wildlife / livestock construction of eight and maintenance (dredge and apply Bentonite) of 21 earthen dams with follow-up effectiveness monitoring	Jemez	RD, Wildlife/Range files	Project based
Wildlife habitat improvement	West Mesa shrub enhancement, ~112 acres of pruning and creating openings	Jemez	RD, Wildlife files	Project based
Wildlife and other resources (public safety)	Monitoring implementation of NM 126 project mitigation measures (i.e., signage, log decks, culverts, fences, and seeding/mulching)	Jemez	RD, SO engineering files	Project based

The Forest Plan's monitoring requirements follow. For each action, effect, or resource to be monitored the data source and intent is specified. Frequency for measuring and reporting the monitored item is established, and variability which would initiate evaluation is specified. Expected precision and reliability of the measurement is stated. (Precision is the exactness or accuracy with which the data will be collected; reliability is the degree to which the monitoring accurately reflects the total Forest situation).

TABLE 2. FOREST PLAN MONITORING REQUIREMENTS

Actions, Effect or Resource	Units	Data Source	Intent	Frequency	Precision/ Reliability	Variability which Initiates Evaluation
AIR QUALITY						
Visibility in Class I areas	N/A	Automated Camera System	Obtain baseline visibility data to determine air degradation	Two times Day	±10% / 90%	Actual and potential visibility degradation will be evaluated after collection of sufficient baseline data.
CULTURAL RESOURCES						
Inventories	Acres	Field review	Compare actual and planned outputs	Annually	+20% / 80%	When planned inventories vary by +20% after 5 years.
Disturbances to Cultural Resources Listed or Eligible for NRHP	Sites	Field review	Assure protection of high value sites	Quarterly	5% / 100%	If vandalism or natural deterioration threatens integrity of site.
Project Clearances and Site Marketing	Acres	Field review	Assure protection of cultural sites.	Each Project	+5% / 100%	When site marking is insufficient to protect sites or site disturbance indicates ineffectiveness of system.
FACILITIES						
Forest Transportation System	Miles of open road	TIS report	Evaluate the effectiveness of road management.	Annually	±20% / 80%	When miles of open road varies by ± 20% of planned levels after 3 years.

Actions, Effect or Resource	Units	Data Source	Intent	Frequency	Precision/ Reliability	Variability which Initiates Evaluation
FACILITIES (cont.)						
Road Construction/ Reconstruction	Miles	MAR	Compare actual and planned amounts	Annually	±20% / 80%	When miles of construction/ reconstruction varies by ±20%
Timber Purchaser Road Construction/ Reconstruction	Miles	MAR	Compare actual and planned amounts	Annually	±20% / 80%	When miles of construction/ reconstruction vary by ±20% of planned after 3 years.
FIRE MANAGEMENT						
Actions, Effect, or Effectiveness of Fire Suppression	N/A	Field reviews; Fire reports; Fire management analysis	Determine if suppression programs are cost effective and meet management area objectives	Annually as appropriate	±10% / 90%	When compliance with standards and guidelines is not insured on at least 90% of wildfires and when analysis indicates planned budget is not cost effective.
Fuel Treatment	Acres	MAR report	Compare actual and planned outputs.	Annually	±10% / 90%	When 80% of prescribed treatment is not accomplished within one year of planned.
INSECT AND DISEASE						
Levels of Insects and Disease Organisms Affecting Forest Lands	Acres	Aerial surveys; Field surveys	Determine if insect and disease levels increase to potentially damaging levels	Every three years	±40% / 70%	When survey indicates out-break could become epidemic.
LANDS						
Rights-of-way Acquired	Number of cases	MAR report	Compare actual and planned outputs.	Annually	±5% / 95%	When actual acquisitions are less than 80% of planned after 5 years.

Actions, Effect or Resource	Units	Data Source	Intent	Frequency	Precision/ Reliability	Variability which Initiates Evaluation
RANGE						
Permitted Grazing Use (Livestock)	Permitted Grazing Use (Livestock)	Permitted Grazing Use (Livestock)	Permitted Grazing Use (Livestock)	Permitted Grazing Use (Livestock)	Permitted Grazing Use (Livestock)	Permitted Grazing Use (Livestock)
Grazing Capacity and Trend	Grazing Capacity and Trend	Grazing Capacity and Trend	Grazing Capacity and Trend	Grazing Capacity and Trend	Grazing Capacity and Trend	Grazing Capacity and Trend
Allotment Management Plans	Plans	RAMIS	Attain satisfactory management on all allotments.	Annually	±5% / ±95%	Variation of ± 25% from having all allotments with AMP's which will attain satisfactory management by the end of the decade.
RECREATION						
Dispersed Recreation Use by ROS Class	Recreation visitor Days	RIM report: Field inspections	Compare actual and planned outputs.	Annually	+40% / 80%	When actual use exceeds planned use by 30% after 3 years.
Developed Recreation Use for Public Sector and Ski Area	Recreation Visitor Days	RIM report, Use report.	Compare actual and planned outputs.	Annually	+10% / 90%	When actual use exceeds Practical Maximum Capacity by 30% or more.
User Satisfaction	N/A	Interviews, surveys, correspondence	Assure that recreation experience is satisfactory.	Annually	+50% / 50%	When >25% of respondents indicate lack of satisfaction with facilities or controls
Facility Condition	Sites	RIM Report, Activity reviews.	Assure that sites are not hazardous to public health or safety.	Annually	+10% / 90%	When sites fall below RIM Facility Condition 2.
Trail Construction / Reconstruction	Miles	MAR, Contract administration	Compare actual and planned outputs	Annually	+20% / 80%	When actual changes vary from that expected by +20% after 3 years.

Actions, Effect or Resource	Units	Data Source	Intent	Frequency	Precision/ Reliability	Variability which Initiates Evaluation
			SOIL & WATER			
Watershed Condition	Acres	Allotment Management Plans; Watershed Condition Report	Compare actual and planned outputs.	Annually	±10% / 85%	If estimated improvement acres are less than 20% of predicted after 5 years.
Best Management Practices	N/A	Field review	Assure BMP's are being implemented.	1 project annually	±20% / 90%	Failure to implement at least 90% of required BMP's.
Riparian Condition	Acres	Direct and indirect treatment reports.	Assure improvement is occurring.	Annually	±20% / 90%	If estimated improvement is less than 80% of predicted after 5 years.
Aquatic Ecosystem Condition	Aquatic Ecosystem Parameters	Systematic field sampling	Provide baseline in-formation on health of aquatic ecosystem	7 sites annually	±10% / 80%	Acceptable variation will be determined after 5 years of baseline data collection.
Effect of Activities on Aquatic Ecosystem	Aquatic Ecosystem Parameters	Systematic field sampling	Assure activities do not degrade aquatic ecosystems.	5 projects annually	±10% / 80%	Statistically significant degradation of aquatic ecosystem after 3 years.
Effects of Timber Harvest and Roads on Water Quality.	Selected water quality parameters	Project monitoring above & below high impacting activities.	Assure maintenance of water quality	1 project	±20% / 80%	Statistically significant water quality degradation.
			TIMBER			
Regeneration Harvests - Clearcut and shelterwood	Acres	Timber Mgmt Information System, Field review	Achieve balanced age class distribution; compare actual and planned outputs.	Annually	±10% / ±90%	When actual treatment varies by ± 25% from planned after 3 years.
Intermediate Harvest	Acres	Timber Mgmt Information System, Field review	Achieve balanced age class distribution; compare actual and planned outputs.	Annually	±10% / ±90%	When actual treatment varies by ± 25% from planned after 3 years.
Adequate Restocking of Harvested Lands	Acres	Measurements of random plots in regeneration areas	Insure lands are adequately stocked.	Alternate years after harvest or planting.	±20% / 80%	Indication of Inadequate stocking after 5 years.

Actions, Effect or Resource	Units	Data Source	Intent	Frequency	Precision/ Reliability	Variability which Initiates Evaluation
TIMBER(cont.)						
Timber Stand Improvement	Acres	SILVA report	Compare actual and planned outputs	Annually	±10% / 80%	When actual treatment varies by ± 20% from planned after 5 years.
Sawtimber Offered and Sold	Million Board Feet	PTSAR report	Compare actual and planned outputs.	Annually	±10% / 90%	When cumulative deviation of actual treatment is ± 20% of planned after 3 years.
Size Limits for Timber Cutting Units	Acres	Environmental Assessments; Program reviews	Determine if size limits should be revised.	Every third year	±25% / 80%	When resource obj. are not being met using current size limitations.
Land Suitability for Timber Production	Acres	TES report; Stand exams; Timber Inventory.	Identify changes in land suitability	Before Plan revision	±10% / 80%	Indication that areas need reclassification.
Regeneration Harvest in Aspen Type	Acres	TMIS; Field review	Achieve balanced age class distribution.	Annually	±10% / 90%	When actual treatment varies ± 20% from planned after 3 years.
Small Sales Offered and Sold	Million Board Feet	TMIS; Field review	Compare actual and planned outputs	Annually	±10% / 90%	When actual treatment varies by ± 25% from planned after 5 years.
Skyline Demonstration	Environ-mental and Social Effects	Demonstration sales monitoring items	Determine effects of applying skyline technology	During and after sales as necessary	Varies by item monitored	Demonstration monitoring team will evaluate all skyline activities. Plan evaluation if cumulative effects deviate by ± 20% after 3 years.
Permitted firewood	Cords	PTSAR: Annual Free Use Report.	Compare actual and planned outputs.	Annually	±30% / 70%	When permitted firewood varies from planned output by ± 20% after 5 years.
Regeneration Harvest in Woodland Type	Acres	TMIS; Field review	Achieve balanced age class distribution	Annually	±10% / 90%	When actual treatment varies by ± 20% from planned after 3 years.

Actions, Effect or Resource	Units	Data Source	Intent	Frequency	Precision/ Reliability	Variability which Initiates Evaluation
VISUAL QUALITY						
Effects of Activities on Visual Quality	Acres by VQO met	VMS system, Activity reviews.	Assure that Forest retains a natural character in commonly seen areas	Annually	+10% / 90%	When activities in Retention or Partial Retention areas fail to meet objectives on 10% of lands after 5 years.
WILDERNESS						
Wilderness Use	Recreation Visitor Days	RIM Report	Compare actual and planned outputs.	Annually	+20% / 80%	When actual use exceeds planned use 30% after 3 years.
Condition of Wilderness Use Areas	Sites	LAC system, Site Inspections	Compare actual and desired site conditions.	Annually	+10% / 90%	When 10% of identified sites exceed LAC in one year.
Condition of Wilderness Use Areas	Sites	LAC system, Site Inspections	Compare actual and desired site conditions.	Annually	+10% / 90%	When 10% of identified sites exceed LAC in one year.
WILDLIFE						
Fisheries Habitat Trend	Index numbers	GAWS, Field sampling; Aquatic ecosystem inventory	Assure fisheries habitat is being maintained or enhanced.	Every 4 years	±15% / 85%	When comparison to initial baseline monitoring on aquatic systems indicates significant statistical down-ward trend of fish habitat after 4 years.
Management Indicator Species Habitat Trend	Acres	State G&F surveys, Field inspections, RO3 WILD	Assure MIS habitat maintenance	Annually	±20% / 80%	When comparison of selected indicator species indicates a downward trend of habitat that deviates ± 20% from the planned rate after 4 years.
Horizontal and Vertical Diversity and Old Growth	Acres	Range analysis reports, TMIS	Compare actual and planned outputs.	Annually	±20% / 80%	When actual changes vary from that expected by ± 20% after 5 years.

WILDLIFE (cont.)						
Bald Eagle and Peregrine Falcon Habitat Trend	Acres	Field surveys; US FWS surveys; State G&F surveys	Assure T&E habitat maintenance	Annually	±20% / 80%	When actual changes vary by the % determined to be significant in the individual species plan.
Selected Species of State & Federally Listed T&E and Sensitive Plants and Animals - Habitat Trend	Acres	Field surveys U.S.F.&W.S. surveys State agency surveys	Assure habitat maintenance.	Annually	±20% / 80%	When actual changes vary by the % determined to be significant in the individual species plan.

COST						
Unit Costs for Selected Activities	$	PAMARS	Determine cost changes and efficiencies. Verify ability to implement forest plan	Annually	±10% / 90%	When actual unit costs vary from plans by ± 50% after 5 years.
Total Forest Budget	$	PAMARS	Evaluate the rate of implementation.	Annually	±5% / 95%	When actual budget varies from planned by ± 10% after 5 years.
Budget by Program Component	$	PAMARS	Evaluate the ability to implement the plan based on national program emphasis	Annually	±5% / 95%	When budgets vary by ± 10% from planned after 5 years.

Appendices

Santa Fe Municipal Watershed, Wildlife Monitoring Progress Report and Summary, March 2008

Monument Canyon Forest Restoration Project: Final Report, June 2007

Santa Fe National Forest GIS Layers, May 2008

SANTA FE WATERSHED FUELS REDUCTION PROJECT

WILDLIFE MONITORING PROGRESS REPORT AND SUMMARY

Submitted to the Santa Fe National Forest by the Rocky Mountain Research Station, Albuquerque Lab · 333 Broadway SE, Suite 115, Albuquerque, NM, 87102; Contact Karen Bagne, Ph 505-724-3684; Deborah Finch, Ph 505-724-3671; March 2008

Introduction

Changes in the historic fire regime in addition to various land management practices have increased the likelihood of high severity crown fires in the Southwest (Covington and Moore 1994, Swetnam and Baisan 1996). During these types of fires, most trees are killed, and soils left bare and prone to erosion. Conditions that increase the risk of high severity fires exist in the Santa Fe Municipal Watershed, which contains two reservoirs that provide 40% of the drinking water for the city. To protect water quality, to preserve reservoir storage capacity, and to restore sustainable watershed conditions, the Santa Fe National Forest initiated a fuel reduction program in the Santa Fe Municipal Watershed (USDA Forest Service 2001). Fuel reduction included removing smaller trees leaving an average of 50 to 100 trees per acre (124 to 247 trees per hectare). Prescribed burning is being used in conjunction with mechanical treatments to remove material left from thinning and to reduce fuels in areas too steep to thin.

Thinning and burning has the potential to affect wildlife populations, primarily by altering habitat, though measures were taken to reduce negative impacts and habitats in the watershed were not treated uniformly. Monitoring was initiated as an adaptive management strategy, but is of additional interest in the study of ecological response to disturbance and restoration. Findings will also be informative for future projects. Rocky Mountain Research Station has completed the sixth year of monitoring, including 2 years of baseline data, the response of resident wildlife to fuels reduction treatments begun in 2002. The primary focus of data collection has been on bird communities and small mammals. As budgets are reduced, we have shifted our monitoring strategy to collect data on birds or small mammals in alternating years, thus bird point counts were conducted in 2007 and no mammal trapping took place. Habitat availability was measured as structure and composition of the plant community. In addition, we collected information on arthropods, an important resource for foraging insectivores. This report summarizes data collected 2002 to 2007 on populations of resident birds (including owls), small mammals, arthropods, and the composition and structure of the vegetation. In 2006 and 2007, invasive plant species were mapped when encountered.

Methods

Study Area

The study area is comprised primarily of ponderosa pine forest at elevations ranging from 7500 to 8800 feet (2300 to 2680 m) in the Santa Fe National Forest. Additional forest types include riparian and mixed-conifer. Within the study area there are treated areas (thinned and/or burned) as well as untreated reference areas. Two reservoirs are located in the treatment area along the Santa Fe River which is bordered by riparian forest. In anticipation of future fuels reduction projects in the area, two additional reference areas were added to the study. The two original reference areas are outside of the watershed, but within 4 miles (6.5 km) near the Black Canyon Campground and the Chamisa Trailhead. The new reference areas are at the upper end of the watershed near the wilderness boundary and at the lower end below Nichols Reservoir. All reference areas remain untreated as of the time of this report.

The fuel reduction activities include; (1) reducing the density of small trees (<6" DBH, maximum 16" DBH), (2) burning piles of slash, and (3) burning of unthinned forest where steep slopes cause thinning to be impractical. Fuels reduction treatments began in the fall of 2002 and continued through 2006 though most thinning in the study area followed data collection in 2003. Most thinning in the project area has been completed as of 2006 and burning of the backlog of piles began in November 2007. Broadcast burning to maintain treatments is planned.

Study design

Linking changes observed to treatment activities is confounded by differences in space (or locality) and time. To account for differences that may be present because data are collected from different locations, we sampled treatment areas both before and after treatment occurred. Variation in time such as yearly variation can confuse outcomes, because there are more factors affecting populations between years besides the application of the treatment. Thus, multiple reference or control areas are monitored to help assess variation due to factors other than the treatment. The use of replication allows for quantification of variation between locations though, as is often the case, replication was only possible for control locations and not for treatment locations. This is generally known as a modified BACI[1] design and allows a reasonable chance of detecting a change in wildlife population estimates in response to treatments (Stewart-Oaten *et al.* 1986, Underwood 1994). The variance between reference and treatment sites can be compared with the variance within reference sites to determine if the change at the treatment site is within the range of naturally occurring changes.

Originally three reference areas were chosen, but only two remain untreated and these are both to be treated in future projects. The drafting of a new study plan in 2006 resulting in the addition of two reference areas which have no treatment planned in the foreseeable future. For 2006 results, no new areas were treated and thus there are four reference locations. Changes in sampling location by treatment are detailed in Table 1. Reference areas were chosen because they represent a range of habitat types and elevations similar to that within the thinned conditions.

Permanent points were established across the study area to collect information on bird populations, vegetation, and arthropods (Map 1). Points were chosen to cover reference areas and treatment areas as well as variation in habitat type. Small mammals were monitored at permanent locations in the same general, though more restricted, area (Map 2).   Mammal sampling locations are in two kinds of habitat, upland and riparian.

[1] Before-After, Control-Impact

Data collection began in 2002. The first two years are considered baseline data, though many protocols were being tested in 2002 which was also a drought year. There was some disturbance caused by contract work in 2003. When vegetation data was collected (~July) in 2003 only 7 permanent points were treated. Sampling over multiple years helps to sort out variation and allows us to assess when treatment effects occur and for how long within the limitations of the study period.

Table 1. Number of sampling locations used 2002 to 2006. 2002 and 2003 are primarily baseline data with little or no treatment. Only avian and vegetative data were collected in 2007. The Hyde Park Project, which will affect some reference points, is scheduled to begin in 2008.

	Avian and Vegetation Points		Mammal Webs (upland)		Mammal Transects (Riparian)		Mammal Transects (upland)	
	R	T	R	T	R	T	R	T
2002	20	71	4	6	3	3		
2003	20	71	4	6	3	3		
2004	20	71	4	6	3	3		
2005	20	71	4	6	3	3		
2006	50	64			4	2	8	4
2007	50	64						
2008 projected					3	3	6	6
2009 projected	41	73						

Bird Populations

The primary data collection method for bird populations was a variable-distance point count. Spacing between points ranged from 200 to 400 m. Collected distance data suggests that detections rapidly fall off past 110m, thus spacing at 250m and more appears to be adequate. 64 points were in ponderosa pine to be thinned, 15 points were in mixed conifer forest along drainages to be thinned, 16 points were along the riparian corridor of the Santa Fe River, 18 points were established in 2 untreated areas outside the watershed. An additional 9 points were established in the upper watershed as reference points, but 7 were treated in 2004 and are now combined with the other treated points. Two new reference locations with 16 points each were added in 2006 (Figure 1).

At each pre-established point we carried out point count surveys. We conducted point counts during four visits to each point 2002 to 2006 (May 19 – October 8). Starting at sunrise, trained observers stood at a point and recorded all birds seen or heard for a period of 8 minutes (Ralph *et al.* 1993, Ralph et al 1995). Distance from the point to each individual bird was estimated or measured using a laser range-finder. At the end of the eight-minute count, the observer continued to another point and continued the procedure until bird activity noticeably diminished (generally around 10 AM). Observers were spread evenly in space and time to reduce bias due to differences in observers in 2005 and 2006. In addition, birds recorded were divided into those seen in the first three minutes and the last five minutes of the count; the three minute data allowed for comparisons with Breeding Bird Surveys conducted in similar habitat types elsewhere (Ralph *et al.* 1993).

Because the above method is employed during daylight hours, we did additional surveys at night to establish owl species presence. Owls do not vocalize as consistently as many passerine birds, thus playbacks of owl calls were used to illicit response. A reduced number of points near roads or trails were used due to the limited ability of the technicians to safely navigate much of this rugged terrain at night. Two surveys for each of 15 points were carried out in reference and treated areas 2002 to 2005. Points were added to new reference locations for 2006 and several points that overlapped in calling area or were in areas outside the watershed were discontinued (Figure 3). Observers in teams used both silent listening and tape playback in May and June and again in July and August (Mosher *et al.* 1990). To minimize risk of predation for smaller owls, Great-horned Owl calls were only played when no other owls had been heard. If other owls were detected then Great-horned Owl playbacks were conducted on a different night alone (2005 data only). The study area is too small to obtain an accurate estimate of the population of these species and data are treated as presence/absence rather than abundance.

Avian Nest Success

Treatment effects may be manifest as changes in population size or they may have more subtle effects such as on productivity. The probability of a pair of birds fledging at least one young from the nest is a measure of nesting success. Because most failures are due to predation, this measure is correlated with predation risk.

Nests were located in the study area from 2002 to 2007. Located nests were monitored to determine contents of the nest either through direct viewing or based on parental behavior until nests either fledged young or were no longer active. Before 2005, nests were only monitored once every 7 days making the determination of fate difficult. In 2005 and subsequent years, nests were monitored every 3 - 4 days and only these data are used in nesting success calculations. Apparent success rates (# success/# nests) is biased because nests found late in the nesting cycle are likely to succeed and nests that fail early are not found. Nests were found at all stages in the nesting cycle and thus estimates of nesting success are based on the Mayfield method (Mayfield 1975), which takes into account the number of days the nest has been under observation. Nests of any species were located 2002 to 2005, but to better assess success, we targeted particular species in 2006. These included primary cavity nesters, secondary cavity nesters (chickadees), vireos, and flycatchers.

Mammals

For small mammals, two habitat types were monitored and up until 2006 had different methods (Fig. 2). In upland habitats, we used trapping webs composed of 80 traps per web to estimate density (Anderson *et al.* 1983, Link and Barker 1994). Each web consisted of eight 50-m transects arranged from a permanent center point 45 ^{o} apart. Traps were placed in 5-m intervals from the center of the web, creating 10 concentric circles of 8 traps each. Trapping webs were located in ponderosa pine and mixed-conifer forest types at a total of 6 webs in the treatment area and 4 webs in reference areas. Unfortunately sampling rates are low, especially in the upland habitats, resulting in sample sizes to small to make accurate density estimates as intended. As of 2006, uplands are sampled using the same transect method used in riparian area because transects have higher capture rates, have more traps (80 vs 100), and are comparable to riparian methods. In riparian habitats, traps were placed in linear transects to estimate abundance and species composition (Otis *et al.* 1978). Three riparian transects were located in the treated areas and three in untreated areas for 2002 to 2005. In 2006, one treated transect, that was immediately adjacent to another, was discontinued and a new reference transect established below Nichols Reservoir. Starting points are permanent and each transect consists of 100 traps at

5m intervals. For both types of sampling, traps were set and sampled over three consecutive nights twice a year, once in June/July and once in August/September. Standard procedures were followed to minimize adverse effects on mammals and to adequately protect field crews from infectious diseases including Hantavirus. All individuals were ear-tagged in order to gather survivorship data and to allow future population size estimation based on mark-recapture methods,.

In addition to trapping, we noted the occurrences of sciurids (squirrels and chipmunks) during regular point count surveys for birds.

Arthropods

Arthropods are an integral component of the ecological community and serve as a critical food base for both birds and small mammals. Arthropod diversity and abundance were estimated using beating sheets at the vegetation points (see plant community composition and habitat structure below) in each habitat (Ausden 1996). Generally one sample was taken from each quadrant in vegetation plots attempting to maximize sampled plant diversity. Samples were preserved in alcohol for later identification to family. To date all but a few samples have been identified and cataloged.

Plant community composition and habitat structure

Plant community composition and habitat structure in each plot were characterized using 0.04 ha (0.1 acre) circular plots (a circle with an 11.3m radius) at each point (Higgins et al. 1996). All points were sampled in each year 2002 to 2005, but in 2006 we switched to sampling of a random half of the points each year because vegetation is anticipated to change little annually at this point. To avoid characterizing ground cover that is disturbed by repeated visits to the points for avian point counts, we randomly selected a bearing and placed the center of each vegetation plot at 40 m from the permanent point and this location is used in every year. Some variables were sampled in a nested 5-m plot (Bullock 1996). Estimates of canopy cover were done using a sighting tube at 1-m intervals in 4 cardinal directions. The presence or absence of canopy was totaled over the 40 points to estimate percent canopy cover. Ground cover was estimated using a 1m square in the 4 quadrants. The cover of abiotic, litter, and biotic material was estimated in each. In 2002, 2005, and 2006, the amount of bare soil was estimated in addition to abiotic cover. All trees, including snags that occurred within the 0.04 ha (0.1 acre) circle were recorded by species and size (dbh or diameter at breast height at 1.3m above the ground). Photos were taken at each vegetation point.

Vegetation measurements were also made at nest locations generally following the above and the Breeding Biology Research and Monitoring Database (BBIRD) protocol in 2006 (Martin et al. 1997). Additional measurements include characteristics of the nesting substrate, nest concealment at 1 meter, and distance to water.

Invasive plants

In 2006 and 2007, we inspected areas within the fuels treatment area of the Santa Fe Municipal Watershed for invasive species occurrence, primarily where we conduct wildlife monitoring. In 2007, we also conducted a few surveys in areas outside our usual routes (Figure 2). We noted presence by species and also estimated quantities in each single location.

A species is generally defined as invasive if non-native with a high potential to spread and we targeted those listed in the Final EIS Invasive Plant Control (USDA Forest Service 2005). We included a few additional non-native species. One is prickly lettuce, *Lactuca serriola*, a biennial from Europe that is on the weed alert lists for the Northeast and North Central regions and is listed as invasive in Weeds of the West (Whitson 1996). The other is *Bromus tectorum*, cheatgrass, a widespread species from the Mediterranean listed as a noxious weed in Colorado. In 2007, we noted dalmation toadflax (*Linaria dalmatica*) and Russian thistle (*Salsola kali*) for the first time and noted a few known locations of Russian olive (*Elaeagnus angustifolia*). Russian olive and dalmation toadflax appear on the New Mexico state noxious weed list.

Not all areas within the Santa Fe Watershed were surveyed. Surveys focused on trails where equipment accessed the site as these areas were more disturbed and equipment is a potential source of seeds (D'Antonio et al. 1999, Merriam et al. 2006). We did not focus on the road or riparian area as there already is some information on invasive occurrence and these areas are easily accessed. When practical, invasive plants were removed by hand when found.

Management Indicator Species

Santa Fe National Forest recognizes a number of species whose populations are sensitive to forest management practices and considered good indicators for assessing impacts of forest activities. These are management indicator species (MIS). Bird species that are MIS and potentially detected during day or night time surveys include Merriam's turkey (*Meleagris gallopavo* merriami), mourning dove (*Zenaida* macroura), Mexican spotted owl (*Striz occidentalis lucida*), hairy woodpecker (*Picoides villosus*), and piñon jay (*Gymnorhinus cyanocephalus*). The remaining two MIS are large mammals not targeted by Rocky Mountain Research Station for monitoring, elk (*Cervus elaphus nelsoni*) and Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*). No portion of the watershed sampled during monitoring activities was suitable for Rocky Mountain bighorn sheep and is not considered further. Because MIS are of particular interest, this section reviews information from MIS monitored and presents any additional information known.

Statistical analyses

-Birds

Because individuals sampled use a larger area than that immediately at the point and treatment may affect populations within a broad area, data was assigned to treatment or reference based on the surrounding area rather than specific activities at the point of measurement. For example, no thinning may occur at a point, but if the majority of surrounding areas are thinned, then the point was designated as treated. Because count periods included the breeding season and migratory periods, bird populations are expected to vary considerably over time. Thus data were divided into early (mid-May to mid-July) and late counts (mid-July to October) though there was still considerable variation in date of counts particularly in 2002. In this report, counts were used as an index of avian abundance and are represented as detections/point/year. Any points not surveyed in every year were removed from this analysis along with riparian points which differ in habitat and detection rates because of water noise. Additionally, 12 points in the late counts were removed for 2003, because treatment was noted near these locations during August and September. Distance was not used to estimate detectability because only two species had adequate sample sizes for each year in each treatment type. Avian species with low counts (<40 total) were excluded from analysis, but are listed in Appendix A.

For evaluating the abundance by index, impact was evaluated using PROC GLIMMIX (SAS Institute 2002) with a Poisson distribution (to accommodate count data) for summed counts of early and late rounds separately (2 counts/point/year). Year was considered a random rather than a fixed effect with point as the subject, because counts are repeated within a year on each point. This addition helps removing differences due to repeating counts in locations and differences due to point locations, both of which may be present in data, but are not of interest to evaluating treatment effects. A significant interaction term of time (before vs. after) and treatment (yes or no) was considered indicative of a treatment effect. The interaction term evaluates if change over time is different between reference and control sites. Thus we would expect the measure of interest to change differently between the two types of sites if treatments are affecting populations. Species were included if the total N was greater than 120 (i.e. average 10 per treatment per year), but some species' populations could still not be modeled. This was sometimes due to low sample sizes, but strong treatment effects which resulted in strongly skewed data were also problematic. Some species also fit poorly when modeled with the generalized mixed model according to deviance values (0.6> X^2 >1.4). All these species were of interest, thus we used a second approach to evaluate treatment effects. A multi-permutation procedure (MRPP) was used for the remaining species. This technique does not require that the distribution of data be known and tests the differences between groups using Euclidian distance and testing the uniqueness of differences based on permutations or other possible combinations of the data (Zimmerman et al. 1985). Lastly, for species of lower populations ($40<N<120$) we combined data into 2 year intervals and evaluated using MRPP. Timing of response is of interest, thus we grouped "before" data and compared against each "after" year when possible. A *P*-value of <0.05 was used for significance.

-*Nest Success*

From 2005 to 2007, nests were monitored for the entire nesting period and only those data were used to estimate nest success. Mayfield estimates are used to estimate success rates for nests located in treated and reference areas (Mayfield 1975). Standard errors are estimated following Hensler and Nichols (1981). Additionally, nests are grouped by type, cavity or open nests, as these have known differences in success rates. Success rates between treated and reference areas for these two nesting groups are compared using the program CONTRAST (Hines and Sauer 1989).

-*Mammals*

Mammal data was collected in two habitats with two methods and are analyzed separately. For both datasets, mammal populations were estimated from mark-recapture data using Program MARK when sample sizes were large enough. To reduce the number of parameters that need to be estimated, we used the Huggins closed population estimator for each round separately and estimated initial capture and recapture probabilities. Where data were too sparse, initial capture and recapture probabilities were set as equal which is the equivalent of assuming there is no behavioral response to trapping (i.e. trap happy or trap shy). There is concern that probability of capturing individual mammals may differ between reference and treatment locations so we estimated populations and capture probabilities separately for treatment and reference locations in each year. Estimated parameters were then used to generate population size estimates for each sampling locations. These population estimates were analyzed for treatment effect using a generalized linear mixed model in PROC GLIMMIX. Populations differed significantly between rounds so the two rounds were analyzed separately. Each year after treatment is compared with the baseline years using the interaction terms. The use of program DISTANCE, while appropriate for the web data, is not recommended when samples sizes are small (<50). Thus we used the population estimates from the mark-recapture data for both upland and riparian sites noting that trapping area differed between these two habitats. For upland sites in 2006, trapping effort was altered by converting from webs to transects and these data are included separately though now trapping area is the same between habitats.

For those species with too few recaptures to estimate population sizes in MARK, the number of unique individuals captured is used as an index of abundance and analyzed using the generalized linear mixed model described. Many species were caught too infrequently to evaluate statistically, thus data are also presented as individuals per trapnight (the number of traps available for capturing individuals over time) for all species.

-*Vegetation*

For vegetation analyses, treatment and reference areas were assigned based on conditions immediately at the point of interest. Generalized linear mixed models were used by implementing PROC GLIMMIX (SAS Institute, 2002) to evaluate treatment effects ($p < 0.05$) as indicated through the interaction term (time*treatment). Mixed models can account for random effects in the data such as assignment of treatment. Nonlinear link functions can be used with this procedure to deal with violations from the normal distribution instead of transforming the data. Fit of the data was evaluated by testing normality of the studentized residuals.

Results

Birds

Considerable annual variation was observed across years. Mean counts for all species are presented in Appendix A. Seventy-nine species have been recorded during counts though many are infrequently encountered. For analysis by post treatment year, 28 species were analyzed statistically (Table 2). Direction of estimate is in comparison to reference sites, thus a positive value indicates a negative response to treatment. Mourning Doves, Broad-tailed Hummingbirds, Northern Flickers, Hairy Woodpeckers, Western Wood-Pewees, Common Ravens, Clark's Nutcrackers, White-breasted Nuthatches, Plumbeous Vireos, Western Bluebirds, Violet-green Swallows, and Pine Siskins responded positively to treatment in at least one year. Hermit Thrushes, *Empidomax* flycatchers, Yellow-rumped Warblers, Steller's Jays, Townsend's Solitaire, American Robins, and Western Tanagers had negative responses. Warbling Vireo had a mixed response. Six species show no differences in counts in response to treatments in any period. For less common species, Olive-sided Flycatcher had a positive response to thinning while there was no response for Black-headed Grosbeak or Brown Creeper (Table 3). Eleven bird species presented are on the Partners in Flight list for regional concern in the southern Rocky Mountains. This designation is based on population assessments created by Partners in Flight and includes population trend, extent of breeding populations, etc. (Panjabi et al. 2005). Eight of these species had a positive response to treatment and one had a mixed response. Grace's Warbler is regionally declining and had a borderline negative response (P = 0.08), but only in the first year following treatment (Table 2, Figure 1.A). Broad-tailed Hummingbirds have increased on thinned points while they declined on reference points. Western Bluebirds are only recorded at treatment points and have increased following thinning

Table 2. Response of common (total N>120) bird species to thinning over each post-treatment year. Mean differences between reference and control points over time are presented along with *P*-values from statistical tests. Generalized linear mixed models (GLMM) were used with multi-response permutation procedure (MRPP) used when models did not converge or fit was poor ($0.6>X^2/DF>1.4$). Direction of estimate is in comparison to reference sites, thus a positive value indicates a negative response to treatment. *P*-values <0.05 appear in bold.

Species	Period[a]	Analysis	Post year 1 mean difference[b]	*P*	Post year 2 mean difference[b]	*P*	Post year 3 mean difference[b]	*P*	Post year 4 mean difference[b]	*P*
Mourning Dove	early	MRPP	-0.05	0.12	-0.06	0.14	-0.26	**0.04**	**-0.05**	0.39
Broad-tailed Hummingbird*	early	GLMM	-0.23	0.06	-0.21	0.06	-0.16	0.12	**-0.26**	**0.05**
	late	MRPP	-0.18	0.10	**-0.30**	**0.03**	0.04	0.83	0.05	0.64
Northern Flicker	early	GLMM	-0.23	0.12	**-0.29**	**0.05**	-0.07	0.38	**-0.32**	**0.02**
	late	GLMM	-0.24	0.18	0.07	0.65	-0.11	0.64	-0.26	0.42
Hairy Woodpecker	early	MRPP	**-0.21**	**0.02**	-0.05	0.45	**-0.25**	**0.01**	-0.03	0.67
	late	GLMM	-0.10	0.26	-0.06	0.81	-0.08	0.24	0.09	0.30
Western Wood-Pewee	early	MRPP	**-0.23**	**0.001**	**-0.40**	**<0.001**	**-0.42**	**<0.001**	**-0.51**	**<0.001**
	late	MRPP	**-0.27**	**0.01**	**-0.37**	**0.01**	**-0.69**	**<0.001**	**-0.77**	**<0.001**
Empidomax Flycatcher[c]	early	MRPP	-0.01	0.24	0.05	0.35	**0.22**	**0.04**	0.20	0.34
Cordilleran Flycatcher*	early	MRPP	0.02	0.68	-0.16	0.16	-0.01	0.88	-0.09	0.72
Plumbeous Vireo*	early	MRPP	-0.01	0.35	-0.09	0.18	**-0.30**	**0.01**	**-0.24**	**0.04**
	late	MRPP	0.01	1.00	0.26	0.21	0.19	0.09	-0.13	0.12
Warbling Vireo*	early	MRPP	**-0.32**	**0.01**	**0.51**	**<.001**	**0.06**	**<.001**	**0.32**	**<.001**
Steller's Jay	early	GLMM	0.07	0.44	0.01	0.41	-0.07	0.61	**0.53**	**0.01**
	late	MRPP	**0.42**	**0.02**	0.23	0.39	0.39	0.07	0.03	0.48
Clark’s Nutcracker*	late	MRPP	**-0.64**	**0.07**	**-0.62**	**0.03**	**-0.65**	**0.02**	**-0.53**	**0.02**

Species	Period[a]	Analysis	Post year 1		Post year 2		Post year 3		Post year 4	
			mean difference[b]	*P*	mean difference[b]	*P*	mean difference[b]	*P*	mean difference[b]	*P*
Common Raven	early	GLMM	-0.13	0.63	-0.32	0.09	-0.20	0.24	-0.11	0.51
	late	GLMM	**-0.48**	**0.01**	-0.26	0.18	**-0.43**	**0.02**	-0.08	0.80
Violet-green Swallow*	early	MRPP	**-0.30**	**0.02**	**-0.30**	**0.04**	**-0.66**	**0.00**	**-0.57**	**<0.001**
	late	GLMM	**-0.35**	**0.01**	-0.51	0.05	**-0.42**	**0.03**	**-0.71**	**0.01**
Mountain Chickadee	early	GLMM	-0.45	0.09	0.22	0.36	-0.29	0.16	0.23	0.37
	late	GLMM	0.06	0.93	0.58	0.50	0.30	0.33	-0.06	0.63
White-breasted Nuthatch	early	GLMM	-0.01	0.54	-0.10	0.20	0.06	0.57	0.21	0.70
	late	GLMM	**-0.42**	**0.001**	**-0.54**	**0.001**	0.04	0.66	-0.27	0.07
Red-breasted Nuthatch	early	GLMM	-0.19	0.28	-0.11	0.75	-0.18	0.55	0.11	0.18
	late	GLMM	0.00	0.22	-0.09	0.97	-0.17	0.85	-0.10	0.10
Pygmy Nuthatch*	early	MRPP	**-0.36**	**0.01**	-0.08	0.20	**-0.33**	**0.01**	**-0.31**	**0.00**
	late	MRPP	-0.02	0.26	**-0.59**	**0.001**	0.03	0.13	**-0.15**	**0.01**
Western Bluebird*	early	MRPP	**-0.08**	**0.01**	**-0.35**	**<0.001**	**-0.19**	**0.00**	**-0.26**	**0.00**
	late	MRPP	**-0.02**	**0.05**	**-0.20**	**0.01**	0.04	0.18	**-0.41**	**<0.001**
Townsend's Solitaire	early	GLMM	0.07	0.46	0.20	0.10	0.29	0.06	**0.33**	**0.03**
American Robin	early	GLMM	0.05	0.59	0.10	0.37	**0.61**	**<0.001**	-0.01	0.93
Hermit Thrush	early	GLMM	0.20	0.14	**0.42**	**0.02**	**0.48**	**0.01**	**0.70**	**0.00**
Yellow-rumped Warbler	early	GLMM	**0.52**	**0.01**	-0.07	0.83	0.25	0.42	**0.29**	**0.01**
Grace's Warbler*	early	GLMM	0.29	0.08	0.27	0.21	0.23	0.22	-0.04	0.68
Western Tanager	early	MRPP	-0.07	0.38	0.02	0.76	**0.32**	**0.03**	0.30	0.39
Chipping Sparrow	early	MRPP	0.23	0.07	-0.11	0.23	-0.03	0.68	-0.08	0.59
Dark-eyed Junco	early	GLMM	0.06	0.43	-0.27	0.14	-0.02	0.29	0.01	0.65

Species	Period[a]	Analysis	Post year 1		Post year 2		Post year 3		Post year 4	
			mean difference[b]	*P*	mean difference[b]	*P*	mean difference[b]	*P*	mean difference[b]	*P*
	late	GLMM	-0.32	0.13	0.29	0.25	-0.32	0.12	-0.09	0.96
Pine Siskin*	early	MRPP	-0.12	0.40	-0.29	0.20	-0.18	0.50	**-0.33**	**0.02**
	late	MRPP	0.11	0.38	-0.19	0.11	-0.07	0.09	**-0.57**	**<.001**

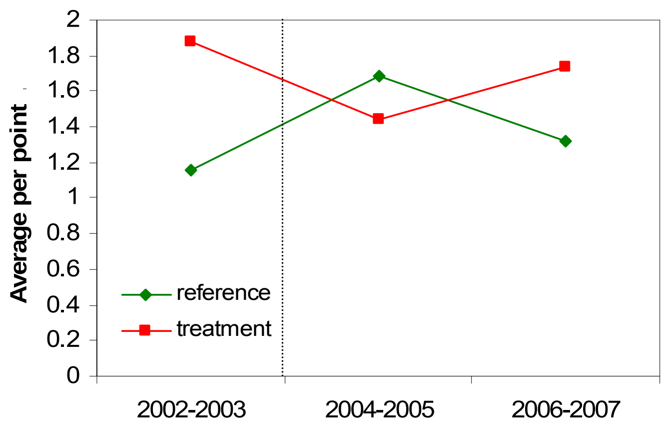
[a] Period of point count. "Early" are points conducted mid-May through June. "Late" are August through September
[b] Difference in average number per point based on (REFpost - REFpre) - (TRTpost - TRTpre), REF = reference TRT = treatment
[c] Includes species identified as Hammond's Flycatcher and Dusky Flycatcher
* Partners in Flight species of regional concern in southern Rocky Mountains

Table 3. Uncommon species response to treatment for the study period divided into two year intervals. Results from multi-response permutation procedure (MRPP). *P*-values <0.05 appear in bold.

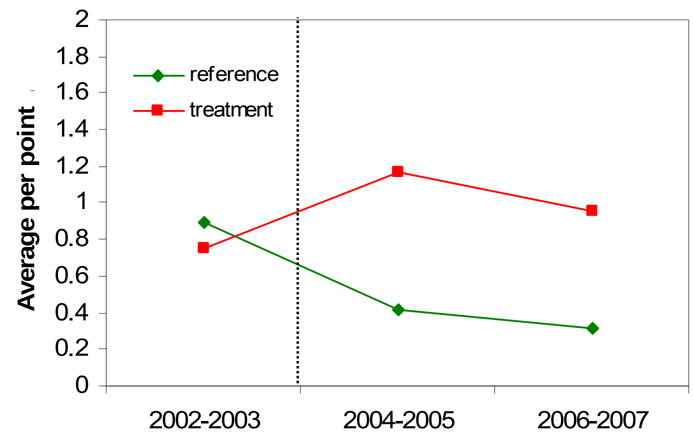
Species	Period[a]	Post year 1-2		Post year 3-4	
		mean difference	*P*	mean difference	*P*
Brown Creeper	early	0.004	0.71	0.08	0.37
	late	-0.02	0.12	-0.12	0.12
Olive-sided Flycatcher*	early	-0.09	0.14	**-0.31**	**0.002**
Black-headed Grosbeak	early	0.15	0.21	-0.06	0.27

[a] Period of point count. "Early" are points conducted mid-May through July. "Late" are August through September
* Partners in Flight species of regional concern in southern Rocky Mountains

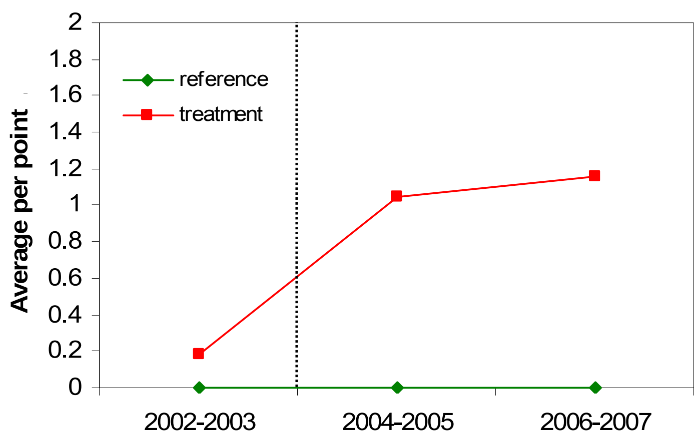
Figure 1. Changes in counts on reference and treatment points over time for selected regionally declining bird species



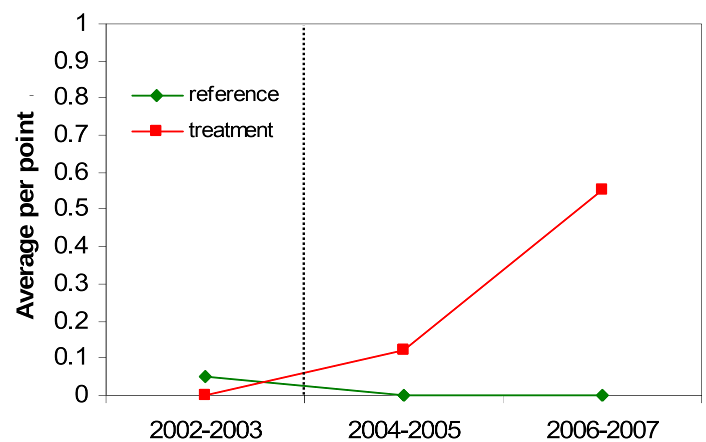
A. Grace’s Warbler counts from mid-May to mid-July.



B. Broad-tailed Hummingbird counts from mid-May to mid-July.



C. Western Bluebird counts from mid-May to mid-July.



D. Olive-sided Flycatcher counts from mid-May to mid-July.

(Figure 1.C). Olive-sided Flycatchers have seldom been recorded at reference points and have increased at thinned points (Figure 1.D).

Few owls were heard during surveys (2003-2007). Data on owl species are best viewed as presence/absence because survey points are only visited twice and repeat detections can be from the same individuals. Reference surveys for owls were shifted to the upper and lower boundaries of the watershed, thus some differences in habitat are likely. For example, a pair of Western Screech Owls is regularly detected at the lower boundary of the watershed where the habitat contains more piñon pine and open rocky areas. The most commonly present owls throughout the study area are Flammulated Owls and Great-horned Owl (Table 4). Both these species occurred on treatment and reference areas after thinning for all periods post-treatment. Overall owl detections were higher in treatment areas before treatment then declined on treatment areas immediately after thinning before returning to the pre-treatment pattern. Mexican Spotted Owls have not been detected during any survey, but we detected a single male Spotted Owl in 2007 outside of regular surveys. On June 4, a Spotted Owl was heard spontaneously calling near the Black Canyon Campground around 10:30 PM. On June 5, playbacks were used unsuccessfully to elicit response, but the individual was heard again later in the evening. This male was assumed to be a floater, a male not holding a territory, because the owl was not heard again even though the field crew was staying at the campground throughout the season.

Table 4. Average numbers of owls detected per point per year by species before (2003) and after treatments (2004-2005, 2006-3007). There were some differences in reference locations for 2006-2007.

	Before		2004-2005		2006-2007	
	Reference	Treatment	Reference	Treatment	Reference	Treatment
Flammulated Owl (*Otus flammeolus*)	0.5	0.3	0.5	0.1	0.4	0.4
Northern Pygmy-Owl (*Glaucidium gnoma*)	0.2	0	0	0.1	0	2
Northern Saw-whet Owl (*Aegolius acadicus*)	0	0.2	0.2	0	0	0
Western Screech-Owl (*Otus kennicotti*)	0	0.1	0	0	0.4	0.3
Mexican Spotted Owl (*Strix occidentalis*)	0	0	0	0	0	0
Great-horned Owl (*Bubo virginianus*)	0	0.2	0.2	0.2	0.1	0.4
TOTAL	**0.7**	**0.9**	**0.8**	**0.4**	**0.9**	**1.3**

Avian Nest Success

Nests of targeted species were monitored in 2006 (54 nests) and 2007 (73 nests) (Table 5). Estimates of success were higher for cavity-nesting birds, which is typical because predators have reduced access to the nest (Table 6). Probability of a nest surviving to 30 days was somewhat higher on treatment areas for open-cup nesters and slightly lower for cavity nesters. In 2005, there was no difference between reference and treatment success rates for cavity nesters (X^2_1 = 1.05, P = 0.30), but success in reference areas was higher in 2006 (X^2_1 = 17.13, P <01). Success rates was lower on reference locations for open-cup nesters in 2006 (X^2_1 = 57.03, P <01) and the effect was borderline in 2005 (X^2_1 = 3.60, P = 0.06). Sample sizes for reference areas are small making interpretation difficult. By 2007, nesting success was no longer different for open-cup (X^2_1 = 0.48, P = 0.49) and was only somewhat different for cavity nests (X^2_1 = 3.54, P = 0.06), though now in the opposite direction from 2006.

Table 5. Numbers of nests by bird species in 2006 and 2007 when specific groups of species were targeted. These are for the data that appears in Table 6.

	2006		2007	
Species	T	R	T	R
Cavity				
Hairy Woodpecker	4	1	2	1
Northern Flicker	6	4	7	4
Red-naped Sapsucker	1	1	1	3
Mountain Chickadee	7	5	4	5
Open-cup				
Cordilleran Flycatcher	1	0	11	4
Hammond's Flycatcher	2	2	1	3
Plumbeous Vireo	0	2	5	0
Warbling Vireo	8	9	10	8
Western Wood-Pewee	1	0	4	0

Table 6. Percent of nests that were successful at 30 days as estimated by the Mayfield method for 2005 to 2007 by treatment. Nests are also categorized as cavity or open-cup nests.

	Treatment				Reference			
	Open-cup		Cavity		Open-cup		Cavity	
	n	% success	n	% success	n	% success	n	% success
2005	26	48.3	18	73.7	11	35.6	10	80.1
2006	15	54.3	18	62.6	11	10.5	12	82.7
2007	31	59.4	14	83.7	15	62.0	13	75.3

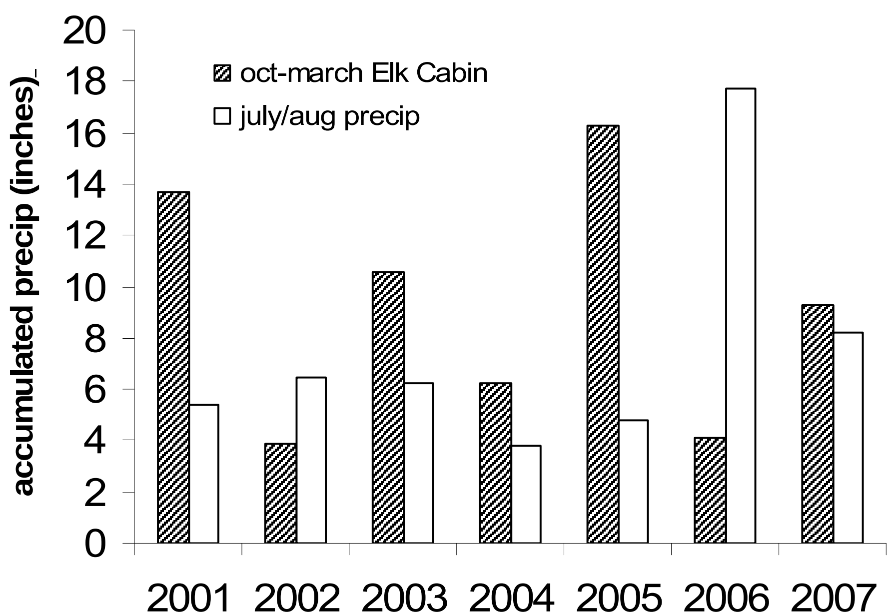
Mammals

A total of 2,725 individual small mammals, not including recaptures, were trapped from 2002 to 2006 (Appendix B). Mammal trapping was temporarily suspended in 2007. Seventeen species have been identified though shrews were not identified to species. Shrews, along with other mammals, that died in traps were donated to the museum of Southwestern Biology at the University of New Mexico and all these were identified as montane shrew, *Sorex monticolus*. Capture rates for diurnal species such as squirrels are dependent on the hours when traps are open and thus differences between years may reflect this effect rather than differences in populations. A manuscript related to mammal populations was submitted to the journal *Fire Ecology* and appears at the end of this report. Information related to deer mouse, vole, and chipmunk populations is the same as appeared in the 2006 report, but information on total biomass, and the relationship between rainfall and deer mouse populations appears in the manuscript.

In summary, deer mouse populations had a significant positive treatment effect overall and evaluation based on post treatment years indicates that the positive effect was in 2005. This was true for both upland and riparian habitats though for upland habitats it was only for August trapping. This response was not found for any of the other years post treatment. Voles (*Microtus longicaudus* and *Microtus pennsylvanicus*) were captured only on riparian transects and populations were estimated using recapture data in MARK. Voles also showed a significant positive treatment effect with populations generally declining on reference areas (average decline of 7 voles per transect per round) and generally increasing on treatment sites (average increase of 2 voles per transect per round). Dividing data into post-treatment years revealed that the treatment effect was present in 2005 and 2006. Evaluation of this data are confounded by the fact that all treatment riparian locations are below dams (i.e. water flow is regulated) while all reference riparian locations are not below dams. Chipmunks were regularly trapped in upland areas though numbers were too small to estimate populations based on recapture data. Using the number of unique individuals as an abundance index, we found no effect of treatment on these species (treatment*time, F = 0.32, P = 0.57). There was no effect of treatment on total biomass of small mammals.

Precipitation varied considerably during the study period, both for winter and summer (Figure x). Removing the periods when deer mice showed treatment effects,

Figure 2. Accumulated precipitation in inches for winter (Oct.1 to March 31) and July/August only. Data from Elk Cabin SNOTEL site in the Santa Fe Municipal Watershed. 2001 is the year prior to the start of the study.



we found that their populations had a curvilinear relationship with winter precipitation. In other words, deer mice increased as winter precipitation increased up to a point where more winter precipitation depressed populations. Summer precipitation had a negative effect on deer mice in riparian but not upland habitats and this effect was linear. In the winter of 2005 there was high winter precipitation for which we would predict a decline in deer mouse populations. This was also the year when we found an increase in deer mice on treatment areas relative to reference areas. We hypothesized that thinning alleviates the negative impacts of high winter snows by stimulating earlier melting of the snow allowing herbaceous growth (i.e. cover and food for deer mice) to appear earlier. See the attached manuscript for more details.

Sciurids recorded during point counts could be analyzed using the same methods described for birds. Most recordings were auditory only and red squirrels (*Tamiasciurus hudsonicus*) were the most vocal species. Sciurids

Table 7. Counts of sciurids detected during avian point counts. Analysis is from multi-response permutation procedure. *P*-values <0.05 are shown in bold.

Species	Period[a]	Post year 1		Post year 2		Post year 3		Post year 4	
		mean[b] difference	*P*	mean difference	*P*	mean difference	*P*	mean difference	*P*
sciurids	early	**-0.17**	**0.05**	-0.04	0.1	-0.38	0.18	**0.37**	**<0.001**
	late	**0.33**	**0.006**	**0.70**	**<0.001**	**0.29**	**0.03**	**0.94**	**<0.001**

[a] Period of point count. “Early” are points conducted mid-May through June. “Late” are August through September
[b] Difference in average number per point based on (REFpost - REFpre) - (TRTpost - TRTpre), REF = reference TRT = treatment

decreased on thinned areas as compared to reference areas for all late counts in all years and for early counts in 2007 as well.

Arthropods

Arthropods were collected from up to 4 quadrants for 122 points in the study area in each year with some variation in effort and date. The most samples were collected in 2002 with 800 samples and the lowest was in 2004 with 326 samples though this does not include sampling that resulted in zero individuals. Individuals have been identified to family for 2002 through 2006 (Table 8). River points represent a different habitat and are not treated, but are adjacent to treated areas. Thus to avoid confusion riparian samples are included separately. Arthropods sampled come from 2 classes, Insecta and Arachnida (spiders). In general there was greater abundance of arthropods in the riparian habitats. Treatment seems to have had a fairly neutral effect though large numbers in 2003 make interpretation difficult.

Table 8. Average number of individual arthropods collected per sample and the number orders and families per year. Treatments do not occur until after most sampling in 2003. River or riparian areas are adjacent to treated areas. 2006 is for a random subset of half the points.

	Reference		Treatment		River		Orders	Families
	n	#/sample	n	#/sample	n	#/sample		
2002	197	4.1	523	4.2	80	5.3	11	46
2003	79	12.3	316	7.5	62	14.8	15	82
2004	52	5.1	214	7.4	60	7.2	13	60
2005	64	4.3	283	4.7	57	7.0	19	126
2006	63	6.4	119	5.7	31	5.0	15	69

In Table 9, we summarize data from a number of commonly collected arthropod families. The family Thomisidae (crab spiders) has generally increased from low collections in 2003. Reference areas had higher numbers in 2006, but this was not observed consistently over all post-treatment periods (Table 9). In the Chrysomelidae or leaf beetles, the number collected was higher on treatment than reference in one post-treatment year, but was similar in the other two years. Aphidae (aphids) were more common on treatment areas compared to reference areas in two

Table 9. Average number of individuals per point for common arthropod families on reference, treatment, and points along the Santa Fe River. 2002 and 2003 are primarily before treatment. The number of samples varies by year and location, and is highest for treatment and lowest on the river.

Order	Aranae			Coleoptera		
Family	Thomisidae			Chrysomelidae		
	Reference	Treatment	River	Reference	Treatment	River
2002	0.17	1.00	0.00	0.00	0.01	0.00
2003	0.02	0.04	0.02	0.45	0.33	0.10
2004	0.20	0.28	0.11	0.16	0.15	0.32
2005	0.20	0.15	0.04	0.34	0.33	0.46
2006	0.62	0.42	0.19	0.06	0.17	0.06

Order	Homoptera			Hymenoptera		
Family	Aphidae			Formicidae		
	Reference	Treatment	River	Reference	Treatment	River
2002	12.39	8.33	6.18	0.36	0.57	1.09
2003	8.05	3.50	5.14	0.47	0.68	1.10
2004	0.15	0.12	0.23	1.12	0.56	0.24
2005	0.47	0.64	0.07	0.19	0.60	0.52
2006	0.43	0.63	0.26	0.40	0.54	0.16

post-treatment years whereas treatment locations were lower during both pre-treatment years. Large numbers of aphids were captured in 2002 and 2003. Formicidae or ants had fairly consistent numbers over time on reference and treatment areas. Ants declined on riparian sites, an effect that seems unlikely to be related to sampling.

Plant community and habitat structure

A small subset of the data on plant communities and habitat structure was analyzed to evaluate changes that occurred following treatments. For snags, we used fitted the data with a log link function, similar to log-transforming the data. Data from 2006 was not included as it does not have a complete set of points and has additional points from new reference locations.

Thinning resulted in a reduction of both small and large snags (Table 11). Snags remained relatively unchanged on unthinned plots. Over time, however, snags fall and new snags are created, thus we included data from two post-treatment periods (Table 10). Large snags and small snag densities changed very little over the four years on unthinned points. On thinned plots there was a small increase in large snags, perhaps from bark-beetle kills, and some loss of small snags.

Not surprisingly, thinned areas had a different trees species composition and size distribution than reference locations (Figure 3). This is primarily apparent for ponderosa pines where small trees (≤20 cm dbh) were more sparse in the thinned areas, but larger sizes are similar (Figure 3). Both fir species were less common in thinned areas than reference areas. Limber pines and Gambel oak were similar.

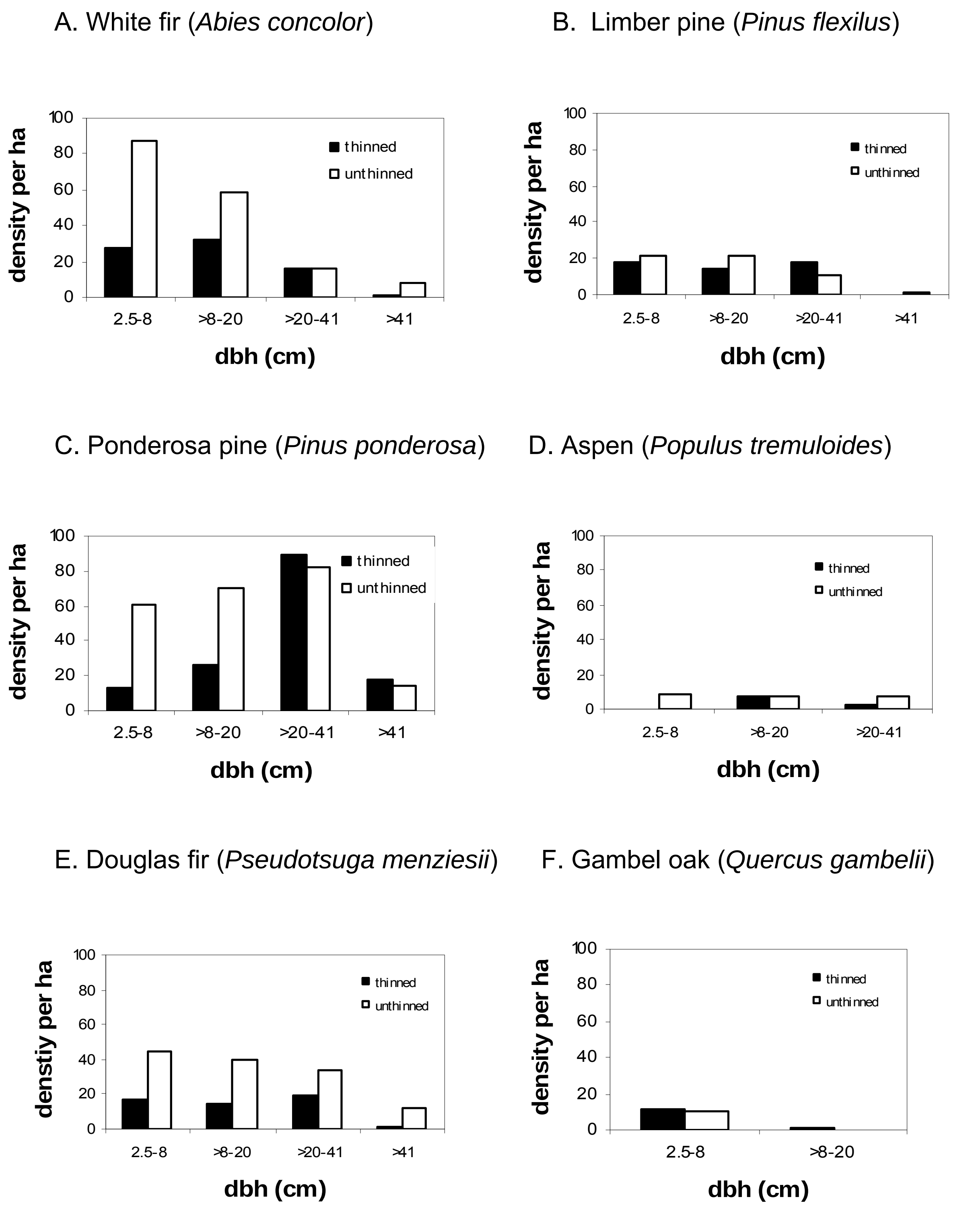


Figure 3. Density and size distribution of common tree species from thinned upland sites and unthinned reference areas.

Table 10. Mean density of snags (ha^{-1}) for points before and after treatment on reference and treatment sites.

	Large snags (≥12cm)			Small snags (<12cm)		
	Before[a]	2004-2005	2006-2007	Before	2004-2005	2006-2007
Unthinned	40.5	48.0	48.4	125.0	133.0	104.9
Thinned	45.0	24.8	28.9	113.8	47.0	31.5

[a] Data from 2002 and 2003

Table 11. Results from generalized linear mixed model for snag numbers showing *F* statistic and *P*-values for 2002 to 2005 (n = 472). The interaction of Time*Treatment indicates a significant effect of treatment.

	Large snags (≥12cm)		Small snags (<12cm)	
	F	*P*	*F*	*P*
Time (Before vs. after)	4.25	0.04	4.19	0.04
Treatment (Reference vs. Thinned)	7.11	0.008	14.73	<0.001
Time*Treatment	10.48	0.001	11.98	<0.001

Aspen was less common overall in thinned areas than unthinned areas, but this species was uncommon and occurred in discrete patches in both areas (Figure 3).

Of particular interest are those snags used by wildlife. Ponderosa pine snags, aspen snags, and snags of large diameter are generally associated with use (Table 12). In the most recent survey there were 44 of 164 snags ≥12cm that were ponderosa pine and 29 that were aspen though these were restricted to drainages. Eighteen snags were >40 cm in diameter and only 6 of these were ponderosa pines. The average diameter of snags >12cm and those able to allow excavation, was 25 cm for both thinned and unthinned sites, smaller than those chosen by most cavity nesters.

Table 12. Cavity nester use of snags by tree species and diameter (cm). Cavities re-used for multiple years only appear once.

Bird species	# snag nests (% snags used)	Average diameter	% Ponderosa pine	% Aspen	% other
Hairy Woodpecker	7 (50%)	26.2	20	60	20
Northern Flicker	16 (86%)	44.2	39	39	22
Mountain Chickadee	18 (38%)	36.4	25	38	37

For percent cover at ground level, there were no significant differences found following treatments. Tests of the interaction of time and treatment (i.e. treatment effect) were non-significant for biotic (*F* = 0.03, *P* = 0.86), abiotic (*F* = 1.25, *P* = 0.26), and litter (*F* = 0.03, *P* = 0.86). Cover of biotic (living plants), litter, and abiotic (soil, rocks, etc.) were not altered by treatment (Table 13). Biotic cover mainly varied annually with rainfall.

Table 13. Mean and standard errors (se) of percent ground cover/m^2 before and after treatments on reference (R) and treatment (T) sites.

		n	Biotic Mean (se)	Litter Mean (se)	Abiotic Mean (se)
R	Before[a]	42	16.2 (2.3)	53.8 (3.8)	29.4 (3.7)
	After[b]	143	13.7 (1.0)	49.4 (1.9)	36.9 (1.9)
T	Before[a]	63	11.5 (1.7)	60.6 (3.0)	27.8 (2.6)
	After[b]	171	11.9 (1.1)	55.1 (2.0)	32.9 (1.7)

[a]Data from 2003
[b] Data from 2004-2007

The percent canopy cover was reduced by the treatments (F_1 = 5.73, P = 0.02). Before treatments canopy cover was similar (66% on reference, 60% in the watershed). While canopy cover remained unchanged over time in reference areas (65%), after thinning, in the upland watershed areas, canopy cover averaged 42% within the treatment area.

Invasive plants

Invasive plant species were located in 2006 and 2007 with some repeat locations and not all on Forest Service lands. Mostly we found small isolated group of plants, but there were occasions where we found extensive and apparently spreading populations of these species (Map 3). *Centaurea maculosa* (spotted knapweed) was found in a number of new locations along the southern boundary of the watershed and in a few isolated patches on the north side of the river whereas it had been only found in one location in 2006. Most spotted knapweed plants within the watershed were removed by hand upon discovery, but one large patch at the southern boundary near Agua Sarca could not be entirely removed (Map 3). The largest infestation of spotted knapweed was located at the Chamisa trailhead near Hyde Park in 2006 and their have been efforts to reduce this population and educate the public. *Bromus tectorum* (cheat grass) was the most abundant invasive species. In addition to the mapped locations, it was also observed in the open meadow area just before the watershed road ends near the wilderness area. The second most common non-native was *Lactuca serriola* (prickly lettuce). Neither of these species is on the New Mexico invasive list. We also noted *Ulmus pumila* (Siberian elm) along roads and the Santa Fe River where it was already know to occur, but also, surprisingly, as isolated plants on steep slopes on the north side of the river. *Linaria dalmatica* (dalmation toadflax) was noted for the first time, but only at two locations, one at the entrance gate and one in an area with extensive weed infestation at our UP03 bird point count station above Nichols reservoir (Figure 3). We also mapped locations of *Elaenagnus angustifolia* (Russian olive) though these individuals seem to occur in only a few isolated locations near Agua Sarca. Only a few plants of *Cirsium vulgare* (bull thistle) were found.

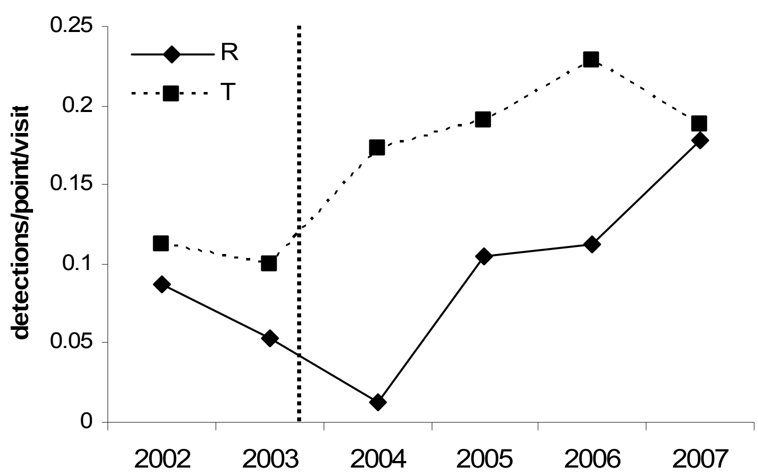
Management Indicator Species

Four of the five bird MIS were detected during point counts (Table 14). Mourning Dove and Hairy Woodpecker populations were high enough to be evaluated statistically for the restricted set of points surveyed in all years. Hairy Woodpeckers had a positive response to treatment in 2004 and 2006 (Table 2, Figure 4.A). Mourning Dove had a positive response in 2006 (Table 2, Figure 4.B). The other two species had populations too low for detailed statistical analysis, the collected data gives some indication of their populations. Pinyon jays have disappeared from both the treated areas in the watershed and reference areas. Declines are likely due to local pinyon mortality and/or West Nile virus. Wild Turkeys were only detected in treated areas of the Santa Fe Watershed though it should be noted that these points cover a larger area than reference points and they are protected from hunting within the watershed. Detections were lower in 2003 and 2004, but otherwise remained consistent during monitoring. Mexican spotted owls did not respond to playbacks during any night-time survey from 2002 to 2007. One male, apparently a floater, was detected for two consecutive nights at the Black Canyon Campground. Elk tracks were seen on a few occasions in the southern portion of the project area near Agua Sarca in 2006 and 2007, thus while they may use the project area, they seem to be rare at least in the lower portions of the watershed.

Table 14. Detections per 100 point visits for management indicator species detected during avian point counts on reference (R) and treated (T) points. Detections at all points are included here.

	Hairy Woodpecker		Piñon Jay		Mourning Dove		Wild Turkey	
	R	T	R	T	R	T	R	T
2002	8.8	11.3	12.5	27.9	8.8	14.0	0.0	1.0
2003	5.3	10.0	0.0	0.2	0.0	3.6	0.0	0.7
2004	1.3	17.3	2.6	0.0	1.3	9.0	0.0	0.5
2005	10.5	19.1	0.0	0.0	6.6	14.0	0.0	1.0
2006	11.3	22.8	0.0	0.0	34.4	43.2	0.0	0.9
2007	17.9	18.8	0.0	0.0	28.1	35.2	0.0	0.9

A.



B.

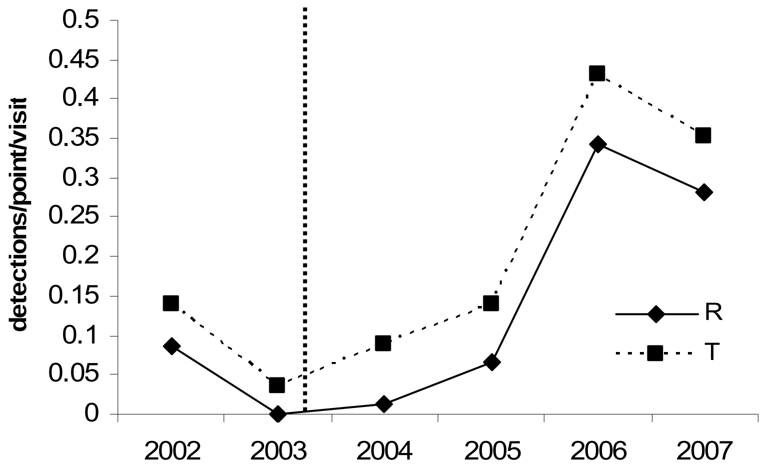


Figure 4. Detections/point/visit for Hairy Woodpecker (A) and Mourning Dove (B) for reference (R) and treated (T) points. Vertical dashed line indicates time of treatment.

Discussion

As expected, response to thinning was species specific. Data collected so far indicates that thinning has not resulted in strong negative impacts on populations. Overall fourteen bird species showed a positive response to treatment while eight had a negative response. The time period of response varied, though in general most negative responses were during one or two periods while positive responses lasted more than four periods. Hermit Thrush was the species most consistently negatively impacted by thinning. One species, Warbling Vireo, had a mixed response, with both positive and negative responses, and their populations varied considerably by year. Hairy Woodpecker, a management indicator species, responded positively to treatment in the first and third years post-treatment. The other management indicator species that could be evaluated statistically was

Mourning Dove which had a positive response to treatment in the third year post-treatment. To further look at the impact of thinning on bird communities, we evaluated species listed by Partners in Flight as species of regional concern for the southern Rocky Mountain region. Eleven of these species were part of our analysis and all these species increased or stayed the same except Warbling Vireo which had a mixed response. This may indicate that thinning treatments, such as the one conducted here, benefit birds with low or declining populations. The preponderance of fire-suppressed forests on the landscape may be responsible for this pattern.

The vegetation data did not indicate significant increases in the percent living ground cover. Increases were perhaps large enough to affect mammal populations, but not large enough to detect statistically. On the other hand, the response in deer mice may be related to some other thinning effect such as increased access to food or reduced predators. Additionally, our measure of ground cover may not be specific enough to identify changes in plant cover that is used as a food resource or hiding cover. Increases in mice have the potential to increase populations of predators including raptors.

The very low success rate for open-cup nests in the reference area for 2006 (10.5 %) was primarily due to weather conditions which were more extreme because the reference nests are located in the upper part of the watershed which is at a higher elevation. All areas experienced high summer rainfall, but at the higher elevation there was more precipitation which included hail and snow. Thus many nests were lost due to abandonment rather than predation, the factor of interest. Cavity nests are less exposed to weather and thus are not as vulnerable to weather.

Differences in response between cavity and open nests may be due to differences in primary predators if predator populations are affected differently by treatment or surrounding habitat of nest locations and thus predation risk may differ. Any differences in nest success between thinned and reference area was no longer apparent in 2007. Deer mice and red squirrels are both potential nest predators and while deer mice increased, red squirrels decreased on treatment areas.

There was considerable annual variability as illustrated by bird and small mammal abundances (Appendices A and B). In particular, there was considerable variability in the two pre-treatment years making it more difficult to assess impacts due to treatments. 2002, in particular, was a very dry year which probably had a large impact on wildlife populations and is probably responsible for the variability seen between 2002 and 2003 (Figure 7). Subsequent years were wetter though drought effects may last for several years. Rainfall patterns of summer and winter precipitation vary in each year.

Small mammal populations increased in 2004 on all sites, perhaps in response to greater food supplies. By the following year, populations returned to levels seen in the previous years though populations remained higher on treatment areas over reference areas. We expect that the differences in populations between the years could be due to normal fluctuations related to abiotic events and/or observer bias/inexperience including differences in detectability due to treatments. Detectability differences by treatment were evaluated for small mammals, but sample sizes were too small for individual bird species to account for potential differences. To hinder assessment of treatments in this analysis, sound attenuation would have to vary significantly between thinned and unthinned sites, because detections were primarily aural.

Owl survey effort is minimal though data indicate that Flammulated Owl, an MIS, remained in the watershed following treatments. Two other indicator species, Hairy Woodpecker and Mourning Dove, had sufficient sample sizes for analysis. Both had positive responses to treatment in at least one post-treatment year and no negative response was found.

Arthropod populations fluctuated widely by year making patterns related to thinning difficult to assess. It is likely this is partially due to weather patterns, but some error may be introduced during specimen identification to family. Aphids showed the clearest pattern of increase on thinned sites. Aphids can be important prey items for granivorous birds during the breeding season (Wilson et al. 1999). Crab spiders show some indication of decline from thinning, but the pattern is unclear. Winter predation by birds on spiders has been shown to be significant (Askenmo et al. 1977). Ant and leaf beetle populations seem to be relatively unaffected by thinning. Ants are a major diet component for Northern Flickers (Major) and beetles in particular are important prey items for insectivorous birds (Raley and Anderson 1990) and their populations appeared to be unaffected by thinning. Thus overall, thinning does not appear to have significantly decreased arthropod prey for gleaning bird species.

It was somewhat unexpected that thinning in the treatment areas did not increase vegetative ground cover significantly in the two years post treatment. There was not an increase in abiotic cover which includes bare soil indicating that erosion potential has not increased. Increases in Gambel oak may be expected when the canopy is opened, but densities were similar on thinned and unthinned areas, and low overall. Snags were altered by treatment though there were also some changes in snags on reference sites. Large snags have the greatest potential to provide nesting and roosting habitat for wildlife. While the numbers did decrease, the lowest density of snags as recorded post-treatment (24.8/ha) is greater than the recommended snag density (6.7/ha) for sustaining populations of cavity nesting birds (Balda). On the other hand, few of the post-treatment snags were large ponderosa pine (7%) or aspen (15%), which are preferred for cavity excavation. In addition, while canopy cover was reduced, the mean canopy cover on the treated site was still 45%, near the recommended 40% for protecting wildlife habitat (USDA Forest Service 2001).

Invasive plant species that are potentially of concern were found in the Santa Fe Municipal Watershed. Despite the fact that the survey effort was low, we did find many occurrences. Other areas seemed free of invasive species indicating a potential for the possibility of control before these species become more widespread. The probability of occurrence appeared to be higher near roads, along ridges, and along the Aqua Sarca Creek. Presumably, invasive occurrence will increase in the watershed as seeds are dispersed from existing populations and from source populations outside the watershed. Cheatgrass *(Bromus tectorum*), while it does provide a food source for wildlife, has high potential to spread, can outcompete native grasses, and alters rangeland fire regimes where it is widespread (USDA 2000). Next steps to further address invasive species in the watershed may include expanding the search area covered by the survey, revisiting areas already surveyed, implementing additional measures to prevent further introductions, and initiating control measures for existing occurrences of invasives.

Summary

Data were collected from 2002 to 2007 on terrestrial birds (including owls), small mammals, arthropods, and vegetation in forests subject to thinning and prescribed fire as well as untreated reference areas. Using an index of abundance, fourteen species of bird had a positive response to thinning while eight bird species had a negative response during some period following the four years after treatment. Response of bird species identified as of regional concern were positive or neutral, thus thinning appears to be benefiting populations of birds that are low or declining. No negative impacts of thinning were found for small mammal species. Deer mice responded positively and this effect was potentially related to alleviation of negative impacts of high winter snowpack within thinned areas. This may also have been true for the positive effect of treatment found for voles. Chipmunk and wood rat populations, and total biomass were not altered by treatments. Terrestrial arthropod numbers were highly variable, but of families commonly preyed upon by birds, none were found to have a strong negative response to treatments. Ground cover, though expected to respond positively to the treatments, did not increase significantly by 2 years post-treatment. Reductions in snags and canopy cover were within guidelines set to protect wildlife habitat though we note that large ponderosa pine snags preferred by woodpeckers, were rare in treated and reference areas. Several non-

native invasive plant species were found, particularly near roads and ridge lines, though none are yet widespread in the watershed. Results to date indicate that there were no strong negative impacts of thinning on small mammals or birds, and thinning may in fact be beneficial to some species. We note that thinning in the Santa Fe Watershed did not involve creation of roads, removal of large diameter trees, or wood removal, factors that differ from other thinning projects and potentially affect wildlife response.

Planned Products and Technology Transfer

We plan to submit all results for publication in peer-reviewed scientific journals. The first year's pre-treatment data and selected results were presented at the Arizona-New Mexico Chapter of the Wildlife Society Annual Conference in Gallup, New Mexico on Feb 8, 2003. We presented a poster of the results of the bird data at the Cooper Ornithological meeting in Flagstaff Arizona, May 2003. A poster of the 2003 results of the effect of the treatment activity was presented at the Arizona-New Mexico Chapter of the Wildlife Society Annual Conference in Safford, AZ on February 6, 2004. Preliminary results were presented at a talk during the Santa Fe Forest Forum in October 2005. A summary of results was presented in a public meeting November 2, 2006. An analysis of mammal populations was presented at the Arizona-New Mexico Chapter of the Wildlife Society in Albuquerque, NM on February 8, 2007 and at the Association of Fire Ecology in Tucson, AZ on Jan. 29, 2008. A manuscript related to these results was submitted for review to *Fire Ecology* and the unrevised version appears at the end of this report. Bird population results were presented at the International Partners in Flight meeting on Feb. 16, 2008 in McAllen, TX. The archive of point count data is complete and is available at the Rocky Mountain Research Station Data Archive (www.fs.fed.us/rm/data_archive). The mammal data will be added to the archive next.

Benefits to Users

The information will be useful to the Santa Fe National Forest to help in future planning of actions to prevent catastrophic fires and to minimize the effect of such actions on wildlife. We hope that other National Forest and other land managers might be able to use this information to plan actions that minimize the effect of forest thinning on wildlife populations.

Acknowledgements

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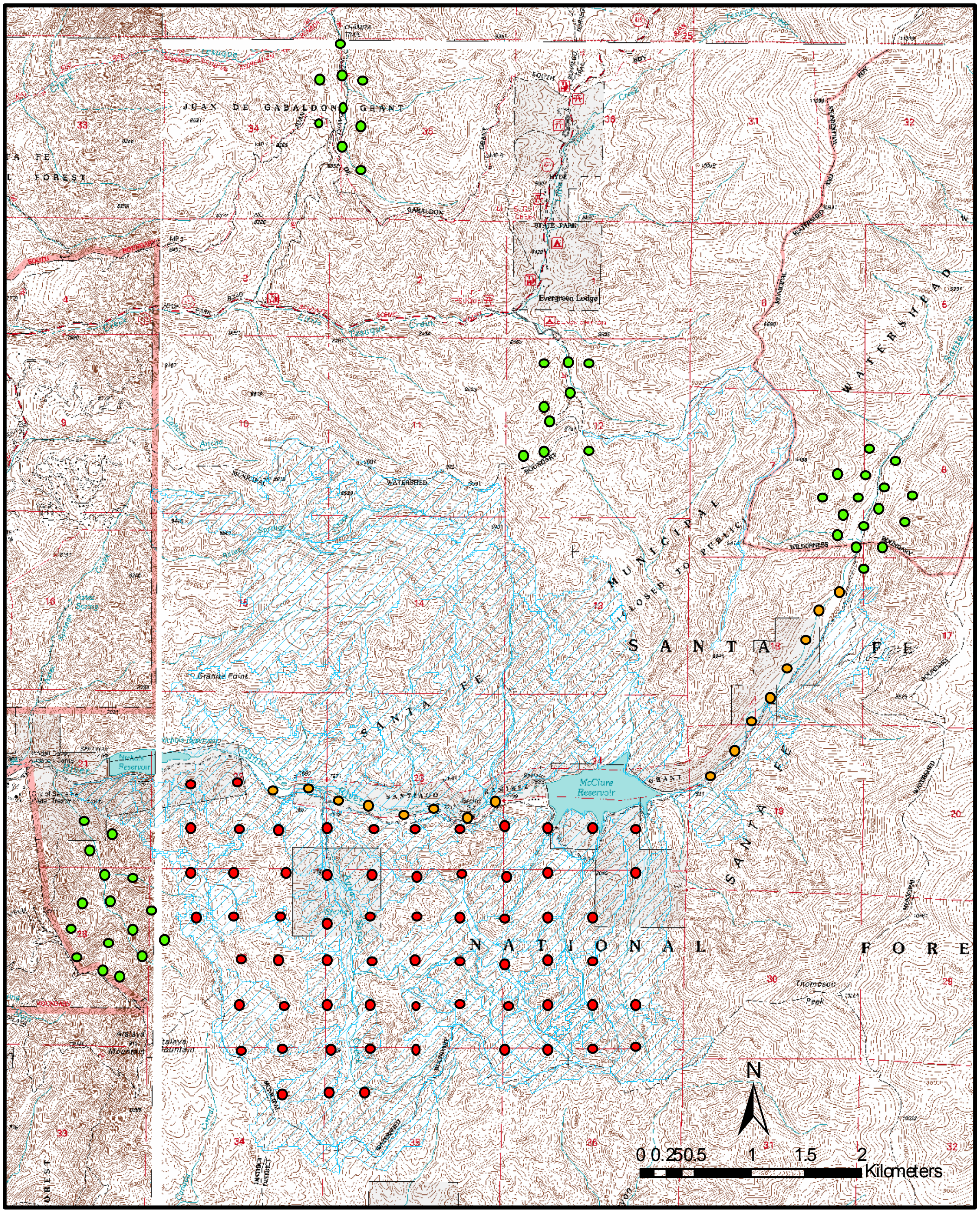
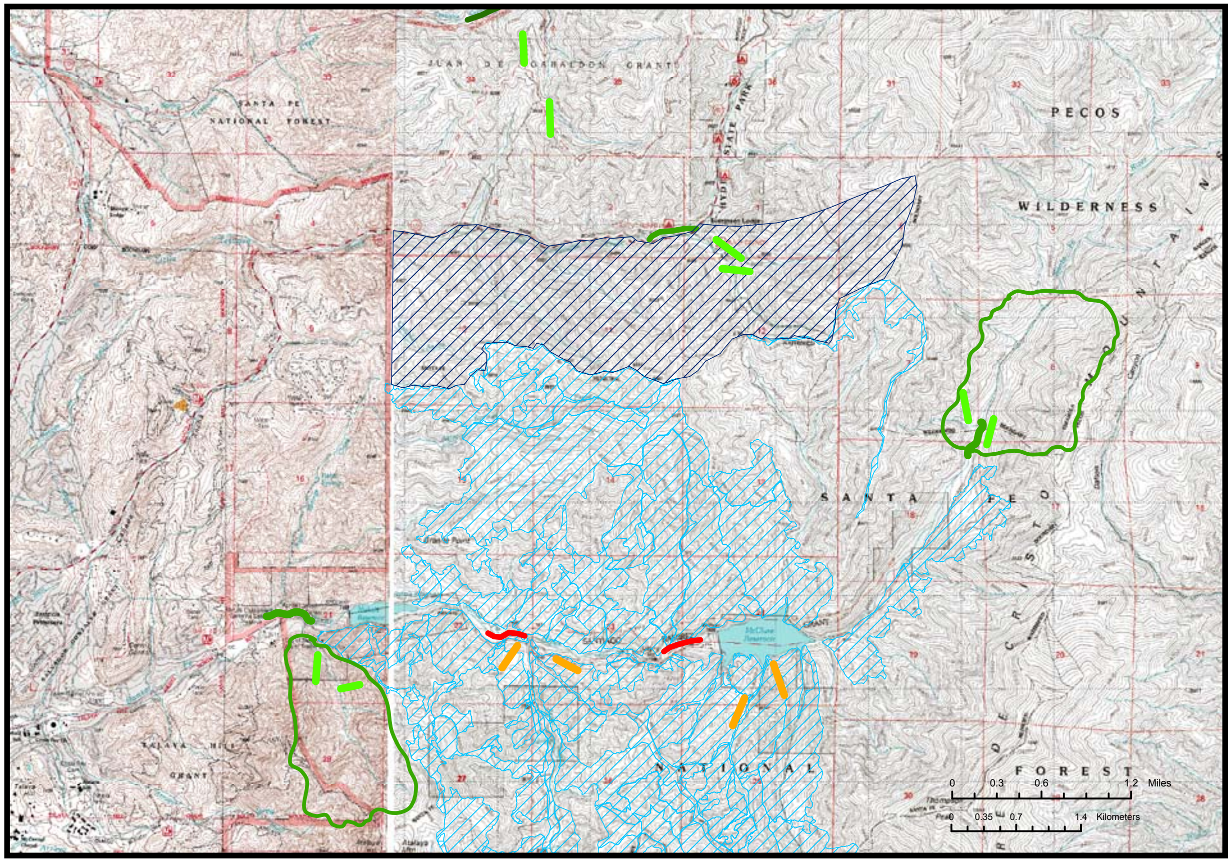
Map 1. Santa Fe Municipal Watershed Avian Point Count Locations

- Reference Points
- Treatment Points
- River Points
- Treated Areas 2003-2005



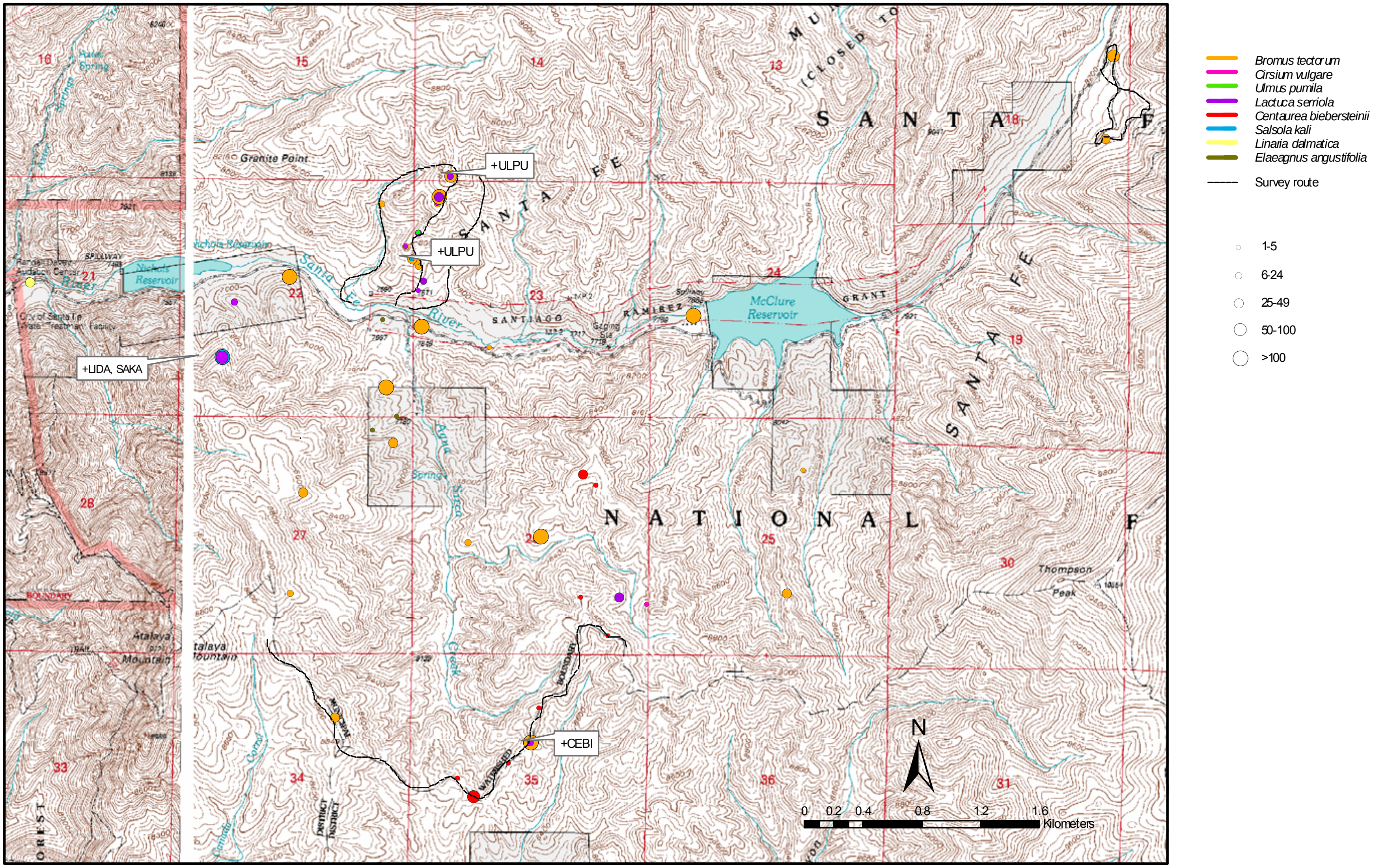
Map 2. Approximate locations of transects for small mammal trapping 2006.

reference upland transect
treatment upland transect
reference riparian transect
treatment riparian transect
treatment area as of 2005
new treatment area for 2007?



Map 3. Santa Fe Municipal Watershed Invasive Plant Species

Rocky Mountain Research Station 2007



Appendix A. Mean count per point by species for birds that were observed on day-time point counts from 2002 to 2005. Counts are the total number of sightings on 4 occasions from May to September or October on 20 reference (R) and 71 treatment (T) sites. For 2006/2007 there are 50 reference (R) and 64 treatment points (T).

Common name	Scientific name	2002		2003		2004		2005		2006		2007	
		R	T	R	T	R	T	R	T	R	T	R	T
Mallard	*Anas platyrhynchos*	0	0.03	0	0	0	0.06	0	0.01	0	0	0	0.05
Turkey Vulture	*Cathartes aura*	0	0.14	0	0.11	0	0.32	0	0.38	0	0.25	0.06	0.31
Sharp-shinned Hawk	*Accipiter striatus*	0.10	0.06	0	0	0	0.01	0	0	0.02	0	0	0.01
Cooper's Hawk	*Accipiter cooperii*	0	0.01	0.05	0.08	0.05	0.11	0.15	0	0.06	0.10	0.14	0.04
Red-tailed Hawk	*Buteo jamaicensis*	0	0.08	0.05	0	0	0.06	0.20	0.04	0.14	0.16	0	0
Osprey	*Pandion haliaetus*	0	0	0	0.03	0	0	0	0	0	0	0	0
Unknown hawk species		0	0	0.05	0.01	0.10	0.07	0	0.04	0.06	0.01	0	0
American Kestrel	*Falco sparverius*	0.05	0	0	0	0	0	0.05	0	0	0	0	0
Dusky Grouse	*Dendragapus obscrurus*	0	0	0	0	0	0	0	0	0.04	0	0	0
Wild Turkey	*Meleagris gallopavo*	0	0.04	0	0.03	0	0.03	0	0	0	0.03	0	0.04
Mourning Dove	*Zenaida macroura*	0.35	0.54	0	0.13	0.05	0.38	0.25	0.62	1.3	1.28	1.12	1.41
White-winged Dove	*Zenaida asiatica*	0	0	0	0	0	0	0	0.03	0.1	0.03	0.29	0.41
Flammulated Owl	*Otus flammeolus*	0	0	0.05	0.06	0	0.13	0	0.01	0	0	0	0
Common Nighthawk	*Chordeiles minor*	0	0	0.30	0.24	0.10	0.18	0.25	0.15	0	0	0	0
Common Poorwill	*Phalaenoptilus nuttallii*	0	0	0	0.03	0	0	0	0	0	0	0	0
White-throated Swift	*Aeronautes saxatalis*	0	0	0	0.04	0	0	0	0	0	0	0	0
Black-chinned Hummingbird	*Archilochus alexandri*	0.05	0	0	0	0	0	0	0	0	0.01	0	0
Broad-tailed Hummingbird	*Selasphorus platycercus*	0.65	0.58	0.75	0.82	0.85	1.65	1.00	2.03	1.08	0.65	1.31	1.62
Calliope Hummingbird	*Stellula calliope*	0	0	0	0	0	0.03	0	0	0	0	0	0
Rufous Hummingbird	*Selasphorus rufus*	0	0	0	0	0	0	0	0.04	0.04	0.02	0.02	0.02
Unknown hummingbird species		0	0.01	0	0.04	0	0	0	0	0.02	0.02	0.08	0.02

Common name	Scientific name	2002		2003		2004		2005		2006		2007	
		R	T	R	T	R	T	R	T	R	T	R	T
Belted Kingfisher	*Ceryle alcyon*	0	0	0	0	0	0	0	0	0	0	0	0
Red-naped Sapsucker	*Sphyrapicus nuchalis*	0.20	0	0.15	0.06	0.20	0.11	0.15	0.11	0.06	0.02	0.02	0.04
Williamson’s Sapsucker	*Sphyrapicus thyroideus*	0.05	0.10	0.35	0.17	0.10	0.13	0.35	0.03	0	0	0	0.02
Downy Woodpecker	*Picoides pubescens*	0	0.03	0.10	0.03	0	0.03	0	0.04	0	0	0	0
Hairy Woodpecker	*Picoides villosus*	0.35	0.52	0.20	0.39	0.05	0.80	0.40	0.77	0.44	0.71	0.71	0.75
Northern Flicker	*Colaptes auratus*	1.10	1.18	1.75	1.11	0.80	1.68	1.10	1.44	2.46	1.61	2.33	2.46
Unknown woodpecker species		0.10	0.17	0.10	0.13	0.25	0.10	0.05	0.08	0.02	0.01	0	0.02
Olive-sided Flycatcher	*Contopus borealis*	0	0.04	0.05	0.11	0.05	0.13	0.10	0.27	0.08	0.19	0	0.42
Western Wood-Pewee	*Contopus sordidulus*	0.10	0.15	0.30	0.44	0.15	1.25	0.25	1.90	0.46	1.60	0.41	2.32
Hammond's Flycatcher	*Empidonax hammondii*	0	0	0	0	0	0.03	0.45	0.28	0.84	0.58	0.61	0.67
Dusky Flycatcher	*Empidonax oberholseri*	0.30	0.13	0.30	0.11	0.40	0.24	0.10	0.04	0	0	0	0
Gray Flycatcher	*Empidonax wrightii*	0	0	0.15	0.13	0	0	0	0	0.08	0.01	0.04	0
Pacific-slope Flycatcher	*Empidonax difficilis*	0	0	0	0.04	0	0	0	0	0	0	0	0
Say's Phoebe	*Sayornis saya*	0	0	0	0	0	0.01	0	0	0	0	0	0
Cordilleran Flycatcher	*Empidonax occidentalis*	0.25	0.17	0.70	0.38	0.75	0.61	0.50	0.77	0.56	0.33	0.53	1.17
Ash-throated Flycatcher	*Myiarchus cinerascens*	0	0.01	0	0.06	0	0	0	0	0	0	0	0
Unknown flycatcher species		0.10	0.18	0.10	0.07	0.05	0.06	0	0.04	0	0.01	0	0
Violet-green Swallow	*Tachycineta thalassina*	0.20	0.08	0.15	0.07	0.10	1.30	1.20	2.79	0.74	1.74	0.29	2.48
Unknown swallow species		0	0.06	0	0	0	0	0	0	0	0	0	0
Steller’s Jay	*Cyanocitta stelleri*	2.70	3.35	1.25	1.06	1.85	1.39	1.90	1.75	2.44	1.36	2.27	1.41
Pinyon Jay	*Gymnorhinus cyanocephalus*	0.50	1.51	0	0.01	0.10	0	0	0	0	0	0	0
Western Scrub Jay	*Aphelocoma californica*	0	0	0	0	0	0	0	0	0	0	0.02	0.01
Unknown jay species		0	0.06	0	0	0	0	0	0	0	0	0	0
Clarks Nutcracker	*Nucifraga columbiana*	4.00	1.86	0.05	0.46	0.85	1.34	0.55	0.96	0.48	0.43	1.47	1.06

Common name	Scientific name	2002		2003		2004		2005		2006		2007	
		R	T	R	T	R	T	R	T	R	T	R	T
Black-billed Magpie	*Pica hudsonia*	0	0	0	0.01	0	0.01	0	0	0	0	0	0
American Crow	*Corvus brachyrhnchos*	0	0	0	0	0	0	0	0	0	0.02	0	0
Common Raven	*Corvus corax*	1.90	1.15	1.90	0.94	0.85	1.14	0.80	1.00	0.46	0.58	0.90	0.75
Mountain Chickadee	*Parus gambeli*	6.20	4.89	3.80	4.15	4.05	4.61	5.05	3.68	2.88	2.01	3.69	2.81
Black-capped Chickadee	*Poecile atricapilla*	0	0	0	0	0	0	0.30	0.24	0.06	0.03	0	0
Juniper Titmouse	*Baeolophus ridgwayi*	0	0	0	0	0	0	0	0	0.06	0	0	0
Bushtit	*Psaltriparus minimus*	0.25	0.37	0	0.10	0	0.07	0	0.03	0.22	0	0	0
White-breasted Nuthatch	*Sitta canadensis*	1.45	0.59	1.25	1.77	0.70	1.39	1.20	2.24	1.6	1.32	2.35	2.25
Red-breasted Nuthatch	*Sitta carolinensis*	4.65	4.07	1.05	0.45	2.00	1.89	0.70	0.44	0.1	0.10	2.18	1.26
Pygmy Nuthatch	*Sitta pygmaea*	2.55	2.38	2.20	3.45	3.10	4.66	2.20	4.39	3.1	3.53	3.35	4.59
Unknown nuthatch species		0	0.03	0	0.01	0	0	0	0	0	0	0	0
Brown Creeper	*Certhia americana*	0	0	0.60	0.37	0.40	0.44	0.65	0.48	0.22	0.04	0.39	0.23
Rock Wren	*Salpinctes obsoletus*	0	0	0	0	0	0	0	0	0	0.03	0	0
Canyon Wren	*Catherpes mexicanus*	0	0	0	0	0	0	0	0	0.02	0	0	0.01
Bewick’s Wren	*Thryomanes bewickii*	0	0	0	0	0	0	0	0	0.02	0	0	0
House Wren	*Troglodytes aedon*	0.05	0	0.10	0.10	0	0.08	0.15	0.18	0.06	0.01	0.06	0.35
Golden-crowned Kinglet	*Regulus satrapa*	0.05	0.01	0	0.03	0	0	0	0	0	0	0.02	0
Ruby-crowned Kinglet	*Regulus calendula*	0.80	0.32	0	0.01	0.25	0.07	0.15	0.07	0	0	0.06	0.10
Western Bluebird	*Sialia mexicana*	0	0.17	0	0.21	0	0.39	0.15	1.44	0.1	0.70	0.20	1.30
Mountain Bluebird	*Sialia currucoides*	0	0	0	0	0	0.01	0	0	0	0	0	0
Hermit Thrush	*Catharus guttatus*	2.80	1.85	1.10	1.61	1.85	1.28	2.25	1.37	1.84	0.76	1.98	1.51
Townsend’s Solitaire	*Myadestes townsendi*	0.45	0.20	0.30	0.54	0.35	0.35	0.70	0.52	0.7	0.34	1.22	0.49
American Robin	*Turdus migratorius*	1.10	0.56	0.85	0.89	0.60	0.49	0.65	0.52	1.22	0.30	0.63	0.64
Plumbeous Vireo	*Vireo Plumbeus*	0.10	0.03	0.10	0.07	0.30	0.24	0.85	0.52	0.66	0.68	0.53	1.33
Warbling Vireo	*Vireo gilvus*	0.85	0.21	2.05	0.86	1.15	1.03	2.35	0.83	1.3	0.33	1.88	1.41

Common name	Scientific name	2002		2003		2004		2005		2006		2007	
		R	T	R	T	R	T	R	T	R	T	R	T
Orange-crowned Warbler	*Vermivora celata*	0	0.01	0	0	0	0	0	0	0.06	0	0.08	0
Nashville Warbler	*Vermivora ruficapilla*	0	0.01	0	0	0	0	0	0	0	0	0	0
Virginia's Warbler	*Vermivora virginiae*	0.15	0.03	0.15	0.01	0.05	0.08	0.05	0.10	0.04	0.01	0.06	0.01
Yellow Warbler	*Dendroica petechia*	0	0	0.20	0.15	0.05	0.08	0.10	0.07	0	0.01	0	0
Yellow-rumped Warbler	*Dendroica coronata*	0.80	1.75	1.80	1.63	1.55	0.79	0.80	1.31	1.72	1.16	1.81	2.02
Black-throated Gray Warbler	*Dendroica nigrescens*	0	0	0	0	0	0	0	0	0.1	0.02	0.02	0
Townsend's Warbler	*Dendroica townsendi*	0	0.01	0	0	0	0	0	0	0.06	0.03	0	0
Grace's Warbler	*Dendroica graciae*	0.30	0.59	0.95	1.34	0.80	0.68	1.10	0.87	0.68	0.50	0.41	0.90
MacGillvray's Warbler	*Oporornis tolmiei*	0	0.03	0	0.08	0.50	0.20	0	0.03	0	0	0	0
Wilson's Warbler	*Wilsonia pusilla*	0	0	0	0.03	0	0	0	0	0	0	0.02	0
Unknown warbler species		0.05	0.04	0	0.03	0	0	0.10	0.01	0.02	0.02	0.02	0
Hepatic Tanager	*Piranga flava*	0	0	0	0	0.05	0.03	0	0	0.02	0.01	0	0
Western Tanager	*Piranga ludoviciana*	0.35	0.20	0.35	0.62	0.40	0.62	0.80	0.92	1.24	0.70	1.53	1.42
Black-headed Grosbeak	*Pheucticus melanocephalus*	0.30	0.20	0.25	0.28	0.15	0.15	0.20	0.11	0.08	0.08	0.02	0.07
Green-tailed Towhee	*Pipilo chlorurus*	0	0	0	0	0	0	0	0	0.02	0	0	0
Spotted Towhee	*Pipilo maculatus*	0.15	0.04	0.10	0.07	0.30	0.15	0	0.01	0.06	0.01	0	0.02
Chipping Sparrow	*Spizella passerina*	0.15	0.08	0.80	0.92	0.85	0.49	0.05	0.15	0.42	0.54	0.33	0.43
Song Sparrow	*Melospiza melodia*	0	0.01	0	0	0	0.04	0	0	0	0	0	0.07
Dark-eyed Junco	*Junco hyemalis*	3.55	2.38	2.20	2.14	1.95	1.46	2.80	2.11	2.64	1.95	2.27	1.86
Brown-headed Cowbird	*Molothrus ater*	0	0.01	0	0	0.05	0.04	0	0.04	0	0.02	0	0
Red Crossbill	*Loxia curvirostra*	0	0	0.10	0.06	0.25	0.73	0.05	0.11	0	0.02	0.49	0.68
Evening Grosbeak	*Coccothraustes vespertinus*	0.05	1.17	0	0	0	0.07	0	0.08	0.02	0.07	0.04	0
House Finch	*Carpodacus mexicanus*	0	0.44	0	0	0	0	0	0.06	0.04	0.02	0.02	0.10
Pine Siskin	*Carduelis pinus*	0.25	0.66	0.55	0.30	0.25	0.49	1.30	2.51	1.3	1.58	1.00	2.17
Lesser Goldfinch	*Carduelis psaltria*	0.05	0.07	0	0.01	0	0	0	0	0	0.02	0	0.01

Common name	Scientific name	2002		2003		2004		2005		2006		2007	
		R	T	R	T	R	T	R	T	R	T	R	T
American Goldfinch	*Carduelis tristis*	0	0.01	0	0	0	0	0	0	0	0	0	0
Unknown finch species		0	0	0	0	0	0	0	0	0	0	0	0
Unknown species		0.80	1.00	1.20	1.96	0.30	0.80	0.60	0.49	0.24	0.27	0.02	0
TOTAL		**41.50**	**36.85**	**32.30**	**32.08**	**29.95**	**37.34**	**38.90**	**43.85**	**37.04**	**30.27**	**42.33**	**47.35**

Appendix B. Mammal species and number of individuals trapped (2002-2006) between treatment (T) and reference (R) conditions on upland and riparian habitats. Trapnights are the total number of traps available during trapping or number of traps*number of nights set. Treatment areas are not treated prior to 2004.

	2002				2003				2004				2005				2006			
	Web (Upland)		Transect (Riparian)		Web (Upland)		Transect (Riparian)		Web (Upland)		Transect (Riparian)		Web (Upland)		Transect (Riparian)		Transect (Upland)		Transect (Riparian)	
Scientific Name (Common name)	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R
Long-tailed vole (*Microtus longicaudus*)			3	26		1	16	37			17	26		1	28	17			7	19
Meadow vole (*Microtus pennsylvanicus*)				15		1	5	25		1	1									10
Heather vole (*Phenacomys intermedius*)				1																
Southern red-backed vole (*Clethrionomys gapperi*)	1		1	1																
White-throated wood rat (*Neotoma albigula*)					3	1	26	5	6	2	5	1						1		
Mexican woodrat (*Neotoma mexicana*)	7		17	7	6	2	42	4	6	3	20	2	1		18	5	1	4	7	4
Deer mouse (*Peromyscus maniculatus*)	53	29	106	114	67	48	132	144	115	77	124	173	68	21	146	109	55	118	50	104
White-footed mouse (*Peromyscus leucopus*)			1	2			2	2			2			1	1	3	4	12	3	52
Brush mouse (*Peromyscus boylii*)				1																
Western harvest mouse (*Reithrodontomys megalotis*)			1				2				2								1	4
Shrew species (*Sorex species*)				2				1			6	13			11	13			2	2
Golden-mantled ground squirrel (*Spermophilus lateralis*)	1		1	1		1	1	5	2		1	1					2	1		
Audobon's cottontail (*Sylvalgus auduboni*)													1							
Least chipmunk (*Tamias minimus*)	13			1	14	5		5	31	12	5	25	20	5		10	12	4		
Colorado chipmunk (*Tamias quadrivittatus*)					1				1								11	15		
Red squirrel (*Tamiasciurus hudsonicus*)			1																	
Western jumping mouse (*Zapus princeps*)			2	14			3	12			4	4				5				7
Number of species	5	1	11	11	5	7	9	10	6	5	11	6	5	4	6	7	6	7	6	8
Number of individuals	75	29	133	185	91	59	229	240	161	95	187	245	90	28	204	162	85	155	70	202
Individual/trapnight X 100	2.6	2.1	7.5	13.1	3.3	3.2	13.3	14.5	5.7	5.4	10.9	14.9	3.2	1.5	12.0	9.2	4.9	3.4	6.0	8.7

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Response of small mammal populations to fuel treatment and precipitation in a ponderosa pine forest, New Mexico

Karen E. Bagne[2], *USDA Forest Service, Rocky Mountain Research Station, Albuquerque, NM 87102, USA*

Deborah M. Finch, *USDA Forest Service, Rocky Mountain Research Station, Albuquerque, NM 87102, USA*

Abstract: Small mammal populations were monitored for two years before and three years after a 2,800 ha fuel reduction project in the Santa Fe Municipal Watershed, New Mexico. Mammals were trapped in both upland and riparian habitats from 2002 to 2006 during two summer trapping sessions. Populations for deer mice (*Peromyscus maniculatus*) and voles (*Microtus* sp.) were estimated using mark-recapture data. The number of unique individuals was used as an index of abundance for chipmunks (*Tamias* sp.) and woodrats (*Neotoma* sp.) where sample sizes were smaller. Treatment effects were evaluated using a generalized linear mixed model and testing the difference between reference and treated areas during the periods before and after treatment. Positive effects of treatment were found for deer mice in 2005 for upland and riparian habitats. Positive effects of treatment were found for voles in 2005 and 2006 for riparian habitats. Numbers of chipmunks, woodrats, and the total biomass of small mammals showed no response to treatments. After removing treatment effects, deer mouse populations were modeled with winter and summer precipitation. In both upland and riparian habitats, deer mouse

[2] *E-mail: kebagne@fs.fed.us*

populations had a curvilinear response to winter precipitation with positive effects at low levels and negative effects at high levels. There was a linear negative effect of summer rainfall on riparian habitats and no effect in upland habitats. Results suggest precipitation may play a role in determining timing of response to treatment.

Key words: chipmunks, deer mice, fuels, *Microtus,* New Mexico, *Peromyscus manuculatus,* precipitation, *Tamias*, voles

Introduction

Small mammals, in addition to being abundant and relatively easy to study, are capable of rapid population growth allowing them to respond to habitat and environmental changes rapidly. In addition, they have important relationships with ecosystem components such as plant community composition (Brown et al. 1986), seed dispersal (Hollander and Vander Wall 2004, Schnurr et al. 2004, Li and Zhang 2007), mycorrhizal fungi dispersal (Pyare and Longland 2001), and predator population dynamics (Zielinski et al. 1983). These characteristics make small mammal populations good subjects for assessing ecosystem health and landscape alterations including natural and anthropogenic disturbances.

In coniferous forests of the western United States, fire has been the most important natural disturbance, and human intervention has led not only to changes in fire occurrence and severity, but also changes in forest structure, particularly density and composition (Weaver 1951, Pickett and White 1985, Covington and Moore 1994, Keeling et al. 2006). Forest management in this region is increasingly focused on improving forest health, which has generally been compromised by high stand densities exacerbating the effects of drought, fire severity, and insect outbreaks (Covington and Moore 1994, Keeling et al. 2006). Fire severity, in particular, is of interest to the public when forested areas are close to urban areas or provide essential resources such as drinking water. Fires of high severity have a direct and lasting negative impact on water supplies through increased erosion and sedimentation (Cannon et al. 2001). Mechanical thinning and prescribed fire, collectively fuel reduction treatments, are two methods commonly used to reduce tree density and, consequently, fire severity (Brose and Wade 2002, Storm and Fulé 2007). These treatments, to some extent, also restore historic forest structure and return fire to the ecosystem (Lynch et al. 2000).

Fuel reduction strategies strive, in part, to reduce woody debris, a major fuel source. Woody debris created during thinning may provide greater cover for small mammals, but removal of these materials may result in reductions of small mammals (Converse 2006). Fuel reduction strategies also strive to reduce tree densities which relate to connectivity in fuels and fire spread. The resulting reductions in canopy cover may increase herbaceous plant and shrub cover (Moore and Deiter 1992), which may benefit small mammals (Carey and Johnson 1995, Block et al. 2005, Converse 2006c). On the other hand, more open forests may increase success of predators hunting small mammals (Gese et al. 1995) and predator populations may themselves be affected by treatment and thus alter prey populations (Desy and Batzli 1989). Several studies have found positive response in small mammals to thinning (Wilson and Carey 2000, Suzuki and Hayes 2003, Muzika et al. 2004, Sullivan et al. 2005, Converse et al. 2006a, Converse et al. 2006b), though these were not always linked to the presumed causative sources such as woody debris or herbaceous cover (Converse et al. 2006c, Craig et al. 2006).

While a number of studies have examined small mammal response to thinning, few include thinning on a large scale or in multiple habitats. We monitored small mammal populations in upland and riparian areas of a ponderosa pine forest before and after a large-scale fuel treatment (~2,800 ha) near the city of Santa Fe, New Mexico undertaken to reduce the risk of high severity fire. While burning was part of the treatment strategy, little burning occurred in the trapping areas during the study period except of slash piles, which were not wholly consumed. Thus, primarily overstory forest structure was altered when these data were collected. Opening of the forest canopy was predicted to increase plant ground cover and, potentially, food resources for small mammals. To evaluate these responses we took into consideration differences in capture probabilities between reference and treated areas which potentially can confound results of these types of studies. Variations in capture probabilities, particularly as related to thinning, are presented. Our study also spanned six years during which there was large variation in precipitation patterns. Rainfall patterns, which directly relate to resource availability, are also considered important in population cycles of small mammals, particularly in arid regions (Mutze et al. 1991, Lima et al. 1999, Ernest et al. 2000, Brown and Ernest 2002, Bradley et al. 2006). We used this opportunity to examine rainfall and mammal population patterns.

Methods

Study area and treatments

The study took place in the southern Sangre de Cristo Mountains, New Mexico. Study sites were located in, or within 4 kilometers of, the Santa Fe Municipal Watershed outside the city of Santa Fe (Figure 1). The study sites, ranging from 2,300 to 2,600 m, are primarily ponderosa pine forests with some mixed conifer forest especially in drainages and at higher elevations. Treated sites were along the Santa Fe River and reference sites were on untreated portions of the Santa Fe River, as well as on Little Tesuque and Tesuque Creeks (Figure 1). Small amounts of piñon-juniper woodland are present in the lower elevations, particularly along rocky ridges. Riparian areas generally occur as narrow ribbons of mesic vegetation at the bottom of steep mountain sides ranging from approximately 25 to 100 meters in width. Riparian areas along the Santa Fe River were dominated by narrow-leaf cottonwood (*Populus angustifolia*) cottonwood, thin-leaf alder (*Alnus tenuifolia*), and willow (*Salix* sp.) whereas along Tesuque and Little Tesuque Creeks riparian forests were mostly dominated by alder and willow. The understory was sparsely vegetated with grasses and forbs away from drainages. Winter precipitation falls as rain or snow. Summer monsoons generally bring rain in mid-July and August.

The Santa Fe Municipal Watershed has had a long history of logging, grazing, and homesteading. These activities ceased in 1932 when the watershed was closed to the public, but active fire suppression continued until the treatment described in this study. Within the Santa Fe Municipal Watershed, 2,800 ha of forest was planned to be treated, beginning in 2003, with a combination of mechanical thinning, burning of slash piles, and broadcast burning. Smaller trees (mostly < 15 cm diameter) were removed preferentially to reduce tree densities overall from 200 to 400 trees per ha to 20 to 40 trees per ha overall (US Forest Service 2001). While mastication or shredding was used in the treatment area, thinning in trapping areas was primarily achieved using chainsaws with slash piled by hand. Soil disturbance was minimal, no roads were built, and no seed was applied. No wood was removed and though slash (limbs and needles) was to be burned, weather precluded burning of many piles during the study period and burned piles were not wholly consumed. Ridges were more heavily thinned as fire breaks and no thinning occurred on slopes > 40%, thus treatment was not uniform. Riparian areas along the Santa Fe River were not thinned. Thinning began in February of 2003 and burning of slash piles began in November 2003. Mechanical thinning was primarily complete by the fall of 2004, though application of prescribed fire is ongoing. Little of the area where mammal trapping was conducted received treatment during the 2003 trapping season and thus we considered 2004 to be the first post-treatment year though there may have been some disturbance due to increased human activities prior to this time.

Precipitation data were compiled from the Elk Cabin SNOTEL (SNOwpack TELemetry) site operated by the USDA Natural Resources Conservation Service located at the upper end of the municipal watershed at 2,500 m elevation near trapping locations (Figure 1). Data were collected in inches and converted to mm after analysis.

Small mammal populations

Small mammals were trapped in folding Sherman live-traps (7.6 cm × 8.9 cm × 22.9 cm) from 2002 to 2006 in two habitats with two trap arrangements following a BACI (before-after control-impact) design. In riparian habitats, traps were laid out in linear transects of 100 traps 5 m apart following the water's edge. There were 3 treatment and 3 reference riparian transects which was altered in 2006 to 2 treatment and 4 reference transects in anticipation of expansion of fuel treatments. The added reference transect was located at the lower end of the municipal watershed below Nichols Reservoir (Figure 1). In upland habitats, traps were arranged in a web of 80 traps radiating along 8 lines of 10 traps, 5 m apart. Six treatment web locations and 4 reference web locations were used 2002 to 2005. We altered methods for upland habitats in 2006 to increase capture rates and excluded those captures from this analysis. All locations were trapped in every year except for one reference location that was not trapped in August 2002 and one reference riparian transect that was added for 2006.

Traps in each location were baited with rolled or crimped oats and checked for three consecutive nights. Every location was trapped for two sessions a year, once from mid-June to mid-July and once in August. Due to concerns about hantavirus, used traps were always replaced by a clean trap, and all traps were cleaned and disinfected after use. Individuals were identified by species, age, and sex, and uniquely marked with one ear tag. Measurements included ear length, foot length (to the tip of the nail), tail length, and weight. Mammals were released at the point of capture.

We intended to estimate density for captures from upland trapping webs in the program DISTANCE (Anderson et al. 1983, Laake et al. 1993), but capture rates were too low and thus similar analytic methods were used for both habitats though it is noted that trapping area differed. Sample sizes were generally small, and the analytic strategy was to minimize the number of parameters estimated while allowing for differences between treatment and reference areas. We used mark-recapture data in Program MARK to estimate population sizes for each location in each year where the number of unique individuals was >30 per year. While the trapping schedule followed Pollack's Robust Design (Pollack 1982), where survival is estimated between sessions during which the population is considered to be closed, we estimated populations for each session separately, because the Robust Design would require estimating additional parameters (e.g. survival, availability). Population estimates (N_{est}) were made from recapture data in each session using Huggin's closed capture model which has been shown to perform well with small sample sizes and was appropriate for our 3-night trapping sessions (Huggins 1989, Huggins 1991). Rather than use an information-theoretic approach and including uncertain models supported by too little data, we chose to estimate a model with minimal parameters to get the best possible population estimates. Parameters estimated were probability of capture (p) and probability of recapture (c). These were estimated collectively within a treatment type, but treatment and reference areas were estimated separately to avoid results that would confound the analysis of treatment effects. Generally, we allowed for a behavioral response ($p \neq c$), but removed this when standard errors and population estimates were nonsensical (e.g. N >1,000). Once parameters were estimated by treatment for each trapping session, populations were then derived in each session for each location. Population estimates were not converted to density due to the trap configurations, but all trapping locations had the same layout in riparian or upland habitats, and thus populations can be compared within, but not between habitats.

Statistical Analysis

Estimated populations were analyzed in a generalized linear mixed model using PROC GLIMMIX (SAS Institute 2000). Locations over years were repeatedly sampled and location was designated as the subject of the random effect. The design was unbalanced and denominator degrees of freedom were estimated using the Kenward-Roger method (Kenward and Roger 1997). Proper fit of the model was evaluated using the residual dispersion estimate (X^2/degrees of freedom) with distributions other than normal and testing the normality of the residuals. Treatment effects were evaluated using the interaction of time and treatment. When this interaction had a *P*-value of <0.25, we then divided time into each year after treatment to identify when treatment effects occurred. Others have used analyses weighted by the standard errors of the estimates, because the estimation for each location is based on parameter estimates for a group of locations. Weighted analyses proved problematic and standard errors varied considerably between treatments and years. Because weighted analysis calls for exact estimates of errors (Ryan 1997), which were not obtainable from our methods in MARK, we present results from unweighted analyses.

For species with captures of unique individuals >10 and <30 per year we used the same analytical methods with an index of abundance (the number of unique individuals, M_{t+1}) rather than estimate populations size (McKelvey and Pearson 2001). In 2006, new reference riparian locations were added and these were tested for differences from original reference riparian locations before including in the model using Welch's *t*-test.

The total biomass was calculated by summing the weights in grams recorded for each unique individual caught per location per trapping period. The effect of treatment was evaluated using the generalized linear mixed model as described above.

The southwestern United States has two distinct periods of precipitation thus we used two measures, one for winter precipitation and one for summer precipitation. Winter precipitation was compiled as the accumulated precipitation from October of the previous year to three months prior to the first day of trapping for a location. This lag was used, because small mammal populations have been shown to respond to precipitation with a lag of three months (Bradley et al.2006). Summer precipitation (monsoonal rain) was quantified as the accumulated precipitation for a one month period previous to the first trapping day for each location. Nonlinear effects were suspected based on graphical inspection of the data thus we tested polynomials including the linear, quadratic, and cubic effect for each rainfall parameter. The effect of rainfall on deer mouse populations was tested similarly to treatment effects using PROC GLIMMIX with random effects. Populations that were found to be significantly affected by the treatments in the previous analysis were removed to eliminate treatment effects in evaluating precipitation effects. A categorical variable for the trapping session was included, because of breeding activities between the trapping periods (June/July and August). To model the relationship between rainfall and mammal populations we selected models in what was essentially a stepwise process with modification. Trapping session was a covariate and always remained in the models. The remaining variables were winter precipitation and summer precipitation and their higher order polynomials up to the third order. The full model was fit to the data as for the models of treatment effect and remove variables based on their *P*-values ($P>0.25$), but requiring that higher order effects be removed first. Once all variables in the remaining model were significant ($P<0.05$) then variables were added back in to test the validity of the model. Fit was reassessed with each step. Upland data from 2006 was excluded because of alterations in trapping area. Graphical representation of the best model of the effect of precipitation on deer mouse populations was created by substituting the observed range of precipitation values for the study into the equation.

Results

We caught a total of 2,698 individual mammals of 15 species over 5 years. Capture rates averaged 21.3 mammals/100 trapnights for riparian transects for 2002 to 2006. For upland webs, mammals were captured at an average rate of 8.6/100 trapnights for 2002 to 2005. Four species, or groups of species, had >10 individuals/year (deer mice, *Peromyscus maniculatus*; voles, *Microtus* sp.; chipmunks, *Tamias* sp.; and woodrats, *Neotoma* sp.). Deer mice and voles had >30 individuals/year, thus their populations were estimated using recapture data.

Deer Mice

Deer mice were the most commonly captured species in both riparian and upland habitats. Captures varied by session, year, and location (Table 1). We found that populations for the added 2006 reference locations were not different from the original reference locations and were included in the dataset ($F = 0.0$, $P = 0.99$). Initial results indicated differences between trapping sessions within a year, but model fit was poor when a variable for this effect was included, thus we analyzed the sessions separately. The best model fit for treatment effect was obtained with a normal distribution for riparian habitats and a negative binomial for upland habitats (X^2/degrees of freedom = 2.1). For both upland and riparian habitats, the interaction of time and treatment was significant when evaluating before vs. after treatment, thus we then ran the model again with each year after treatment separated. In the June/July session, there was a significant positive effect of thinning in 2005 in riparian habitats, but not upland habitats. In the August session, there was a significant positive effect of thinning in 2005 for both riparian and upland habitats (Table 2). In 2005, deer mouse populations were, on average, 77% higher on thinned vs. reference in riparian areas and 114% higher in upland areas (Table 1).

We were able to estimate both probability of initial capture (p) and recapture (c) for 10 of 20 riparian trapping sessions 2002 to 2003. These were primarily August sessions 2003 to 2006, when capture were highest. Probabilities of initial capture (p) in riparian habitats differed between reference and treatment areas for two of the four years with no consistent pattern while c, recapture probability, differed in all four years with probabilities greater on reference areas as compared to treatment in three years (Figure 2). For June/July sessions, only p could be estimated for four of five years. Three of those years p differed between reference and treatment, but with no consistent pattern. Upland habitats had smaller sample sizes so we were unable to include behavioral effects in population estimating models. Probability of capture (p where p =

c) differed between treatment and reference upland areas in two of four years for June/July and in all four years for August. Probabilities were greater on treatment than reference areas for five of the six comparisons (Figure 3).

Voles

The most commonly identified vole species was long-tailed vole, *Microtus longicaudus*, (n = 193) and we combined this with data on meadow vole, *Microtus pennsylvanicus* (n = 59) as we expected their ecological role and thus response to treatment would be similar. All captures are from riparian transects. Populations were estimated using MARK with no behavioral response to trapping (p = c). Best model fit was obtained with a lognormal distribution (X^2/degrees of freedom = 0.7). Trapping session was not significant and was deleted from the model ($F = 0.05$, $P = 0.82$). The time by treatment interaction was significant ($F = 7.93$, $P = 0.007$) and we then conducted the analysis with the 3 post-treatment years coded individually. Populations were positively affected from pre-treatment periods by treatment as compared to reference areas in 2005 and 2006, but not 2004 ($F = 6.05$, $P = 0.02$; $F = 6.05$, $P = 0.02$; $F = 1.22$, $P = 0.28$, respectively).

Chipmunks

Two species of chipmunks were captured in upland habitats, least chipmunk, *Tamias minimus* (n = 156) and Colorado chipmunk, *Tamias quadrivittatus* (n = 32). These were combined because ecological roles are similar and there was some difficulties distinguishing between these species in the field. A lognormal distribution fit best (X^2/degrees of freedom = 0.4). Trapping session was not significant and this variable was removed (*F* = 0.20, *P* = 0.66). There remained no effect of treatment on chipmunk populations (treatment*time, *F* = 0.32, *P* = 0.57).

Woodrats

Woodrats were caught primarily in riparian habitats (n = 146 vs. 37) and were primarily identified as Mexican woodrat, *Neotoma mexicana*, (n = 141) with fewer individuals whitethroat woodrat, *Neotoma albigula* (n = 42). These species were combined, because, like voles, we felt the response to treatment would be similar. Riparian captures were variable by year and tended to be lower on reference than treatment areas (Table 1). The best fit for the riparian data was a lognormal distribution (X^2/degrees of freedom = 0.7). Woodrat abundance differed between trapping sessions (*F* = 8.4, *P* = 0.01) with the usual increase during the summer, and fit of the model was not improved by analyzing these separately, thus session was retained in the model. There was also no effect of treatment (treatment*time, *F* = 0.02, *P* = 0.88).

Total Biomass

Average total biomass was higher on treatment than reference areas before treatment (1309 gm vs. 995 gm). In the post-treatment period, biomass was lower with an average of 808 gm in treated areas and 664 gm on reference locations. The best fitting model for biomass was a lognormal model with an unstructured covariance matrix. Fit was improved by analyzing trapping sessions separately. For upland habitats in June/July and August there was no effect of treatment (treatment*time, *F* = 0.94, *P* = 0.34 and *F* = 0.45, *P* = 0.51, respectively).

Precipitation

Precipitation varied considerably during the study period ranging from 80 to 480 mm for winter and 10 to 270 mm for one month accumulation in summer (Figure 4). The effect of trapping session on population size was significant, positive, and approximately equal for both habitats (Table 3). The best fit was found using a lognormal distribution with an unstructured covariance matrix. The effect of winter precipitation was nonlinear with a positive influence on deer mouse populations at low levels with a negative influence at higher levels. Slope was zero (inflection point) at 270 mm of precipitation. The amount of summer precipitation had a negative linear effect on deer mouse populations for riparian habitats (Figure 5) and no effect in upland habitats. Upland populations had a similar pattern to those shown in Figure 1 with a slope of zero at 260 mm without the effect of summer rainfall.

Discussion

We found positive or neutral effects of thinning on the small mammal species examined. Positive effects lasted two years or less out of four post-treatment years. Positive effects of thinning have been attributed to increases in downed woody debris, herbaceous understory plants, and habitat heterogeneity (Carey and Wilson 2001, Suzuki and Hayes 2003, Manning and Edge 2004, Muzika et al. 2004, Converse et al. 2006a, Converse et al. 2006b), all of which are potential factors in our study area. In riparian areas where thinning did not occur, small mammals may be using resources in thinned areas adjacent to the narrow riparian areas or predator populations in the area may have been depressed by thinning. Changes in predator populations may better explain the positive response of voles as they are more unlikely to use areas outside the riparian zone.

In addition to deer mice, chipmunks and woodrats were expected to respond positively to treatments because of increases in woody debris in the form of slash piles, but we found no response. Sample sizes for these species were small and we were unable to correct for differences in capture probability as we were for deer mice and voles. Chipmunk and woodrat populations showed considerable variation during the study period and between trapping areas prior to treatment which may have masked treatment effects. Additionally, these were the largest of the species studied and thus may not be affected by the same predators.

While the rainfall model presented can only be applied to this study, our finding of a curvilinear effect of rainfall is consistent with others (Brown and Ernest 2002). It also provides an additional explanation for why there has been inconsistency in correlating rainfall and populations. For summer rainfall, we found a negative effect in riparian areas, a response that has been attributed to flooding (Elliot and Root 2006). Though water was regulated on parts of the Santa Fe River, the summer thunderstorms are intense and flooding occurs even where water is regulated by dams. Flooding does not occur on the steep slopes of the upland areas and we did not find the same effect of summer precipitation there indicating that soils, slope, and other physical features of the landscape may be important covariates in the precipitation relationship. Effects of winter precipitation, on the other hand, which was a measured 3 months before trapping, are not adequately explained by flooding. Much of the winter precipitation is snowfall and at moderate to high levels may limit access to food (Korslund and Steen 2006), and delay seed germination and plant growth.

Treatment effects were removed when modeling precipitation and deer mouse populations, but 2005, a wet year, was the year where we saw a positive response. The model predicts that at 2005 winter precipitation levels, populations should decrease, but we saw the opposite effect on thinned areas. Thinning of the forest canopy may increase snow accumulation, but also accelerate melting (Troendel and Leaf 1981, Kirchhoff and Schoen 1987). In thinned forests, earlier melting of snow along with increased plant cover and seed production may have alleviated the negative effects of high winter precipitation predicted by the model. Thus, abiotic factors such as precipitation may interact with fuels management and natural disturbances to affect wildlife populations.

When estimable, we found capture probabilities often differed in reference and treatment areas, but this was apparent before and after treatment indicating that site differences, including habitat, were at least as important as treatment in variation in capture probabilities. In this study, we could identify the same treatment effects using M_{t+1} as with N_{est}, but the observed variation in capture probabilities supports adjusting for probability of capture, especially when data are collected in only a few years. Behavior that affects recapture rates may differ in other studies where traps are reused without cleaning.

Management Implications

The lack of negative effects on small mammals indicates that ecosystem function remained intact following large-scale thinning with minimal soil disturbance. Some species were positively affected for a short period as well. Precipitation likely influenced the timing of small mammal response to thinning, thus abiotic influences need to be considered when evaluating management effects and may be closely tied to detection of effects. In addition to precipitation, results suggest that habitat type, slope, and capture probabilities are important when examining changes in small mammal populations.

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Table 1. Means (se) for number of unique individuals (M_{t+1}) of small mammal species by habitat trapped per treatment across two trapping sessions per year, 2002 to 2006. For those species where populations were estimated in MARK, the estimated population, N_{est}, (se) is also reported. Treatments were thinned (T) and unthinned or reference (R) with 2002-2003 considered "before" treatment. Upland habitat populations are not reported for 2006, because trap layout was altered.

		Deer mice M_{t+1}		Deer mice N_{est}		Voles M_{t+1}	Voles N_{est}	Chipmunks M_{t+1}	Woodrats M_{t+1}
Year	Treatment	Riparian[a]	Upland[b]	Riparian[a]	Upland[b]	Riparian[a]	Riparian[a]	Upland[b]	Riparian[a]
2002	R	23.0 (7.1)	4.1 (1.3)	30.5 (7.1)	5.1 (1.6)	7.3 (1.8)	13.0 (3.5)	0	1.4 (0.9)
	T	20.7 (5.3)	4.8 (0.8)	21.7 (5.2)	6.2 (1.1)	0.5 (0.3)	0.5 (0.3)	1.1 (0.4)	2.8 (1.1)
2003	R	24.7 (4.4)	5.6 (1.1)	27.4 (5.2)	6.5 (1.1)	10.3 (1.7)	13.9 (2.2)	0.6 (0.3)	1.5 (0.8)
	T	20.7 (4.1)	5.8 (1.1)	23.9 (5.1)	6.7 (1.1)	3.8 (1.0)	6.0 (1.7)	1.3 (0.5)	8.7 (1.3)
2004	R	31.5 (5.4)	9.75 (1.3)	37.1 (6.5)	12.4 (1.6)	4.2 (1.4)	9.6 (3.2)	1.1 (0.4)	0.5 (0.3)
	T	23.3 (3.9)	9.7 (2.1)	28.8 (5.2)	11.4 (2.5)	2.0 (1.8)	3.2 (2.9)	2.2 (0.7)	4.0 (0.7)
2005	R	21.5 (2.5)	3.2 (1.0)	23.3 (2.6)	3.5 (1.1)	3.0 (1.1)	4.5 (1.7)	0.8 (0.3)	0.8 (0.5)
	T	30.5 (1.6)	7.2 (1.0)	41.2 (1.2)	7.5 (1.0)	5.2 (1.6)	7.8 (2.6)	1.7 (0.6)	3.0 (0.4)
2006	R	15.1 (2.2)	-	16.7 (2.5)	-	3.5 (1.2)	5.6 (2.0)	-	0.5 (0.3)
	T	16.8 (0.6)	-	17.9 (0.5)	-	2.3 (0.9)	4.8 (1.7)	-	1.8 (1.1)

[a]Number of riparian samples 2002 to 2006; reference = 5, 6, 6, 6, 8; treatment = 6, 6, 6, 6, 4
[b]Number of upland samples 2002 to 2005; reference = 6, 8, 8, 8 treatment = 12, 12, 12, 12

Table 2. Results from generalized linear model for deer mouse populations in two habitats by session including treatment, year (before treatment years combined), and the interactions. Values where $P \leq 0.05$ are shown in bold.

	Riparian		Upland	
Session 1 (June/July)	F	*P*	F	*P*
Before vs. 2004	**4.84**	**0.04**	3.55	0.07
Before vs. 2005	**12.68**	**0.002**	0.47	0.50
Before vs. 2006	0.13	0.72	--	--
Treatment	1.46	0.24	0.59	0.45
Treatment*(2004 vs. before)	1.78	0.20	0.59	0.45
Treatment*(2005 vs. before)	**6.61**	**0.02**	0.71	0.40
Treatment*(2006 vs. before)	1.18	0.29	--	--
Session 2 (August)				
Before vs. 2004	0.52	0.48	**20.79**	**<0.001**
Before vs. 2005	0.78	0.39	**4.00**	**0.05**
Before vs. 2006	**10.75**	**0.004**	--	--
Treatment	1.63	0.22	1.87	0.18
Treatment*(2004 vs. before)	0.94	0.34	0.22	0.64
Treatment*(2005 vs. before)	**7.52**	**0.01**	**4.14**	**0.05**
Treatment*(2006 vs. before)	0.34	0.57	--	--

Table 3. Parameter estimates from selected generalized linear model of the relationship between deer mouse populations and precipitation. Populations were sampled in June/July and again in August, thus this estimate reflects breeding activities. Winter precipitation is accumulated from October to 3 months prior to trapping session date. Summer precipitation is accumulated for 1 month prior to trapping session date. For upland habitats, summer rainfall was non-significant when included in the model and removed. Precipitation data was modeled in inches.

	Riparian			Upland		
	estimate	se	*p*	estimate	se	*p*
intercept	3.07	0.38	<0.001	1.07	0.40	0.01
June/July to August	0.60	0.14	<0.001	0.62	0.14	<0.001
Winter precipitation	0.13	0.06	0.05	0.27	0.08	0.001
(Winter precipitation)^2	-0.006	0.003	0.04	-0.01	0.004	<0.001
Summer precipitation	-0.07	0.03	0.01	---	--	--

Figure 1. Map of study and trap locations 2002 to 2006 in riparian and upland habitats.

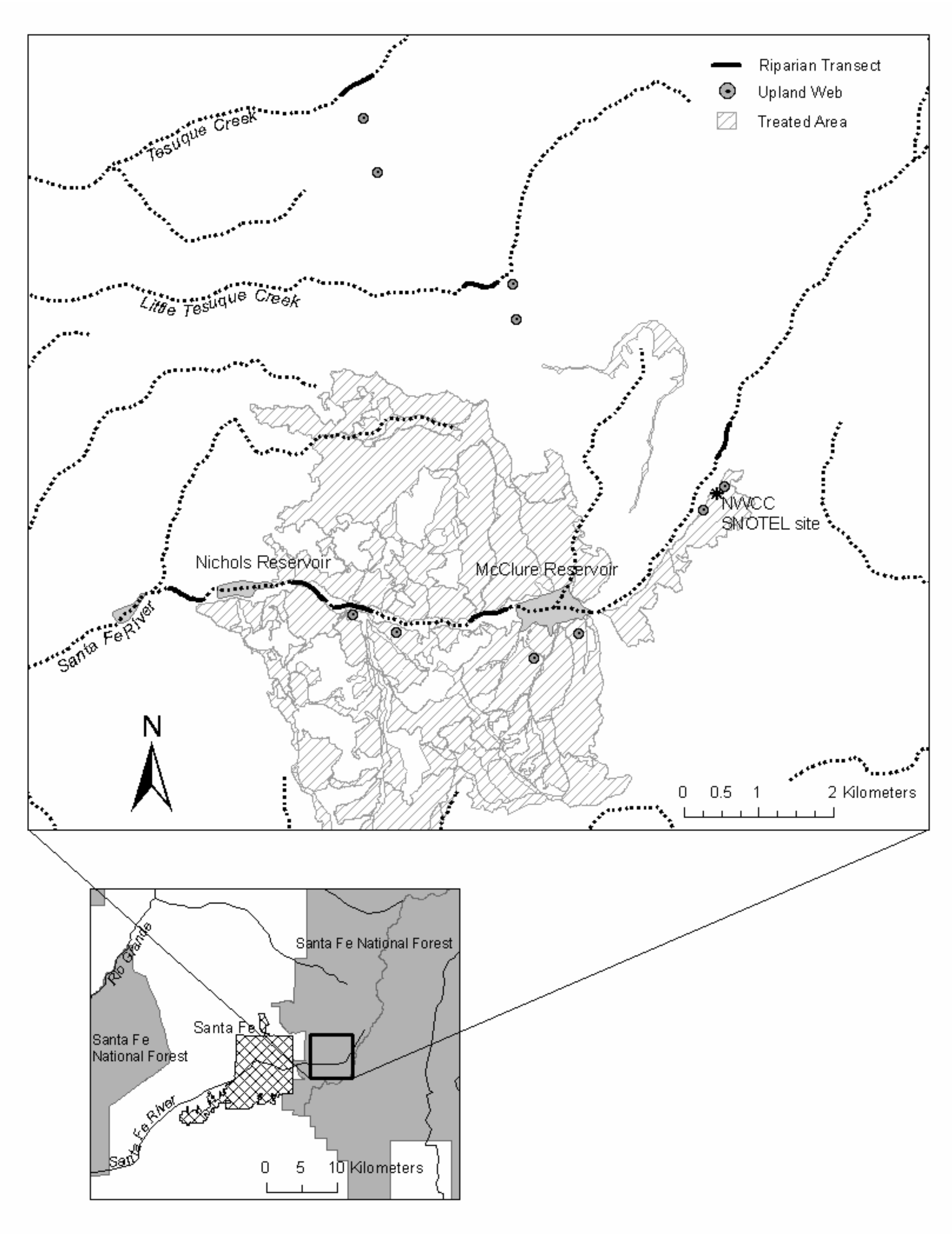


Figure 2. Probability of initial capture (p) and recapture (c) plus standard error bars for deer mouse populations in reference and treatment riparian habitats in August. Estimates of parameters and standard errors were estimated from Huggins closed capture models using mark-recapture data in Program MARK. 2003 is pre-treatment and capture rates were too low in 2002 to calculate both capture probabilities.

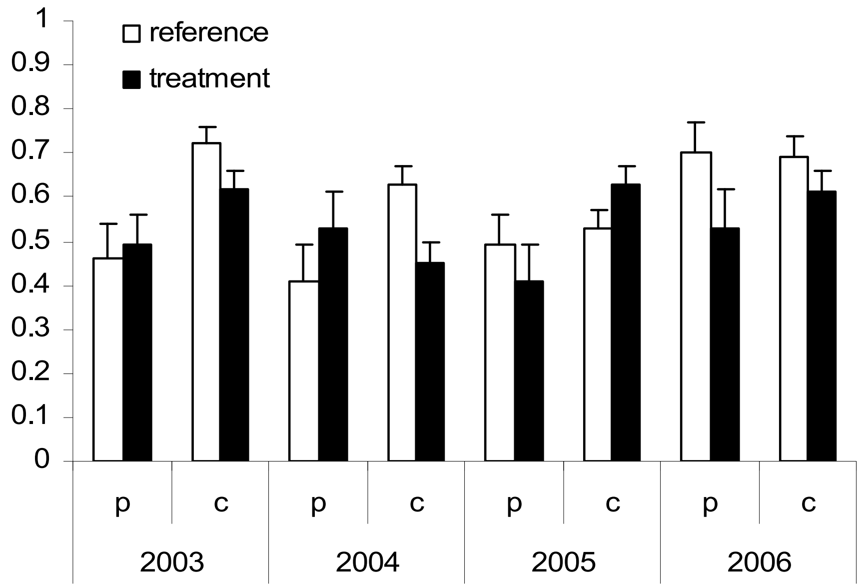


Figure 3. Probability of capture (p where p = c) for deer mouse populations reference and treatment upland habitats for Huggins closed capture models across two trapping sessions. 2002 and 2003 are pre-treatment years.

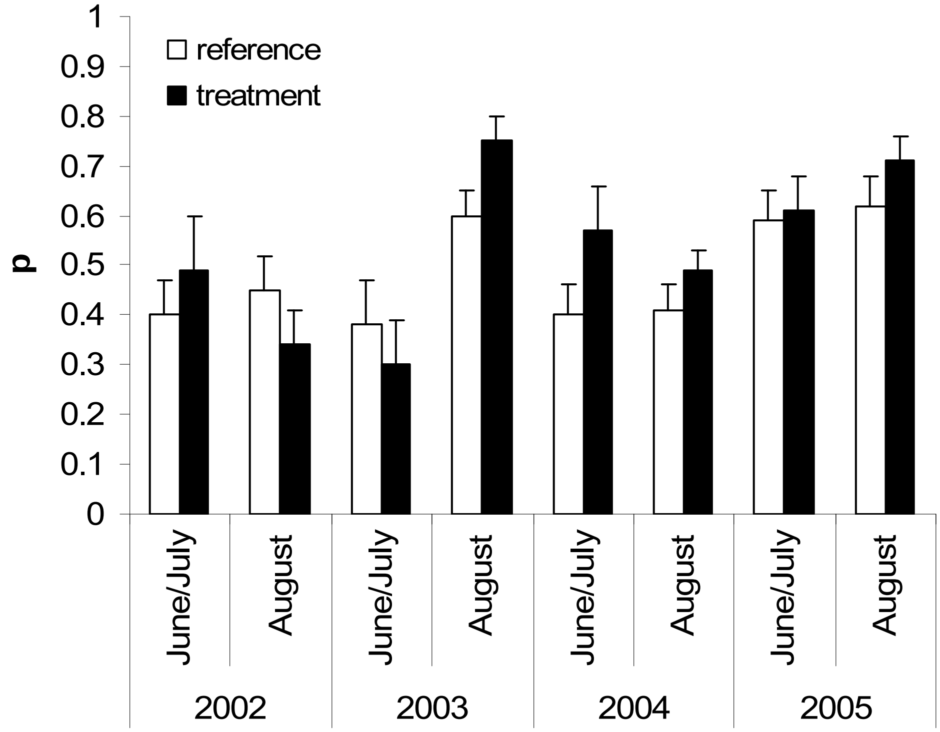


Figure 4. Accumulated precipitation for each trapping session 2002 to 2006. Winter is precipitation accumulated from October to 3 months prior to trapping. Summer is precipitation accumulated in one month prior to trapping.

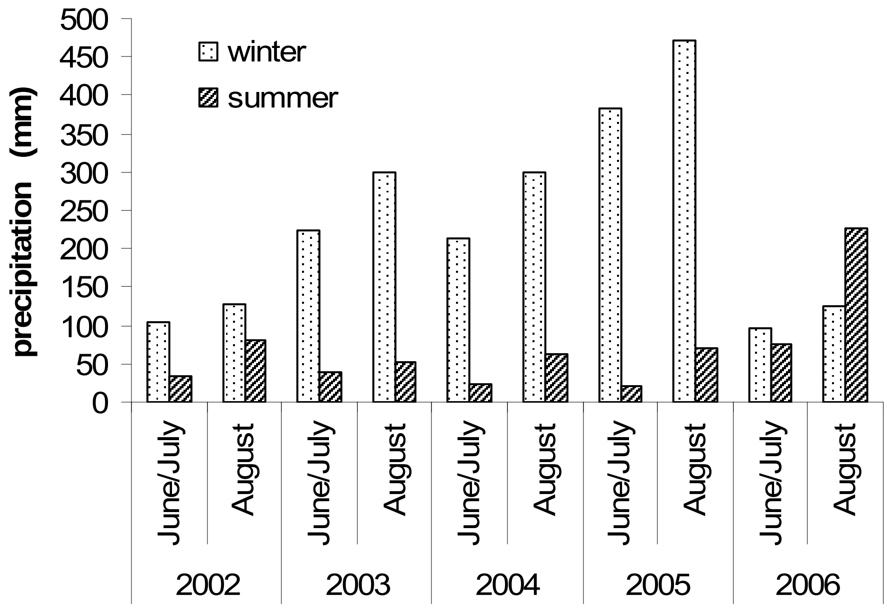
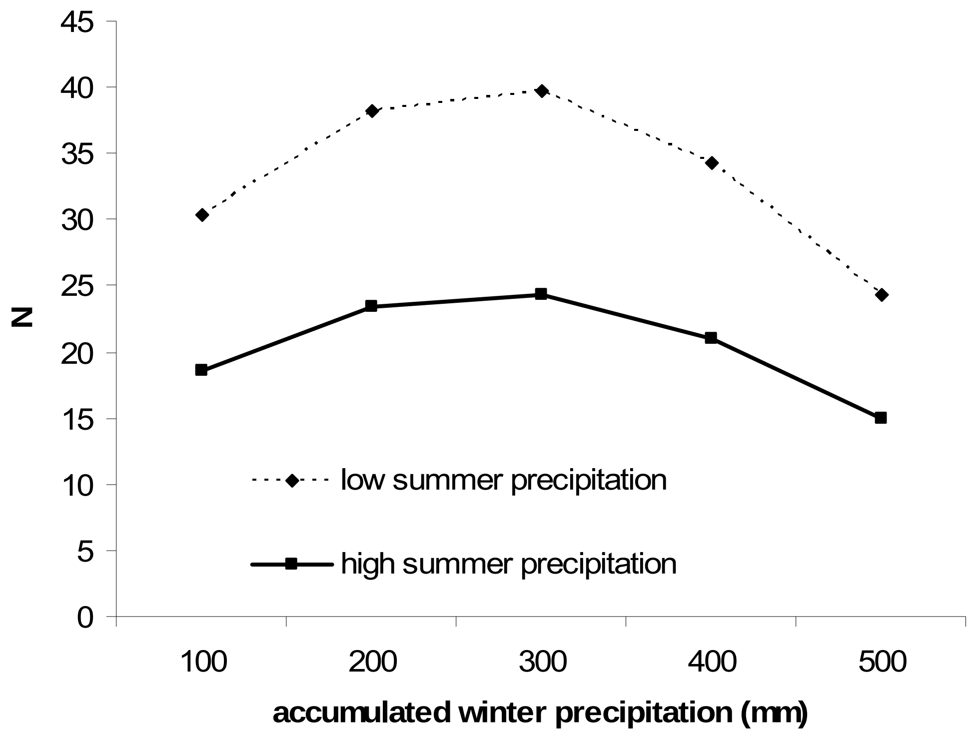


Figure 5. Model results from generalized linear model of the response of August deer mouse populations to winter and summer precipitation in riparian habitats 2002 to 2006. Low summer precipitation was 25 mm and high summer precipitation was 200 mm, both within the range observed during the study. N is the population size (e^x) calculated from the equation estimated by the model, which was fitted with a lognormal distribution. Upland populations showed a similar pattern of winter precipitation without the negative effect of summer precipitation.



Monument Canyon Forest Restoration Project: Final Report

Submitted by the Laboratory of Tree-Ring Research
University of Arizona

To:
USDA Forest Service, Collaborative Forest Restoration Program
and
Santa Fe National Forest

Project Leader: Donald A. Falk

25 June 2007

We are pleased to submit this report summarizing activity on the Monument Canyon Forest Restoration Project ("the Project") from inception through completion of the grant.

A. Project background.

Location and land ownership. Monument Canyon Research Natural Area (MCN) is in the Jemez Mountains of north central New Mexico, USA, on lands administered by the Santa Fe National Forest. The 640 ac (256 ha) Research Natural Area (RNA) is centered at lat. 35° 48' 20" N, longitude. 106° 37' 30" W latitude, and includes all of Section 9, Township 18 North, Range 3 East (Peterson and Rasmussen 1985). Elevations range from 2,438-2,560 m (8,000-8,400 ft) above mean sea level.

Monument Canyon was established as an RNA in 1932, among the first in the United States to be designated (Pearson 1922; Swetnam 1966; Peterson and Rasmussen 1985). RNA designation afforded the area protection from logging and commercial use throughout the remainder of the 20th century, and has contributed to its high value as an old-growth forest to this day. Given its age, size, and cultural history, MCN ranks among the most significant extant old-growth mid-elevation forests in the Southwest.

Topography and soils. The Jemez Mountains lie on the boundary between the Southern Rocky Mountain and Great Basin Provinces (Peterson and Rasmussen 1985). MCN is located on the prow of a rising mesa system on the south margin of the Valles Caldera. Redondo Peak (3,428 m, 11,254 ft), visible to the north, is the highest of a system of emergent domes within the remains of a massive volcano that exploded most recently 1.2 MYA (Allen 2001). Ash and pumice from this event form much of the geologic substrate for contemporary forests.

MCN includes the upper sections of two mesas, Cat and San Juan, originally part of the parent caldera but dissected during the late Pleistocene. The mesas are bounded by 450 m (1,500 ft) Cañon de San Diego to the west, and the 365 m (1,200 ft) canyon of the East Fork of the Jemez River to the north. The upper reaches of Church Creek and Cañon de Cañada drainages originate in the RNA, flowing to the southwest and eventually joining the Jemez River south of the town of Jemez Springs and north of the Pueblo of Jemez. The Cañon de Cañada forms a 60 m (200 ft) cliff at the southwestern corner of the RNA, effectively dividing San Juan and Cat Mesas.

Bedrock of the mesas at MCN is primarily the Otowi Member of Bandelier Tuff resulting from ash flows during the late Pleistocene volcanism, with outcrops of pumice and Valles Rhyolite. The material is poorly consolidated and relatively soft, leading to the occurrence of many naturally occurring caves and alcoves in rock outcrops. Soils are mostly colluvial and well drained, exacerbating the tendency toward plant water deficit during the warm months. The bottomlands of Church Creek and other drainages have deeper alluvial soils with higher organic content.

Climate. The nearest permanent weather station is located in the town of Jemez Springs, only 5.5 km (3.5 mi) SW but 600 m (2,000 ft) lower in elevation. Mean annual precipitation for the instrumental record at Station 4369 in Jemez Springs is 46.5 cm (18.3 in), but Tuan et al. (1973) note that in the Jemez Mountains, areas above 2,400 m (8,000 ft) typically receive more than 58-76 cm (23-30 in) of rainfall annually. The area has a bimodal annual climate pattern, with rains originating from the southwestern monsoon accounting for 45-50% of annual rainfall;

the remainder falls in winter and autumn (Tuan, Everard et al. 1973), with dry seasons in late fall and spring.

Mean temperatures in New Mexico are more strongly controlled by elevation than is precipitation, falling at a lapse rate of approximately 9.0 °C for every 1,000 m (5 °F per every 1,000 ft) increase in elevation between 900 – 2.700 m (3,000 – 9,000 ft) (Tuan, Everard et al. 1973). On this basis the mean annual temperature of 10.0 °C (50 °F) at Jemez Springs corresponds to an annual mean at MCN of approximately 4.5 °C (40 °F). Peak mean monthly summer temperatures are approximately 22.2 °C (72 °F), and mean monthly minima are –5.5 °C (22 °F). Late spring freezes can occur at late as June and as early as September; on average, 100 – 120 days are frost free each year. Plant moisture deficit (potential evapotranspiration exceeds precipitation plus stored soil water) extends over much of the year, from April through October.

Vegetation. Most of MCN is upland forest, although the site also includes riparian areas, rocky outcrops and cliffs. Most vegetation is the Interior Ponderosa Pine type; the site is near the upper elevation limit for ponderosa pine dominance on mixed topography in northern New Mexico (Regional forest type 122.3, Petran Montane Conifer Forest) (Brown and Lowe 1980). At higher elevations and on northerly aspects, forest mixed-conifer communities (121.3, Petran Subalpine Conifer Forest) dominate. In MCN, mixed-conifer stands are found mostly on north-facing slopes and drainage bottoms.

In addition to ponderosa pine, mature individuals of several other tree species are found within MCN, including white fir (*Abies concolor)*, Rocky Mountain juniper (*Juniperus scopulorum)*, two-needle piñon (*Pinus edulis*), limber pine (*Pinus flexilis*), Gambel oak (*Quercus gambelii*), and Douglas-fir (*Pseudotsuga menziesii*. All of these species were present in the presettlement period (prior to the 1880's), and provide a rich and detailed dendrochronological record.

MCN contains some of the oldest remaining ponderosa pine stands in the southwestern United States, some more than 400 years old (Touchan, Allen et al. 1996; Morino, Baisan et al. 1998). The oldest living trees sampled to date in Monument Canyon germinated before 1498, and many trees older than 400 yr are found on the site (Falk 2004). Remnant dead wood has been dated to the early 1300's.

Land use history. The site has a long human cultural history; elders of the nearby Pueblo of Jemez know Monument Canyon as *wa ha dóc wha*, "Place Where the Clouds Live". The Padre Alonzo Trail, which crosses through the RNA, leads to Jemez Springs to the west and is believed to have extended to the Pueblo of Santa Fe some 50 miles to the east, as part of an extensive trail network connecting the Puebloan communities of the region. The trail was used by Basque shepherds in the nineteenth century, and portions of the trail are extant on MCN (T. Swetnam and D. Falk, pers. obs.). Archaeological surveys document hundreds of cultural sites on San Juan and Cat Mesas, including more than 30 in the vicinity of MCN (Santa Fe National Forest, US Forest Service, Archaeological Survey Report 1995).

Livestock grazing became a major ecological force in the late 19th century in the Jemez Mountains, as it did in many areas of the southwestern North America (Allen 2001). Extensive grazing reduced surface fuel loads and continuity, and dramatically altered the natural fire regime decades before active fire suppression became effective (Weaver 1951; Cooper 1960; Savage and Swetnam 1990). Grazing continues to this day in the southwestern Jemez Mountains, although animal densities are a fraction of what they were a century ago.

Historic fire regime. Like most forests of this type in the region, surface fires burned historically on the mesas of Monument Canyon with low intensity, relatively high frequency, and considerable spatial heterogeneity (Touchan, Allen et al. 1996; Morino, Baisan et al. 1998). The fire regime was the subject of a recent dissertation (Falk 2004), which found a mean fire return interval of 3.3 yr $fire^{-1}$ for the site as a whole. Many fires were patchily distributed on the landscape, even at small scales (Figure 3), indicating the importance of local fire history information.

B. Forest and fire risk conditions, and motivation for Project.

Our restoration project at MCRNA is built on a foundation of the following principles:

a) Reduce the risk of catastrophic fire while minimizing impact to the forest;
b) Protect old-growth trees and forest structure;
c) Advance understanding of the effects of fuel and fire treatments on forest dynamics;
d) Reintroduce fire as a keystone ecological process for reducing risk of extreme fires and increasing forest health.

The natural fire regime has been absent for nearly a century due to the combined effects of grazing and subsequent fire exclusion in surrounding areas. As a consequence, unnaturally dense thickets of small stems (> 9,000 stems ha-1 in some areas), most of which are morbid and have little prospect of reaching the canopy, now cover large portions of the RNA (Table 1). The dominant overstory trees have been affected adversely by increased root-zone competition, reflected in deteriorating vigor and increasing vulnerability to disease.

A related justification for the restoration research program in Monument Canyon is the high probability that a catastrophic high-intensity fire will destroy this irreplaceable old-growth Ponderosa pine forest if forest conditions are not improved. Even if a crown fire does not occur, without restoration the old overstory trees will continue to decline, with individuals and groups of trees succumbing at an increasing rate to episodic droughts, beetle attacks, and other pathogens. There are already signs that the overstory is losing vigor and the old-growth structure is deteriorating, including slow ring-growth, very thin crowns in the old trees surrounded by thickets, and increasing mortality rates.

More than 100 homes are located within 2 miles of Monument Canyon in the nearby communities of Sierra Los Piños and Los Griegos. These communities are located ENE of MCRNA, in alignment with the prevailing winds which come from the WSW. Most of the homes are nestled within dense Ponderosa pine thickets and pole stands similar to those occurring in MCRNA. They would be in the direct path of a wildfire as well as burning embers lofted from a wildfire. The community of Ponderosa is located below the mesa and would be vulnerable to flood and erosion should a high intensity fire burn the mesas and canyons above. The Monument Canyon Restoration Project qualifies as a wildland-urban interface (WUI) area under Title IV for hazardous fuel reduction.

A Hazard Assessment conducted by the SFNF (DeGray 1997) found that fuel loadings, which would be ± 3-5 tons/ac under natural conditions, are now in excess of 18-30 tons/ac. Fuel accumulations are influenced by the excessive 20th century thickets, which die and create extraordinarily high standing fuel loads in the 10-100 hr classes, increasing the probability and intensity of a crown fire. Absence of surface fires contributes to fine fuel accumulation in deep litter and duff layers. Under standard predictive models (BEHAVE, Nexus, Fuels Management

Analyst) and average summer weather conditions (10 mph windspeed, surface spread), an ignition could spread to 32 acres in an hour and 285 acres in 3 hours. Vertical fuel continuity increases the probability of a crown event under moderate winds or drought conditions, with spotting from groups of torching trees up to 1-2 miles under moderate wind conditions. While fuel management and restoration in MCRNA cannot guarantee that a future crown fire will not occur, it will greatly decrease the probability of this outcome.

MCRNA is nested within a larger landscape of the San Juan-Cat Mesa system, comprising more than 3,200 ha (8,000 acres). The SFNF manages much of this area as a natural fire use area, and restoration of the RNA will facilitate its integration into this larger natural landscape.

C. Pre-treatment baseline ecological monitoring.

We conducted pre-treatment baseline ecological monitoring beginning in 2002 and continuing until treatments were implemented in late 2005/early 2006. For additional details, see *Monument Canyon Restoration Research Project Field Sampling Protocols*, Appendix A). Our monitoring system included establishment of more than 30 nested plots on the MCRNA grid system, with plot sizes of 0.25, 0.1, and 0.01 ha (Figure 2). At these plots we designed and conducted a collection of complete plot data in the nested plot series (Figure 2) including:

- Complete inventory of overstory trees (≥ 25 cm dbh) identified to species, location (*x*, *y* coordinates), diameter, and condition (0.25-ha outer plot) (Figure 6);
- Complete age structure of all overstory trees (0.1-ha plot), as well as species, diameter, and locations;
- Complete age structure of all trees ≥ 2.5 cm dbh, and random samples of seedlings and small trees ≥ 2.5 cm dbh in 15 0.01-ha $(10\ m)^2$ plots across the RNA;
- Species composition, density, and basal area at all scales from 0.01 ha to full study area (250 ha);
- Establishment and periodic monitoring of understory plant diversity plots at 13 (later expanded to 16) locations throughout MCRNA, every 2-3 weeks through the entire growing season. The purpose of this protocol was to capture the full species diversity present on the site, as well as to evaluate potential changes to phenology as a result of treatments.
    - Experimental collections of understory plant biomass for use in fire behavior modeling. These were used to establish a reference understory species biomass data set for about 50 species, calibrated to percent cover. These will permit us to estimate mass from field observations of cover. Of particular interest are the perennial bunchgrasses, which influence fine-scale surface fire behavior and fire frequency.
- Detailed measurements of litter and duff depth and mass at a subset of 15 locations in the study area. At each location, we measured litter and duff depth on a grid of 25 points within a 100-m2 plot; we also measured fuel depths at a series of points arrayed around each plot and then collected samples of each layer separately. These collections will be used to calibrate fuel depth to biomass, and the data used to develop site-specific fire behavior models and as predictive variables for seedling and small tree mortality. Samples were dried and weighed at facilities of the University of Arizona.
- Field measurements of a variety of additional variables that influence fire behavior, including crown base height (the height to the lowest live foliage) for trees in the study

plots. These data will be used to calibrate the fire behavior model to local stand conditions.

- Annual surveys of overstory tree condition in 16 plots. Large and old trees, which are a focus of CFRP, are threatened both by current overstocked forest conditions, and potentially by treatments such as fire. Their deteriorating condition is further exacerbated by the recent multi-year drought and regional outbreaks of cambial and defoliating insects. In each study plot, we examined every tagged tree and recorded condition in a 5-part ordinal ranking system. We will use these rankings for repeat observations of old trees, both with and without restoration treatments.
- Digital canopy images to our pre-treatment data collection (Figure 5). Mechanical thinning of trees affects the forest canopy directly, but there is generally little effort to quantify the effects of thinning on canopy coverage. Digital images can be processed and measured to provide a quantitative measure of canopy cover; these images are georeferenced and can be repeated following treatments.

In addition to this extensive baseline data collection, we experimented with an innovation in field sampling methods. Instead of using paper forms, we employed handheld field data recorders for all data recording. The recorders, which are common PDA's, are loaded up in advance with spreadsheets containing previous years' data, and fields for recording of new data types at each plot. At the end of each field day, we downloaded the data to a notebook computer in base camp, and then saved the data set to CD. Every few days we mailed or emailed files from the Jemez Springs District office back to our laboratory in Tucson. This provided a high degree of data security, and greatly increased our efficiency in the field. We also believe that this method will increase our efficiency here at the Laboratory when the time comes for data analysis, since all data will already be in spreadsheet form.

For our understory collection, we established a set of mounted voucher specimens of all vascular plants recorded on the restoration site, which were verified at the University of Arizona Herbarium.

Tree competition and ecophysiology. In 2004 we added a new component to examine the effects of competition on old and large trees, as a complement the detailed monitoring of overstory tree condition. This component is being conducted in collaboration with lead researcher Nate McDowell at the Los Alamos National Laboratory (LANL). We collected increment cores from a sample of trees in open and dense forest conditions, which are being used for isotopic analysis of the effects of drought and competition old and large trees. The summer's work included joint support of 2 students by the MCN-FRP and LANL (the latter made a significant financial contribution to the project and provided facilities and laboratory space). This extra effort complements our other CFRP objectives and will provide insight into a poorly understood component of forest health and restoration.

Key personnel in the MCN field effort included:

Faith Crosby, botanical consultant to the MCN project, spent several days in the University of Arizona Herbarium working to identify voucher specimens and verify identify of material collected on the site. Monument Canyon is now one of the best-documented forest restoration sites in New Mexico.

It is not feasible to list all the people who participated in field sampling at MCN during the CFRP grant period. The following played key roles in the field and laboratory effort:

Soo-hyun Baek, University of Arizona (currently at Johns Hopkins University)
Hanna Coy, University of Arizona
Calvin Farris, UA (currently National Park Service)
Ari Fitzwater, UA (currently US Coast Guard)
Ellis Margolis, University of Arizona
Laura Marshall UA (currently at University of California, Irvine)
James Riser, Rocky Mountain Research Station
Dan Ryerson, UA (currently National Park Service, NM)

NEPA and other legal compliance. The Jemez District, Santa Fe NF issued a scoping letter for incorporation of the project into the current Forest Plan in January 2003. The Jemez Ranger District prepared the Proposed Action, Purpose and Need statement, for which we provided reviews and data during Spring 2004. The NEPA documentation process was completed, including the scoping document, map of treatment area, and archaeological survey. SHPO clearance was finalized and the District Ranger signed the Decision Memorandum on 31 August 2004.

Restoration treatments.

In 2003, we traveled to the site in October to observe the San Juan prescribed burn, along with representatives of the Santa Fe National Forest, Jemez District. The San Juan burn is adjacent to the CFRP restoration study area, and will also serve as a critical firebreak (see 2002 Annual Report). The methods used in the San Juan burn are similar to those proposed for the restoration area, and the site visit helped clarify probable fire behavior under similar topography, stand conditions, and fuels. In the months following we worked with the District to generate a map (Figure 4) outlining the boundaries of the area to be treated using CFRP funds. The thinning and burning treatments will encompass approximately 298 contiguous acres (121 ha) and will be concentrated on San Juan Mesa. A control area will be reserved as proposed originally, primarily on Cat Mesa.

The guiding principle for the MCN-FRP was a “process-centered restoration” (PCR) approach. We plan to use tools such as Behave, Nexus and Fuels Management Analyst to model the effects of a minimal structural modification needed to facilitate surface fire behavior under a range of environmental conditions. This can be achieved by analyzing a range of treatment scenarios (thinning up to 6 and 12 in, for example) across a range of fire weather and fuels conditions (80th to 95th percentiles, for example), and then evaluating outputs based on their probability for surface, passive, or active crown fire potential. Our goal remains to reintroduce fire to this ecosystem and allow it to resume its keystone regulatory influence on many other ecological processes.

In the following months, we continued working closely with the District to plan the upcoming treatments. Extensive discussions during the quarter culminated in a site visit to the District by Falk on December 6-7 to work out final plans described in this Report. William Armstrong (SFNF SO) and Jemez RD FMO Dan Kay took on the lead role for implementation of the thinning design. Dr. David Conklin, Forest Pathologist (SFNF SO) and Ruben Montes, SFNF CFRP Coordinator joined Falk and Armstrong on the site visit and expressed interest in the Project as a model.

Restoration treatments for the MCN-FRP were envisioned in three phases. Phase I will be an initial cut of most trees smaller than 9 in (23 cm) dbh. The main objectives of this first phase are to reduce standing canopy fuels, reduce canopy connectivity, increase light penetration to the forest floor, and reduce belowground competition with overstory trees. The District recommended the use of a masticating chipper using a Quadco mulching head mounted on a Timbco 425 harvester, which grinds whole trees, leaving the foliage, branches, and bole in small fragments in the immediate area. as the preferred method for thinning at MCN. This method is considered preferable to piling and burning, or cutting individual trees and hauling them off-site, in terms of reduced cost, reduced soil disturbance, and simpler logistics (leading to faster implementation). The treatment creates a resilient "bed" of wood chips, which allows the rubber-tired vehicle to move about the forest with relatively little soil disturbance or compaction, except on some steeper slopes. The chipping method also has the advantage of leaving the majority of foliar nutrients (particularly nitrogen) on site, and also contributes to soil stabilization and moisture retention. Chipping has been used extensively at Los Alamos National Laboratory (LANL), and a site visit to one of the LANL areas is planned for January 2005.

Phase II will be a prescribed burn of the treatment area, proposed as a cool burn to remove most of the fine slash and to consume a portion of accumulated litter and duff, but hot enough to stimulate the understory vegetation and torch individual trees or small groups, as well as to reinitiate soil nutrient cycling in areas that have been stagnant due to excessive stand density in recent decades. Experience with areas that have been thinned with masticating chippers suggests that burning can take place within 1-2 years after thinning, depending on particle size and weather. As of this Final Report we continue to work with the District toward prescribed burning of the study area.

In early January 2006, the thinning, contractor (Environmental Land Management, Colorado) was ready to start work. We traveled immediately to the restoration site and completed the marking of research plots according to SFNF and contractor specification for maximum visibility. The contractor began work January 18, and we made another trip to the site the following week to inspect the initial results and establish communication with the contractor. The initial treatments at MCN were also done with snow on the ground, which further reduced soil impacts. Treatment of 208 as (86 ha) was completed in this phase A second contract for 90 acres (36 ha) of areas of steeper slopes was completed by Forest Rehab, Inc. later in the year, along with hand treatments of permanent research plots. The total area treated was 298 ac (121 ha) (Figure 7).

Sensitive species. In September 2005, the MCN field crew reported sightings of Northern Goshawks (*Accipiter gentiles*) at Monument Canyon, within the proposed treatment area. We coordinated transfer of our information to the District through Jo Wargo, District Wildlife Biologist, including a detailed report with maps on August 29. This initiated discussions within the District staff about how the treatment plans should be modified to account for Goshawk presence; typically, guidelines within the proposed treatment area preclude thinning operations for much of the project area between March 31 and September 30. In 2006, treatments were suspended due to Northern Goshhawk (NOGO) breeding season restrictions.

Post-treatment field monitoring. We brought a field monitoring crew to MCN for approximately 2 weeks in July 2006. Sampling at our 16 ongoing monitoring locations using a nested plot design continued to utilize the "grid" established in previous years, which permits monitoring of changes over time in both the treated and control areas. The LTRR will continue to monitor post-treatment effects following conclusion of the CFRP grant to the extent possible with available support for other sources.

Collaboration.

The Project has benefitted throughout from excellent support and cooperation from the Jemez District, Santa Fe National Forest (SFNF), USGS Jemez Field Station and Bandelier National Monument (National Park Service), Forest Service Operations Research Laboratory, Jemez Pueblo Walatowa Woodlands Initiative, and other collaborating institutions.

Santa Fe National Forest: Staff of the Santa Fe National Forest (SFNF) were keystone partners in visioning, planning and implementing the restoration program at MCRNA. At the SFNF-SO, William Armstrong played a key catalytic role in moving the thinning prescription and treatments forward. We maintained communications with SFNF CFRP Coordinator (Ruben Montes), who was also highly supportive throughout the Project, for which we remain extremely grateful.

At the Jemez District, John Peterson, Ronnie Herrera, Dan Key, Phil Neff, , Dalynn Parks, Marie (DeGray) Rodgriguez, Anna Steffan, Andy Vigil, Jo Wargo, and others supported the Project from its inception, and we are grateful for their dedication and professionalism. Virtually every aspect of the restoration plan was worked out in conversation and analyses conducted collaboratively between the LTRR and the SFNF Jemez District. LTRR staff provided tours of our field operations to explain sampling protocols, research objectives, and restoration ideas. District staff assisted the Project with considerable donated time in the field and with office support and technical expertise, and will be key partners in implementing treatments.

National Park Service and US Geologic Survey: The USGS Jemez Field Station, and staff of Bandelier National Monument (National Park Service) were highly supportive through tout the Project. We consulted regularly with Dr. Craig Allen (USGS), among the most knowledgeable resources regarding ecology and fire history of the Jemez Mountains. Dr. Allen is assisting in our plans for long-term monitoring of tree demography, including influences of disturbance (fire, insects) and climate variation. Staff of Bandelier National Monument, especially Kay Beeley, assisted with GIS and GPS support, and also contributed several days of assistance in the field, including organizing the services of three Student Conservation Association (SCA) interns, who helped with field sampling and data recording in two years of field work.

US Forest Service Operations Research Laboratory. We consulted Dr. Robert Rummer of the FS Operations Research Laboratory in Auburn, AL, for application of low-impact thinning technology suitable for the ecologically sensitive context of the RNA. In 2003, Dr. Rummer traveled to Jemez Springs to spend time with LTRR and SFNF staff on-site. We walked the site extensively and identified suitable approaches to thinning this ecologically sensitive site.

Forest Trust and Jemez Pueblo. During our 2003-4 summer field seasons, we had the benefit of assistance from a Youth Conservation Corp (YCC) field crew from the Jemez Pueblo, with over 150 hours of volunteer labor provided to the project. In addition to providing valuable field assistance, the Jemez YCC crew continued our effort to keep the Pueblo involved and aware of this project on their ancestral lands. Thanks to Martha Schumann for helping to organize the availability of this crew.

Visitors: A number of scientists and restoration practitioners have visited MCN during and since the treatments, including:

Dr. Susanna Bautista, University of Alicante, Spain
Dr. Anne Bradley, The Nature Conservancy in New Mexico
Dr. Peter Brown, Rocky Mountain Tree-Ring Research
Dr. David Conklin, Forest Pathologist, Santa Fe National Forest
Dr. Molly E. Hunter, Department of Forest, Rangeland & Watershed Stewardship, Colorado State University
Dr. Merrill Kaufmann, Rocky Mountain Research Station
Dr. Este Muldavin, The Nature Conservancy in New Mexico
Dr. Tom Swetnam, University of Arizona, Laboratory of Tree-Ring Research
Dr. Melissa Savage, Four Corners Institute, Santa Fe, NM.

Public presentations and workshops.

We participated actively in the annual CFRP Grantee Workshop every year of our grant period. In 2004, at the request of Ruben Montes (SFNF CFRP Coordinator), we participated during his presentation on the second day of the workshop with a "Lessons Learned" discussion, given jointly with Dan Key, Jemez District FMO. This was an honor for us, as well as an opportunity to acknowledge the excellent cooperation we have had from the field staff of the Jemez District. In our presentation we stressed the importance of CFRP recipients cultivating a close working relationship with district staff throughout the life of their project.

We were also invited by the CFRP staff and the Meridian Institute (meeting organizers and facilitators) to give a full-length summary of our restoration research and monitoring approach, which we delivered as a slide presentation in the plenary session for "Selected Project Presentations". Again, it was an honor for us to be selected to present our work as a model for others under the heading of "notable successes and accomplishments".

In addition to CFRP Grantee Workshops, we made public presentations and publications based in part on our CFRP project at the following venues:

1. August 2002. Ecological Society of America/Society for Ecological Restoration Joint Annual Meeting; Symposium, Adaptive Management Experimentation in Ponderosa Pine Restoration.
2. April 2003. Laboratory of Tree-Ring Research, Noon Seminar, "Scaling rules for fire regimes".
3. April 2003. Southwest Fire Initiative Conference, Ecological Restoration Institute, Northern Arizona University, "Toward process-centered restoration: Temporal variability as the reference envelope".
4. August 2003. Ecological Society of America, Concurrent session on Fire Ecology: "Scaling Rules for Fire Regimes." Presentation awarded the ESA Edward S. Deevey Award.
5. February 2004. "Event-area relationships: Scaling rules for fire regimes." Invited symposium presentation, Special Symposium: "Scaling laws in fire regimes: moving landscape fire history into the 21st century." Carol Miller & Donald McKenzie (Organizers). International Association for Landscape Ecology (US). Received Honorable Mention, Student Presentation Award.
6. February 2005. Christopher Baisan, Erica Bigio, Falk, Donald, Calvin Farris, Jose Iniguez, Ellis Margolis, Thomas Swetnam. "Using reconstruction of historical ecosystem

processes to guide forest restoration." Invited presentation at: Southwest Fire Learning Network Workshop, Western New Mexico University, Silver City, NM.
7. April 2005. Falk, Donald & W. Wallace Covington. "Emerging principles in ecological restoration." American Association for the Advancement of Science. 80th Southwest and Rocky Mountain Division, Tucson, AZ.
8. August 2005: "Restoring fire as a keystone process: insights from the pine forests of arid North America." Thomas D. Sisk, Northern Arizona University, Donald A. Falk, University of Arizona, Melissa Savage, University of California, Los Angeles, and Patrick McCarthy, The Nature Conservancy (presented by Sisk).
9. September 2005: Presentation by Laura Marshall for DOE Internship in Washington, DC, "Climate Change Implications of Stable Carbon Isotope Dendrochronology in the Jemez Mountains of New Mexico", with Nate McDowell and Don Falk.
10. November 2005: Society for Ecological Restoration, "Reference dynamics: Using reconstruction of ecological processes to restore natural variability", Zaragoza, Spain.
11. December 2005. Technical paper: "Reference dynamics: Using reconstruction of ecological processes to restore natural variability". USGS Wildland Fire Workshop, Tucson, AZ.
12. December 2005: Keynote address to the 10th Annual Conference of the Forest Guild, Santa Fe, NM.
13. February 2006. "Fire as a landscape process". Rx510 Interagency Fire Training Workshop, Tucson, AZ.
14. March 2006. "Process-centered restoration" at Oklahoma State University, Stillwater, OK.
15. September 2006. Presentation by Laura Marshall, "Fire, Water, and Nitrogen: Growth constraints in a New Mexico ponderosa pine forest", co-authors Nate McDowell and D. Falk, Intern presentation to Department of Energy Office of Biological and Environmental Research's Global Change Education Program (GCEP).
16. October 2006. Presented Falk, D. A. and William Armstrong. "Process-centered restoration in a New Mexico ponderosa pine forest." National Conference on Conserving and Restoring Frequent Fire Landscapes of the West: Linking Science, Collaboration and Practice. Northern Arizona University, Flagstaff.
17. November 2006. Presented Falk, D. A. and William Armstrong. "Process-centered restoration in a New Mexico ponderosa pine forest." Association of Fire Ecology, 3rd International Fire Ecology and Management Congress, San Diego, CA.

Involvement in forest health policy and planning. In June 2003, D. Falk and T. Swetnam (UA-LTRR) were appointed by Arizona Governor Janet Napolitano to serve on the Forest Health Advisory Council. This scientific panel is charged to develop a comprehensive set of recommendations for restoration of forest health across the state, including active plans for restoration and reintroduction of fire. The results of the Council's work will be incorporated into state policy, as well as being offered to planners in other states as a model for large-scale planning and implementation of forest restoration programs.

Publications.

1. Allen, C. D., D. A. Falk, M. Hoffman, J. Klingel, P. Morgan, M. Savage, T. Schulke, P. Stacey, K. Suckling, and T. W. Swetnam. 2002. Ecological restoration of

southwestern Ponderosa pine ecosystems: A broad framework. *Ecological Applications* 12(5): 1418-1433.
2. Falk, D. A. and T. W. Swetnam. 2003. Scaling rules and probability models for surface fire regimes in Ponderosa pine forests. Fire, fuel treatments, and ecological restoration. P. N. Omi and L. A. Joyce. Ft. Collins, CO, US Forest Service, Rocky Mountain Research Station. Vol. RMRS-P-29: 301-317
3. Falk, D. A. 2004. *Scaling rules for southwestern surface fire regimes*. Ph.D. dissertation, Department of Ecology & Evolutionary Biology and Laboratory of Tree-Ring Research, University of Arizona.
4. Falk, D. A. 2006. Process-centred restoration in a fire-adapted ponderosa pine forest. *Journal for Nature Conservation* 14: 140-151.
5. Sisk, T. D., M. Savage, D. A. Falk, et al. (2005). "A landscape perspective for forest restoration." *Journal of Forestry* **103**(6): 319-320.
6. D. A. Falk, C. Miller, D. McKenzie, and A. E. Black. Cross-scale analysis of fire regimes. *Ecosystems* (in press).

Project overview. We believe that the CFRP Project at Monument Canyon Research Natural Area has been a great success. All major objectives have been achieved, new concepts are being explored, and ongoing monitoring of the area is underway with support from other sources. MCN is now one of the best-documented restoration sites in the region, and stands to continue as a leading example of the potential for collaborative restoration. We are deeply grateful to the Collaborative Forest Restoration Program for its vision and leadership in promoting forest restoration.

Respectfully submitted,

s/ Don Falk

Table 1. Pre-treatment tree density summary, Monument Canyon RNA, NM.

PLOT	SEEDLINGS AND SAPLINGS < 2.5 CM DBH OR < BH (0.01-ha plot)			STEM DENSITY ≥ 2.5 CM DBH (0.01-ha plot)			ESTIMATED DENSITY ≥ 2.5 CM DBH (stems ha^{-1})			(stems ac^{-1})	ESTIMATED TOTAL DENSITY All DBH (stems ha^{-1})			(stems ac^{-1})	Stand description
	LIVE	*DEAD*	*TOTAL*	*LIVE*	*DEAD*	*TOTAL*	***LIVE***	***DEAD***	***TOTAL***	***LIVE***	*LIVE*	*DEAD*	*TOTAL*	*LIVE*	
109	26	0	26	42	4	46	4,200	400	4,600	1,700	6,800	400	7,200	2,753	Moderately open MC, some thickets
111	1	0	1	24	13	37	2,296	380	2,676	930	2,500	1,300	3,800	1,012	Open SW slope
113	1	0	1	11	1	12	1,120	1,004	2,124	453	1,200	100	1,300	486	Open
115	15	12	27	72	1	73	7,136	296	7,432	2,889	8,700	1,300	10,000	3,522	Thicket
117							192	40	232	78					Open (previously thinned; no small tree data)
119	46	0	46	1	1	2	100	100	200	40	4,700	100	4,800	1,903	Open cliff site, toe slope at bottom
121	17	0	17	11	0	11	760	60	820	308	2,800	0	2,800	1,134	Moderate MC
123				68	18	86	7,604	960	8,564	3,079	6,800	1,800	8,600	2,753	Thicket
125	22	0	22	29	13	42	2,964	1,248	4,212	1,200	5,100	1,300	6,400	2,065	Thicket
127	44	0	44	11	1	12	1,100	100	1,200	445	5,500	100	5,600	2,227	
129	1	0	1	1	1	2	100	100	200	40	200	100	300	81	Lower edge of cliff on sideslope
130	108	0	108	22	0	22	2,612	116	2,728	1,057	13,000	0	13,000	5,263	Valley bottom, dense regeneration
131	222	6	228	30	3	33	4,156	212	4,368	1,683	25,200	900	26,100	10,202	Regenerating MC
133				99	22	121	9,812	1,980	11,792	3,972	9,900	2,200	12,100	4,008	Thicket
137	16	0	16	0	0	0					1,600	0	1,600	648	Open PIPO (ridge top)
139	2	1	3	3	1	4	300	100	400	121	500	200	700	202	SW-facing cliffy/rocky site
141	51	4	55	7	19	26	920	1,020	1,940	372	5,800	2,300	8,100	2,348	MC in valley bottom
143	20	3	23	0	0	0	1,748	156	1,904	708	2,000	300	2,300	810	Thicket
145	10	0	10	0	0	0					1,000	0	1,000	405	Open
147	13	1	14	0	0	0					1,300	100	1,400	526	Moderate density with thickets
149	1	0	1	7	1	8	700	100	800	283	800	100	900	324	Moderately open, level; may have been thinned
151	25	0	25	0	0	0	348	28	376	141	2,500	0	2,500	1,012	Moderately open, some thicket
154	48	0	48	0	0	0					4,800	0	4,800	1,943	
156	31	1	32	15	1	16	1,500	100	1,600	607	4,600	200	4,800	1,862	Thicket
158	1	0	1	29	0	29	2,900	0	2,900	1,174	3,000	0	3,000	1,215	Moderate density PIPO
160	2	0	2	3	0	3	300	0	300	121	500	0	500	202	Moderate density PIPO with other conifers present
162	8	5	13	15	0	15	1,500	0	1,500	607	2,300	500	2,800	931	Moderately open
164	17	1	18	9	0	9	900	0	900	364	2,600	100	2,700	1,053	Moderate density PIPO
166	33	0	33	7	1	8	700	100	800	283	4,000	100	4,100	1,619	Moderately open
Min	1	-	1	-	-	-	100	-	200	40	200	-	300	81	
Max	222	12	228	99	22	121	9,812	1,980	11,792	3,972	25,200	2,300	26,100	10,202	
Mean	30	1	31	18	4	22	2,239	344	2,583	906	4,632	482	5,114	1,875	
SD	46	3	46	25	7	29	2,562	502	2,910	1,037	5,073	705	5,377	2,054	

Plots
29

Verified
2005 treatment area

Note: Plot 117 is in an area previously thinned.

Table 2. Understory species pre-treatment at Monument Canyon RNA.

Species Abbrev.	Site	Family/ Subfamily/Tribe	Genus	Species	Determiner	Common Name
ABCO	Most	Pinaceae	*Abies*	*concolor*	Lindley ex Hildebrand	White fir
ACMI	141	Asteraceae	*Achillea*	*millefolium*	Linnaeus	Yarrow
AGHE	141	Asteraceae	*Ageratina*	*herbaceae*	Greene	Thoroughwort
AGAU	156	Asteraceae	*Agoseris*	*aurantiaca*	Greene	Burnt-orange dandelion
ALAC	164	Apiaceae	*Aletis*	*acaulis*	Coulter & Rose	Indian parsley
ALCE		Lilliaceae	*Allium*	*cernuum*	Roth	Nodding onion
ALGE	141	Lilliaceae	*Allium*	*geyerii*	S. Watson	Wild onion
AMUT			*Amalanchier*	*utahensis*		Utah serviceberry
ANPA	131	Asteraceae	*Antennaria*	*parvifolia*	Nuttall	Pussytoes
ARUV	141	Ericaceae	*Arctostaphlos*	*uva-ursi*	Sprengel	Bearberry
ARLU	141	Asteraceae	*Artemesia*	*ludovicana*	Nuttal	New Mexico wormwood
ASXX		Asteraceae	*Aster*	sp.		Daisy
BEFE	154	Berberidaceae	*Berberis*	*fendleri*	Gray	Fendler's barberry
BLTR	149	Eragrostidaceae	*Blepharoneuron*	*tricholepis*	Nash	Pine dropseed
BRAN		Gramineae/Pooideae/Poeae	*Bromus*	*anomalus*	Ruprecht	Nodding brome
BRXX	111	Gramineae/Pooideae/Poeae	*Bromus*	sp.		Brome grass
BRCI		Gramineae/Pooideae/Poeae	*Bromus*	*ciliatus*	Linnaeus	Fringed brome
CEFE	San Juan		*Ceanothus*	*fendlerii*		Ceanothus
CEMO		Rosaceae	*Cercocarpus*	*montanus*		Mountain mahogany
CLCO	154	Rannunculaceae	*Clematis*	*Columbiana*	Torrey & Gray	Columbian virgin's-bower
CLLI	164	Rannunculaceae	*Clematis*	*ligusticifolia*	Nuttall	Virgin's-bower
ELLO	164	Gramineae/Pooideae/Triticeae	*Elymus*	*longifolius*	Gould	Squirreltail
ELSM	131	Gramineae/Pooideae/Triticeae	*Elymus*	*smithii*	Gould	Western wheatgrass
ELXX		Gramineae/Pooideae/Triticeae	*Elymus*	sp.		Wheatgrass
ERDI	111	Asteraceae	*Erigeron*	*divergens*	Torrey & Gray	Spreading fleabane daisy
ERPU	154	Asteraceae	*Erigeron*	*pulcherrimus*	Heller	Basin fleabane daisy
ERXX		Asteraceae	*Erigeron*	sp.		Fleabane daisy
EUHE	141	Asteraceae	*Eupatorium*	*herbaceum*	Greene	Thoroughwort
EUBR	154	Euphorbiaceae	*Euphorbia*	*brachycera*	Engelmann	Horned spurge
FEAR	137	Gramineae/Pooideae/Poeae	*Festuca*	*arizonica*	Vasey	Arizona fescue
FRVE	131	Rosaceae	*Fragaria*	*vesca ssp. Americana*	Linnaeus	Wild strawberry
GABO	121	Rubiaceae	*Gallium*	*boreale*	Linnaeus	Northern bedstraw
GECA	141	Geraniaceae	*Geranuim*	*caespitosum*	James	Purple geranium
GERI	141	Geraniaceae	*Geranuim*	*richardsonii*	Fischer + Trautvetter	Richardson geranium
GEMA (GETR)	121	Rosaceae	*Geum*	*macrophyllum?*	Willdenow	Cut-leaved avens
HEVI	156	Asteraceae	*Hetertheca*	*villosa*	Shinners	Hairy golden-aster
HIFE	131	Asteraceae	*Hieraceum*	*fenderleri*	Schultz-Bipontinus	Fendler's hawkweed
HODU	Cat		*Holodiscus*	*dumosus*		Ocean Spray
HYRI	131	Asteraceae	*Hymenoxis*	*richardsonii*	Cockerell	Colorado rubberweed
IPAG	131	Polemoniaceae	*Ipomopsis*	*aggregata*	V. Grant	Skyrocket
JAAM	San Juan		*Jamesia*	*americana*		
KOMA	131	Gramineae/Pooideae/Aveneae	*Koeleria*	*macrantha*	Schultz	Junegrass,Zacate deCresta
LALA	147	Fabeaceae	*Lathyrus*	*lanzwertii*	Kellogg	Sweetpea
LIPU	154	Asteraceae	*Liatris*	*punctata*	Hooker	Dotted gayfeather
LIVU	154	Schrophulariaceae	*Linaria*	*vulgaris*	Hill	Butter and eggs
LIMU	111	Boraginaceae	*Lithospermum*	*multiflorum*	Torrey ex. Gray	Puccoon
MASO	111	Orchidaceae	*Malaxis*	*souleii*	Williams	Adder's mouth
MELA	164	Boraginaceae	*Mertensia*	*lanceolata*	A.P. de Candolla	Prairie bluebells
MUMO	113	Gramineae/Chloridoideae/Eragrostideae	*Muhlenbergia*	*montana*	A.S. Hitchcock	Mountain muhly
PEBA	164	Scrophulariaceae	*Penstemon*	*barbatus*	Keck	Red beardtounge
PEJA	149	Scrophulariaceae	*Penstemon*	*jamesii*	Bentham	James beardtounge
PEXX		Scrophulariaceae	*Penstemon*	sp.		Beardtounge
PHMI	156	Hydrangeaceae	*Philadelphus*	*microphyllus*	Gray	Little-leaf mock-orange
PHMO	San Juan		*Physocarpus*	*monogynus*		Ninebark
PIFL		Pinaceae	*Pinus*	*flexilis*	James	Limber Pine
PIPO	Most	Pinaceae	*Pinus*	*ponderosa*	Lawson	Ponderosa Pine
POFE	156	Gramineae/Pooideae/Poeae	*Poa*	*fendleriana*	Vasey	Fendler's muttongrass
POSE	156	Gramineae/Pooideae/Poeae	*Poa*	*secunda*	Presl	Sandberg's bluegrass
POTR	141	Salicaceae	*Populus*	*tremuloides*	Michaux	Quaking aspen
POHI	164	Rosaceae	*Potentilla*	*hippiana*	Lehmann	Silver cinquefoil
PSMO	164	Apiaceae	*Pseudocymopterus*	*montanus*	Coulter + Rose	Alpine mountain parsley
PSME		Pinaceae	*Pseudotsuga*	*menziesii*	Franco	Douglas fir
PTAN	141,123	Monotropaceae	*Pterospora*	*andromedea*		Pinedrops
PYCH	131	Pyrolaceae	*Pyrola*	*chlorantha ?*	Swartz	Wintergreen
QUGA	154	Fagaceae	*Quercus*	*gambelii*	Nuttall	Gambel's oak
RICE	121	Grossulariaceae	*Ribes*	*cereum*	Douglas	Wax currant
RONE	141	Leguminoceae	*Robinia*	*neomexicanus*		New Mexico locust
SCSC	149	Gramineae/Panicoideae/Andropogoneae	*Schizachyrium*	*scoparium*	Nash	Little Bluestem
SEFL	164	Asteraceae	*Senecio*	*flaccidus ?*	Lessing	Thread-leaf groundsel
SENE	156	Asteraceae	*Senecio*	*neomexicanus*	Gray	New Mexico groundsel
SEWO	131	Asteraceae	*Senecio*	*wootonii*	Greene	Wooton's groundsel
SMRA	156	Lilliaceae	*Smilacina*	*racemosa*	Desfontaines	False solomon's seal
SYOR	Cat		*Symphoricarpos*	*oreophilus*		Snowberry
TECA	Cat	Asteraceae	*Tetradymia*	*canescens*		Horsebrush
THFE	156	Rannunculaceae	*Thalictrum*	*fendleri*	Englemann	Fendler's meadow-rue
PIXX	121	Pinaceae	unidentified	sp.		Evergreen seedling
VIAD	147	Vioaceae	*Viola*	*adunca*		Mountain violet
AF01-AF10		Forbs	Various unidentified	sp.		Annual forb
Moss A		Bryophyte	Various unidentified	sp.		Moss
Moss B		Bryophyte	Various unidentified	sp.		Moss
Moss C		Bryophyte	Various unidentified	sp.		Moss
Moss D		Bryophyte	Various unidentified	sp.		Moss
PF01-PF10		Forbs	Various unidentified	sp.		Perennial forb
PG01-PG10		Gramineae	Various unidentified	sp.		Perennial grass

Figure 1. Sampling and monitoring locations at Monument Canyon restoration area.

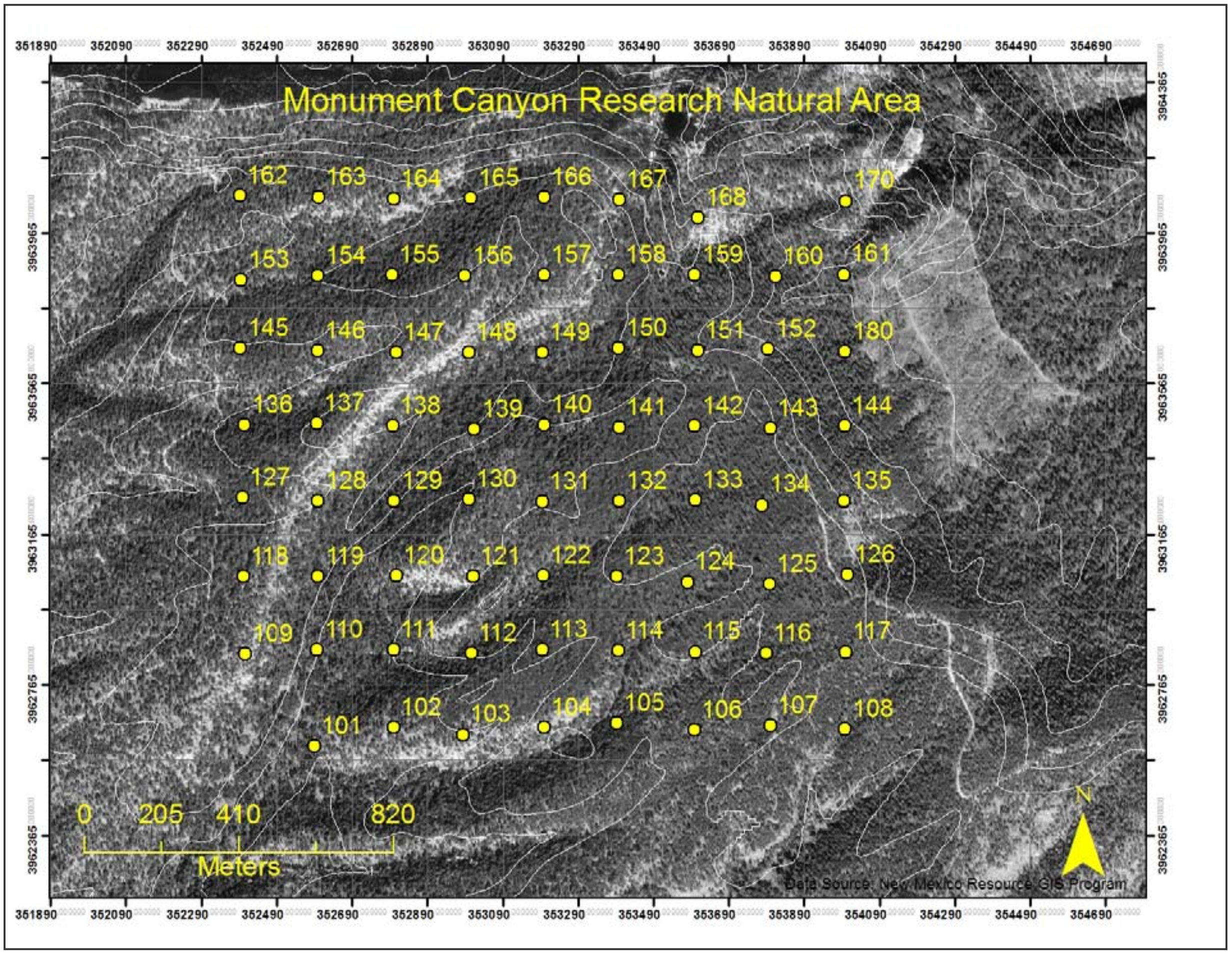


Figure 2. Schematic of nested plot layout at MCN. Large square is 0.25-ha (50 m x 50 m) overstory size/density plot, centered on grid point. Nested 0.1-ha (20 m x 50 m) overstory age/spatial structure plot runs parallel to contours. Cross indicates the grid point center. Four possible locations of 0.01-ha (10 m x 10 m) subplots are centered within overstory plots. Dashed lines indicate order of tape layout. If the plot is correctly laid out, the corner-corner diagonal of 0.25-ha outer plot should be 35.36 m.

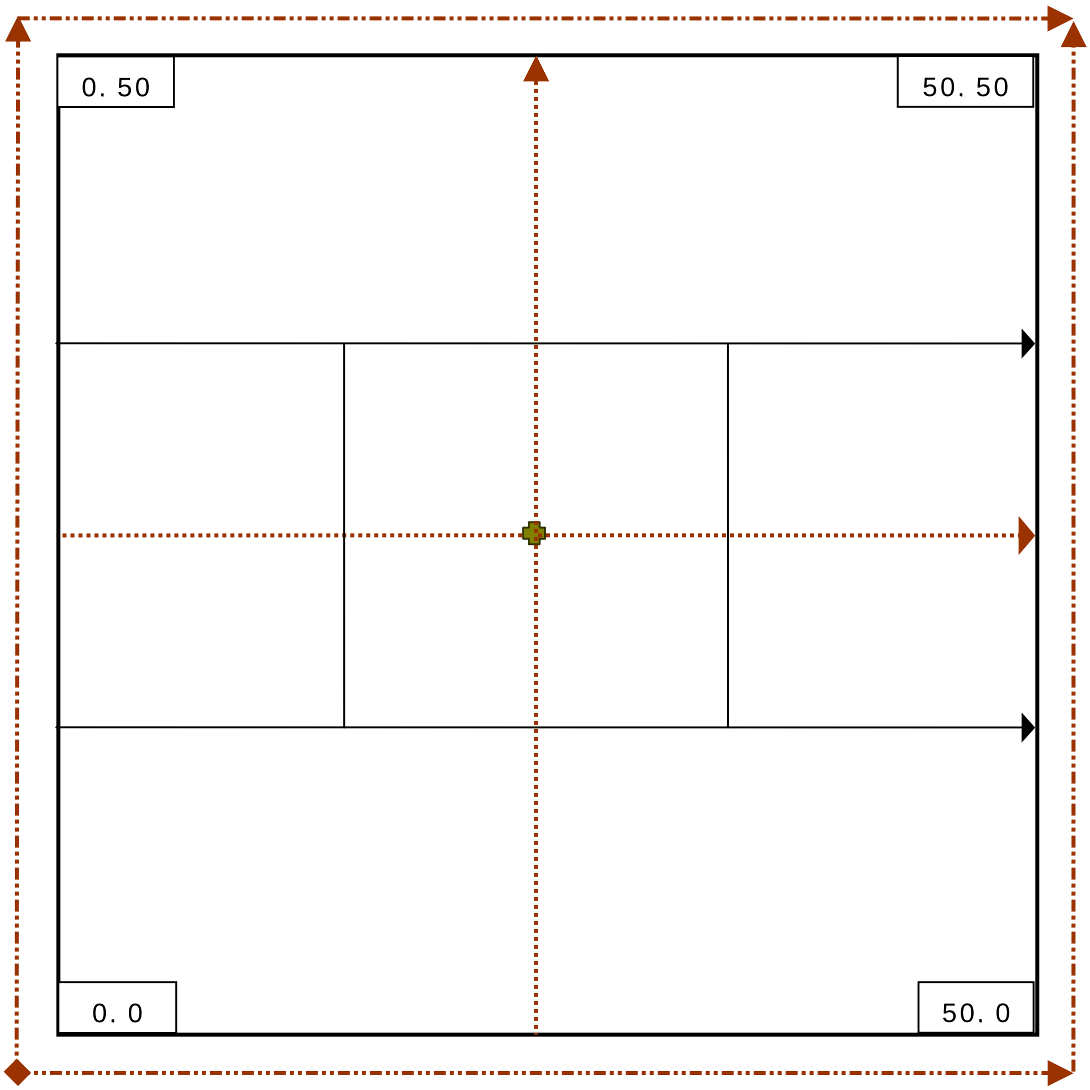


Figure 3. Map of the extent of fire in 1893 at Monument Canyon Research Natural Area, Jemez Mountains, New Mexico. Red area indicates the extrapolated burned area during that year.

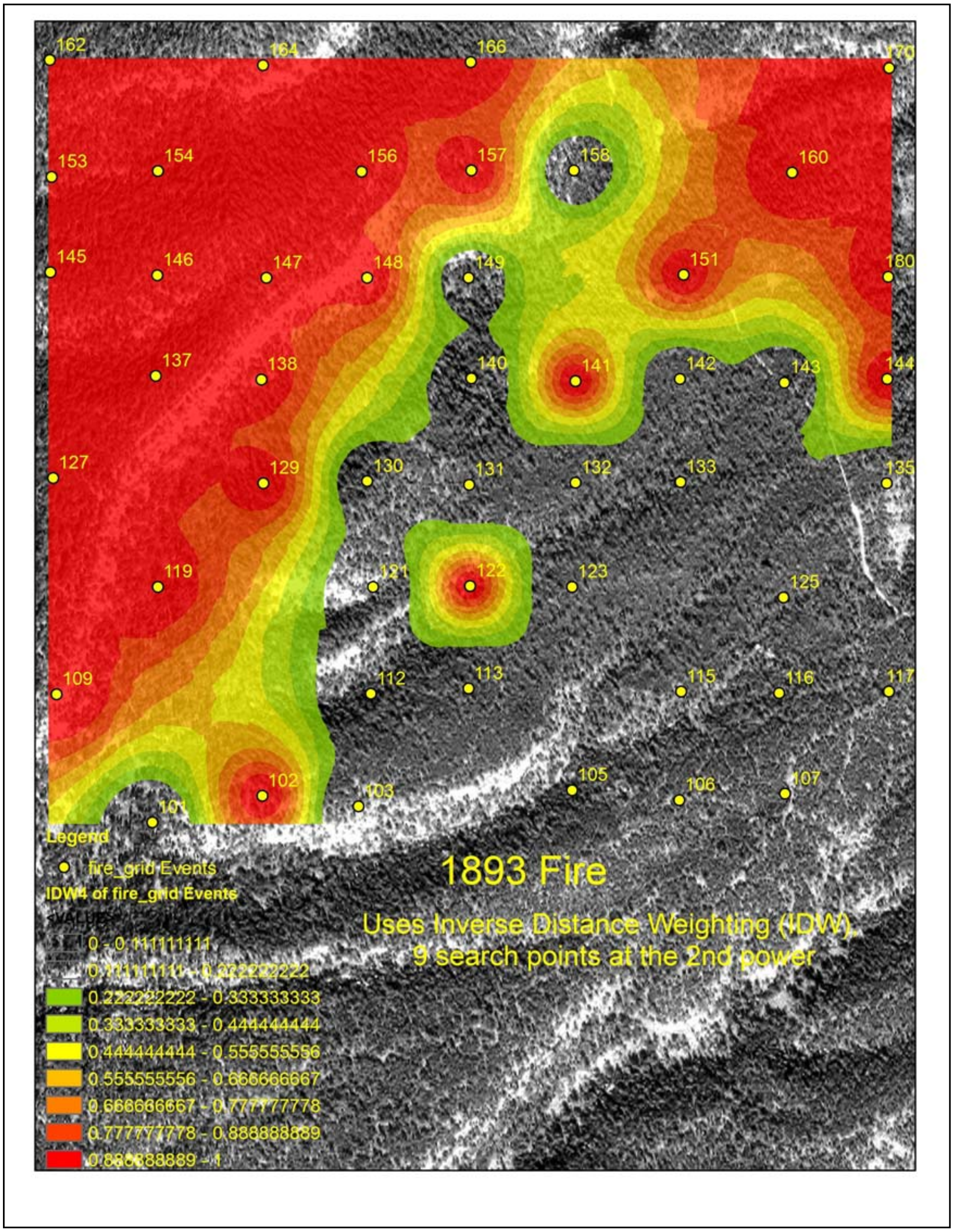


Figure 4. Restoration treatment area at Monument Canyon Research Natural Area, Jemez Mountains, New Mexico.

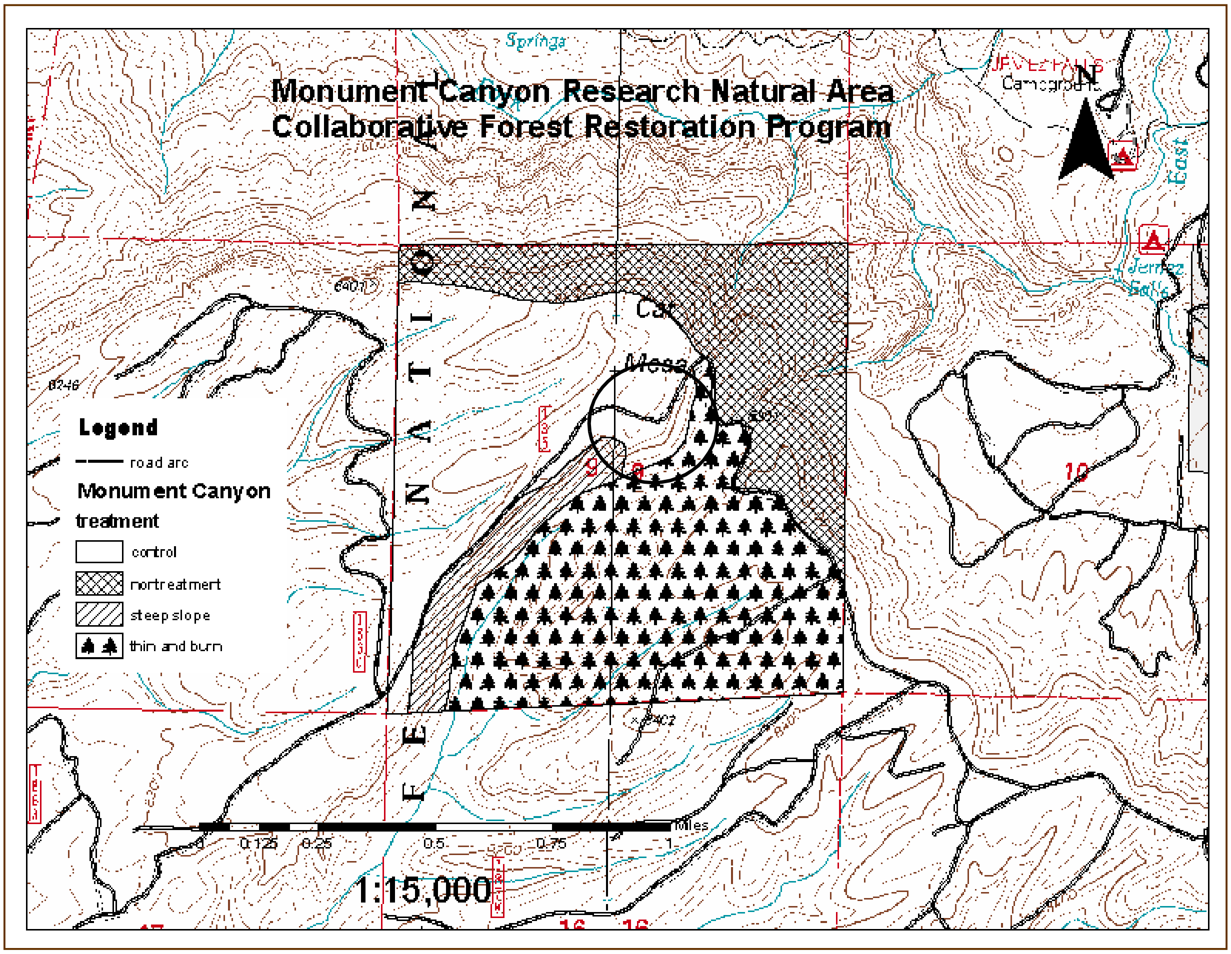


Figure 5. Canopy image, doghair thicket prior to treatment, Monument Canyon RNA.

Figure 6. Stem map of study plot, Monument Canyon RNA.

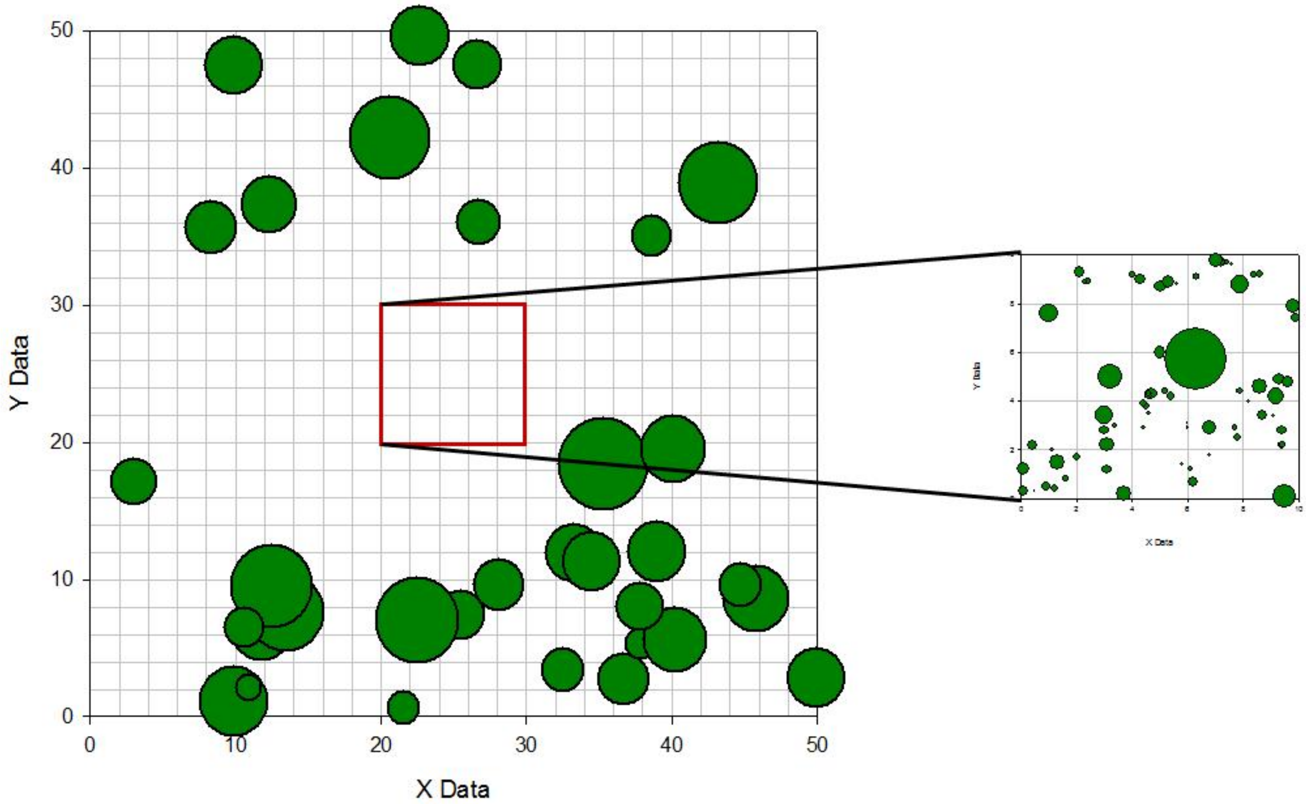


Figure 7. Thinning work and thinned stand, MCN RNA.

APPENDIX A

MCN Restoration: Field Sampling Methods.

Some general notes for all protocols:

1. **Sampling should take place in the order shown, so as to minimize the effect of trampling and disturbance on collected data and samples.**
2. When making measurements in a team, the Measurer should call out the data, and the Recorder should call it back in response. This helps ensure that the Recorder heard the data properly.
3. Try to minimize foot traffic and soil disturbance during the sampling process. In particular, do not walk in the 10 × 10 inner plot unless necessary for sampling.
4. For data consistency, it is desirable for the same person or team to do certain protocols (*e.g.* litter and duff collection) repeatedly.
5. For protocols involving re-visiting trees that have been previously tagged and inventoried (large tree and seedling/sapling demography, crown base heights), field data recording with the handheld can be facilitated by sorting plot data sheets as follows:
    a. First, separate out dead and live trees;
    b. Then, sort the live trees by tree tag number.

This procedure will make it easier to identify trees that do not need to be re-examined, and also to keep track of which trees have been measured and which remain.

6. **If computer files are modified in the field (*i.e.*, while using portable computer or handhelds), be sure to follow the data security protocol (*q.v.*)!**

Plot relocation and establishment

1. Navigate to grid point and set up an existing 10 × 10 m (0.01 ha) plot (Figure 1). There should be rebar in all 4 corners (if not, see step 2). Tape off the plot using the existing plot data; the right and left plot sides should follow the azimuth for the aspect line (recorded in a file called "plottopog"). Lay out tapes so that the lower (downslope)-left corner is at the coordinates {0, 0}; one will be pulled first along the x-axis, and then up the right side of the plot (facing uphill); the other tape will run up the y-axis and then across the top of the plot. Stake-flag corners, one of which should be the rebar grid point marker.
2. If the 0.01-ha plot is not permanently marked, mark the corners with rebar and top with colored rebar caps. Before setting rebar, check the coordinates of a few trees near the boundaries of the 0.01-ha plot to ensure that orientation is correct.
3. If this is a new grid point, use a random selection procedure to pick one of four plot orientations to grid point.
4. For measurements of crown base height and tree condition, the approximate location (but not the actual edges) of the 50 × 50 m (0.25 ha) plot also needs to be re-established. Do this by running a 50 m tape from the grid marker through the opposite corner of the staked 0.01-ha plot and continue for a distance of 25 m following the recorded aspect line. Then run the rest of the tape 25 m in the other direction (which should be aspect ± 180°). Do the same procedure at right angles to the aspect line (*i.e.*, aspect ± 90°). The

end result should be a pair of crossed tapes meeting at the grid point (25, 25) and extending 25 m in 4 directions. Note that the orientation of the tapes should be such that the 0, 0 point (*i.e.*, the ends of the tapes) should be in the lower left corner of the plot when looking uphill. Both *x* and *y* coordinates can be read from these tapes. If the plot is correctly laid out, the corner-corner diagonal of 0.25-ha outer plot will be 35.36 m. Stake the corners for posterity.[1]

5. When plot sampling is completed, flag at least two trees on either side of point with long streamers (5 ft or more) of orange flagging to allow good visibility and movement in wind. Write grid point number on tree flags. Re-spray grid point rebar marker with Day-Glo paint. 2-m lengths of PVC tubing can be placed over the grid point rebar for ease of relocation.
6. Collect and inventory gear, perform data check.

Crew:
2-3 people

Estimated time at plot:
Navigate to plot: 15 min
Plot setup: 15 min
Flagging plot: 5 min
Total: 35 min

Equipment:
GPS and accessories
Table of UTM coordinates
Table of plot orientations
2 sighting compasses
Clinometer
Open reel tapes:
    2 20m or 4 10 m
    2 50 m or 1 100 m
    2 100 m
15 surveyor's stakes
Orange flagging
Orange Day-Glo paint
Heavy black markers
Hand sledge
Field Data Recorder (FDR), spare batteries
1 2-m length of ¾ in PVC tubing

[1] If this plot location encountered a road or other non-natural condition, a different orientation of the .25-ha plot to the grid point may have been chosen. The location should be recorded on a plot diagram and explained.

Litter and duff depth and mass (0.01 ha)

The general fuel sampling protocol follows the FIREMON *Fuel Load Sampling Methods* and the *Integrated Sampling Strategy* v2.0 (see www.firemon.org). Refer to this document for more detail on sampling methods and rationale.

1. Inside the 0.01-ha plot, run a transect following the aspect line (*i.e.*, running up/downslope) from midway along the x-baseline {5, 0} to midway along the top line {5, 10}. Also set up a grid of sampling points (Figure 2) within the 10x10 m plot at 2.5 m spacing, starting with each baseline, using stake flags. There should be 5 rows of 5 flags (25 total). Finally, outside the plot place stake flags 10 m from each corner at the two right angles from each corners of the 10 x 10 m plot (Figure 2).
2. ***Woody fuels:*** Lay out three lines running from the *x*-baseline (*y* = 0 m) to the top of the plot (*y* = 10 m). Along each line, tally and record the number of pieces of wood in 1-, 10-, and 100-hr fuel classes (see FIREMON protocol). All fuel size classes are measured from the *x*-baseline up to the 5 m mark; from 5-10 m, tally and record 100-hr fuels only. Repeat this procedure for all three transects. If there is a rock, tree, or other obstacle in the way of any transect, relocate it 50 cm to either side and record new *x* coordinate.
3. ***Litter and duff depth:*** At each flagged point on the sampling grid, cut through the litter (dry, unconsolidated needles and debris) and duff (darker, partly decomposed material) with a trowel, and then pull the litter and duff back to expose the undisturbed vertical surface. Measure the total depth from mineral soil to the top of the litter layer, to the nearest 0.5 cm. Then gently sweep away the litter from the cut and measure the depth of the duff layer. Calculate litter depth by subtraction of duff depth from total depth, taking care to define the litter-duff boundary. Identify each measurement point by its coordinates (*e.g.* "0, 5" would be the sample at *x* = 0 m, *y* = 5 m). The full set of 25 coordinates should already be set up on each grid point spreadsheet in the FDR or on the FDS prior to beginning sampling.
4. Take litter and duff measurements at the 8 additional points outside the 10 x 10 m plot, giving a total of 33 points per location (Figure 1). These points are identified as "top left", top right", "right upper", "right lower", "left upper", "left lower", "bottom left", and "bottom right" (Figure 2).
5. To ***calibrate litter depth to mass***, go flag 4 points, each 1 m **outside the plot** tape midway along each side. At each of these points, measure and record litter depth as in Step 3 above. Locations are identified in the spreadsheet by their coordinates: Bottom = (5, -1); Right = (11, 5); Top = (5, 11); Left = (-1, 5).
6. Collect a sample of **litter only** using a 0.1 m^2 PVC frame, removing any woody material (*i.e.*, 1-, 10- and 100-hr fragments) before collecting the sample. Also, do not collect live herbaceous material (grasses), or dead material that is still connected to the plant, as these are inventoried in a separate protocol. Place each litter sample in a separate collecting bag labeled with the grid point number and location (*e.g.*, "GP137 litter right"). In some cases it may be necessary to use more than one bag for each location, in which case accurate identification of the bags ("1/3", *etc.*) is essential.
7. Make a similar collection of **duff** at each sampling point in the 0.1 m^2 PVC frame. Be sure to label the **location and contents** of each bag.

Crew:
1 recorder (paired with measurer if available) for each fuel type (one for litter and duff, one for woody fuels), or by location (inside, outside plot)

Estimated time at plot:
Flagging plot: 10 min
Measure and record depths, make collections: 45 min
Total: 55 min

***Equipment*:**
4 10 m open reel tapes
50 pink or yellow stake flags
2 metal hand trowels
0.1 m^2 (= 1,000 cm2) PVC or wooden frame for litter collections (31.62 cm x 31.62 cm inside dimension)
2 short metric rulers or short stiff metal tapes
2 fuel depth and size gauges (metal or plastic)
Many ziplock plastic collecting bags with label section (can use paper but tends to tear)
Black medium Sharpie markers
FDR and accessories
FDS and writing tools if used

Tree seedling demography (0.01 ha)

1. This protocol can be conducted at the same time as *Tree size and condition* in the 0.01-ha plot.
2. Working in quadrants, strips, or other sections of the 10 x 10 m plot (to avoid overlap), place a stake flag at the base of every tree or shrub that it not already tagged; these should be ≤ 2.5 cm stem diameter. If there are very large numbers of seedlings (> 100), see Step 2.
3. For plots with more than 100 seedlings or saplings, estimate the total number in the plot by dividing the plot into quadrants and counting or estimating in each quadrant. Then flag 100 stems in the total plot for measurement, selecting stems randomly by counting off stems as needed to avoid bias. For plots that are extremely dense (≥ 1,000 stems), place a 1-m^2 quadrat frame at the corners and midpoints of the 0.01-ha plot, as well as at the plot center (Figure EE). Count and record the number of seedlings in each quadrat.
4. For each flagged stem, record species, maximum foliage height (to 0.1 cm), maximum stem diameter (0.1 cm), condition scores (see *Tree condition*), and *x*, *y* coordinates (0.1 m) on the 10 × 10 plot coordinate system. Coordinates are easily determined by pulling a tape at right angles to the nearest perimeter tape of the plot; one axis will be the intercept of this tape on the baseline, while the other axis will be the length of the tape or 10 m minus this length.
5. Note that some plants will already have been recorded from previous years; in this case, add data to existing row on spreadsheet if possible; if unsure, make notes or ask crew chief.

Crew: 2-4 people (depending on expected seedling density from previous years) flag, measure, record, coordinates. More for very dense plots.

Estimated time at plot *(times are for typical plot in PIPO; triple sampling times for dense mixed conifer)**:***

Flag seedlings: 10 min
Identify, measure, and call out coordinates: 30 min (for dense plots, 2 hr)
Total: 40 min (for dense plots, 2-3 hr)

Equipment:

2 20 m reel tapes
4 surveyor's stakes
2 10 m reel tapes
120 stake flags
Hand tapes or rulers for measuring heights and diameters
Hand lens
FDR and accessories

Understory biomass (0.01 ha)

2003 protocol.

1. For each species of grass found inside the 10x10 plot, find 2-3 specimens **outside** the plot boundary.
2. Measure cover in cm^2 (this can later be converted to the percent cover in a 1-m^2 plot by multiplying by 100)**.** Record this area for each sample, numbering samples sequentially by species for each grid point (*e.g.* MUAZ117-1, MUAZ117-2, *etc*.).
3. Collect a sample by severing the plant at ground level. Place the material in a collecting bag and the sample ID and cover area (cm^2) on each bag.
4. Dry samples at 65° C for at least 24 hr. Weigh to a precision of 0.01 g.

2004 protocol.

1. Place a 0.25 m^2 frame (50 cm × 50 cm, the same used to read understory microplots) outside of each corner of the 0.01-ha plot. The fifth frame is thrown a random direction and distance outside of the 0.01-ha plot.
2. In each of the five frames, clip all aboveground herbaceous plant matter (both live and dead) to within ½ cm of ground and place in a bag labeled with the GP number and corner (LL, LR, *etc*.).
3. On the bag and/or FDS, also record an estimate of percent plant canopy cover within the sampling frame.
5. Dry samples at 65° C for at least 24 hr. Weigh to a precision of 0.01 g.

Crew: 1 collector/recorder.

Estimated time at plot:

Set up frames and clip: 2 min per frame.
Total: 15 min per plot.

Field equipment:

50 cm × 50 cm metal frame (Crosby Construction, Santa Fe, NM)
Sharp knife or plant shears or clippers
Paper collecting bags
Black medium Sharpie markers
FDR and accessories

Understory composition (0.01 ha)

1. Navigate to grid point with established understory plots.
2. Once per season, record percent cover in broad classes (as used in FS Habitat Typing system) for species found in 10x10 plot but not in one of the 1-m^2 microplots. This will allow us to characterize each plot according to US Forest Service. 1997. *Plant associations of Arizona and New Mexico*. Vol. 1: Forests. 3rd Ed., Southwest Region. Albuquerque, NM. This would

Crew: 2 measurer/collectors/recorders.

Estimated time at plot:

Plot setup: 15 min
Identify species, measure and record cover in 5 microplots: 30 min
Find and measure specimens outside, make collections: 15 min
Total: 60 min

Tree condition, size, and demography (0.01 to 0.25 ha nested plots)

1. For efficiency, divide into separate crews for each plot size; one crew can work the 0.01-ha inner plot (tree seedlings can be done at the same time), while the other records in the overstory (0.1- and 0.25-ha plots).
2. Relocate all tagged individual trees in the 0.01-ha plot, using stem map and tag numbers. If the stem map coordinates or any other data are incorrect, enter corrected coordinates on FDS or into GP file, and mark on map.
3. As each tree is visited, reset loose tag nails; if the tag is missing, write or score tree number on a blank tag and nail to tree.
4. For each tree located, record tree condition class by scoring five variables on scales of 0-2 (see *MCN Live Tree Condition Scoring***,** this document)**.** For dead trees use existing MCN classes. Note: If a tree was alive at the time of the last survey, **do not** overwrite the live condition score. Instead, enter the new dead condition class or scores in a new set of columns.
5. **Crown base and tree height:** The objective is to record the base of a continuous tree crown (foliage). "Continuous" is defined here as less than 5 m away from the next highest branch; the intent is to exclude small isolated clusters of leaves that would be unlikely to spread fire up into the higher branches. Foliage may hang down from the main branch; measure the height of the foliage itself, not the branch connection to the stem.
    a. ***Graduated (stadia) rod:*** Using a telescoping graduated (stadia) rod or laser/tape and clinometer method (below), raise the rod until it touches the lowest live foliage that is part of a continuous canopy. Record the height to nearest 0.1 m.
    b. ***Laser/tape and clinometer method:*** Stand back away from the tree until you have a clear view of the tip through the eyepiece of the clinometer (generally at least 10 m to obtain an accurate clinometer reading). Sight the live top of the tree (the highest leaf-bearing meristem, usually the leader), and record the angle in percent. If the tree has a dead leader (a spike of dead wood extending above the live canopy), record the height to its top in the notes (used in calculating of percent live canopy). Now sight the lowest foliage (crown base) and record percent as above. Finally, sight the base of the tree and measure that angle, also in percent; if your eye is higher than the tree base, this reading will be a negative number (*e.g.*, -20 %). With the tape or laser, measure and record the baseline distance to the tree stem, also to the nearest 0.1 m.
6. Make the same measurements for all standing live, tagged overstory trees in the 0.25- and 0.1-ha plots (these can be separate crews). It is easiest to record all the trees in the 0.1-ha plot first, which will all be on the same page of the spreadsheet, then survey trees in the top and bottom bands of the 0.25-ha plot (Figure 1). Use the 10 × 10 m "cells" on the stem map to find trees; find all the trees in one cell and then move to the next. In less dense sites, the plot can be divided into quadrants or other convenient sizes. Remember, **do not overwrite** the condition class of trees from the previous survey.

Crew: 2-3 people per survey crew (one recorder, 1-2 taking measurements)

Estimated time at plot *(times are for typical plot in PIPO; triple sampling times for dense mixed conifer)****:***

Tree examination: 90 min
Total: 90 min

Equipment:
Stem map for grid point
Graduated (stadia) rod
Laser rangefinder *or* clinometer
2 50-m reel tapes
2 30-m reel tapes
2 dbh tapes
Binoculars
Hammer
Nails
Flagging
Blank (writeable) tags
Tag punch kit
Additional pre-numbered metal tags for new trees added to the sample
FDR and accessories
FDS and writing tools if being used

Canopy images (0.01 ha)

1. Set up camera with fish-eye lens on tripod at the center of the 0.01-ha plot, so that the lens is at 25 cm height. If actual height is different, record; height should be the same for all images. Camera should be level.
2. Set timer and move out of plot while camera takes image. Images should be recorded at medium resolution (1024 × 768 pixels).
3. Check image in viewfinder and record image number and location
4. Repeat steps 1-3 at 4 points 7.05 m and 45 ° from each plot corner (these will be the midpoint of a line connecting the two duff/litter measurement points outside the plot in the fuel sampling protocol) (see Figure QQ).
5. If time permits, canopy images should be recorded at every grid point in the study site, not just those with plots established.
6. When Flash Card is downloaded to PDA or PC, rename file "GP###-XX", where "XX" is replaced with CTR (center), TL (top left), *etc.*.

Crew: 1-2 people

Estimated time at plot *(times are for typical plot in PIPO; triple sampling times for dense mixed conifer)**:***

Camera setup: 5 min
Take images and record information in FDR: 10 min
Total: 15 min

Equipment:
Camera
Fish-eye lens and attachments
Tripod
Extra Li battery
Extra memory chip (Flash Memory card)
FDR and accessories and/or paper FDS and writing tools

Repeat plot photography (0.01 ha)

1. Set up camera level at eye height on tripod or monopod at the center of the 0.01-ha plot.
2. Face camera cardinal north with focal length ~ 50 mm and take image.
3. Record image number and location on data sheet.
4. Repeat steps 2-3 at 4 points facing true east, south, and west respectively.
5. If time permits, canopy images should be recorded at every grid point in the study site, not just those with plots established.
6. When Flash Card is downloaded to PDA or PC, rename file "GP###-XX", where "XX" is replaced with N (north), E (east), *etc.* This can also be done on the plot if time permits.

Crew: 1-2 people

Estimated time at plot *(times are for typical plot in PIPO; triple sampling times for dense mixed conifer)**:***

Camera setup: 5 min
Take images and record information in FDR: 10 min
Total: 15 min

Equipment:

Camera
1.5-m tripod or monopod
Extra camera battery
Extra memory chip (Flash Memory card)
FDR and accessories and/or paper FDS and writing tools

MCN Live Tree Condition Scoring.

Score 0-2 for each of the following five categorical variables, scoring “2” for trees in the best (healthiest) condition for that variable, “0” for trees in the worst (unhealthiest) condition. The minimum and maximum possible aggregate scores are 0 and 10 respectively.

Leaf condition. What is the condition of the leaves (needles) that exist? Healthy trees have leaves or needles with rich dark saturated color. Unhealthy leaves are yellow (chlorotic) or even brown (dead or dying), which can reflect drought stress or nutrient starvation.

Leaf density. How much foliage is there in relation to the size and species of tree? Healthy trees have full canopies, needles well along the branch. Unhealthy trees have few or sparse leaves or needles, often clustered at the tips.

Stem structural condition. Is the trunk of the tree structurally sound? Healthy trees have strong, straight upright stems, robust for their height and free from apparent injury. Unhealthy trees have weak, leaning, bent or crooked stems, appearing too weak for their height, or evidence of mechanical injury, lightning strikes (a characteristic spiral split often running the entire length of the tree).

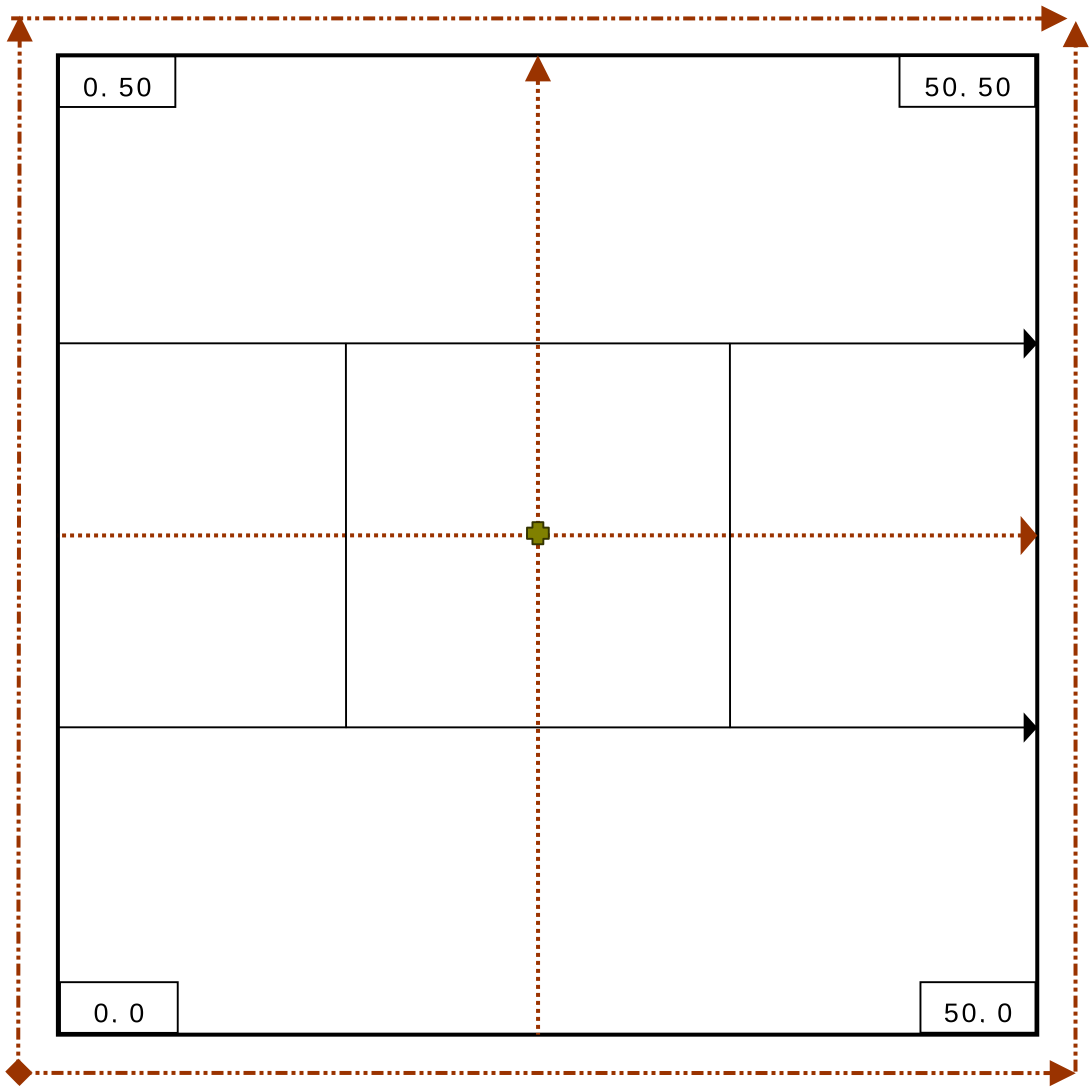
Insects, diseases, and parasites. Healthy trees are free from apparent signs of insect attack, parasites, or diseases. Unhealthy trees may show evidence of the following:

- *Bark beetles* leave small (5-8 mm diameter or sometimes larger) circular or elliptical holes in the bark. A healthy tree can “pitch out” the boring insect, which may result in streams of dried pitch or sap running down the trunk.
- *Other boring insects* may leave small piles of sawdust around the base of the tree as a symptomatic character.
- *Leaf herbivores* (many of which are larval stages) result in leaves with chewed holes, blackened or yellowed portions, or other signs.
- *Mistletoes* are hemiparasitic flowering vascular plants that attach to the host plant and derive its nutrition from the host. Pine mistletoes (*Artheucobium* sp.) are yellow-green in color and attach to branches or the main stem.

Score 2 if there is no evidence of insects, diseases, or parasites, 1 if there is evidence of an attack that the tree was able to resist, and 0 if the tree appears affected.

Growth rate. Healthy trees have a healthy apical meristem, relatively few dead major branches, and evidence of steady stem elongation between annual nodes. The apical meristem of unhealthy trees may have been killed or injured by insects or lightning, resulting in a dead leader or forked tip. Unhealthy trees may also show little or no growth between years (although in old trees, vertical growth slows down naturally and is not necessarily a sign or poor health), and substantial dieback of the lower crown (as evidenced by many whorls of large dead branches, indicating the branch death is occurring faster than the natural shedding of lower branches).

Figure 1. Schematic of nested plot layout. Large square is 0.25-ha (50 m x 50 m) overstory size/density plot, centered on grid point. Nested 0.1-ha (20 m x 50 m) overstory age/spatial structure plot runs parallel to contours. Cross indicates grid point center. Four possible locations of 0.01-ha (10 m x 10 m) subplots are centered within overstory plots. Dashed lines indicate order of tape layout. If the plot is correctly laid out, the corner-corner diagonal of 0.25-ha outer plot should be 35.36 m.



Santa Fe National Forest - Location of GIS Data - Updated 5-13-08
Check metadata for more information on each layer
Geodatabases are located in the Forest library: J:/fsfiles/ref/library/gis/forest
Backup of corporate geodatabases (if you are "locked out") located here: J:/fsfiles/ref/library/gis/forest/corporate_copy

Geodatabase (NAD83)	Feature Dataset	Feature Classes	Description	Data Steward
CFF.mdb		cff lines and points	Cartographic Feature Files (all lines and points that are on 1:24,000 topo maps)	GIS
SFE_ACTIVITY.mdb	Activities (FACTS)	Accomplished_ln	Ground disturbing activities, accomplished line, polygon, point (Only polygon is populated)	David Lawrence
		Accomplished_pl		
		Accomplished_pt		
		Layout_ln	Ground disturbing activities, layout line, polygon, point (Feature classes are empty as of June 2007)	
		Layout_pl		
		Layout_pt		
		Nepa_ln	Ground disturbing activities, NEPA line, polygon, point (Feature classes are empty as of June 2007)	
		Nepa_pl		
		Nepa_pt		
SFE_CONSTRUCT_FEAT.mdb	Constructed Features	Constructed_Feature_ln	Constructed features depicts range improvements. It will soon also have buildings, admin sites, lookouts, and similar features. Water points may also be found in SFE_WATER.mdb Water_Point.	Brian Davidson
		Constructed_Feature_pl		
		Constructed_Feature_pt		
SFE_FIRE.mdb	Fire Management	Communities_at_Risk	Points of communites at risk from wildfire	Robert Morales/Bill Armstrong
		Communities_at_Risk_WUI	Includes both WUI (USFW approved) and additional areas District FMOs added	
		Fire_History_pl	Fire history points and polygons	
		Fire_History_pt		
		Fire_Management_Unit	Relates to prioritization of suppression efforts and resources	
		Fire_Management_Zones	Used to be known as Representative Locations (RLs)	
		Fire_Planning_Unit	Administrative/Organizational boundary for fire planning.	
		Fire_Severity	Areas burned severely by fire - only available for larger fires where BAER work was done.	
		Helicopter_Dip_Sites	Points	
		Wildland_Fire_Use	Areas on the Forest where WFU is allowed or is not allowed.	
		Wildland_Urban_Interface_pl	Wildland Urban Interface Areas approved by USFW	
SFE_LAND.mdb	Land	Admin_Forest		Roger Norton
		Congressional_District	empty	
		County	Entire state	
		Other_National_Designation		
		Proc_Forest	Proclaimed Forest Boundary	
		Quad_Grid	24k entire state	
		Ranger_District		
		Sections	Public Land Survey System sections	
		Special Interest Mgt	Includes Research Natural Areas	
		State		
		Surface_Ownership		
		Townships		
		Wild_and_Scenic_Rivers		
		Wilderness		
SFE_OTHER.mdb	Reference Features	Abandon_Mine		GIS
		Admin_Site_pt	Administrative sites (district offices, work centers, etc.)	
		Air_Photo_Centers		
		Air_Photo_Flight_Line	Only west side	
		City		
		GNIS	Geographic Names Info System	
		Law_Enforcement_Violations_*	From LEIMARS database, offenses include illegal campfire, traffic accident, poaching, illegal removal of timber, etc.	
		Quad_Index_24k	1:24,000 quad boundaries for SFNF	
		Quarter_Quad_Index	QQs for 24k	
		Structure_pt	Points from CFFs (more under /fsfiles/ref/library/gis/county)	
		Tower	Towers (lookouts, cell towers, etc.)	
		Town		
		Utility_Line		
		Weather_Station	RAWS, SNOTEL	
SFE_PLANNING.mdb	Plan Use Boundaries	Ecosystem Management Areas		
		EMA_Subunits		

		Geographic_Area	Empty	
		Ira_sda	Inventoried Roadless Areas AND Special Designated Areas; IRAs are the polygons that have a 1C, 1B, or 1B1 in the CATEGRY field	
		Land_Use_Zones	Empty	
		Management Areas	Management Areas, EXCLUDES "I" areas (contact Mike Bremer for those)	Rob Potts
SFE_RANGE.mdb	Rangeland	Allotment		
		Exclosure		
		General_resource_area		
		Keyarea		
		Pasture		Brian Davidson
SFE_RECREACTION.mdb	Recreation	NVUM_survey_pts_2003	National Visitor Use Monitoring Pts from 2003 surveys	
		Recreation_Niche	Recreation opportunites	
		Recreation_Opport_Spectrum	ROS	
		Recreation_Site_ln	empty (trails are in SFE_TRANSPORTATION.mdb)	
		Recreation_site_pl	empty	
		Recreation_site_pt	Campgrounds, trailheads, etc.	
		Recreation_Site_Route	empty	
		Wilderness_Recreation_Mgt_pl	empty	
		Wilderness_Recreation_Mgt_pt	empty	Diane Taliaferro/Joan Hellen
SFE_TEU.mdb	Terrestrial Ecological Units	TEU_Land_Type	TEU tables also included (e.g. Interps_SoilPotential, SFmagLEG, etc.; link tables to feature class by MUNTNUM); Additional info on TEU fields and definitions under: j/fsfiles/ref/library/gis/forest/metadata/teu*	Carol VanDorn
SFE_TRANSPORTATION.mdb	Transportation	Road_Route	Roads (linked to Infra for maintenace levels, etc: j/fsfiles/ref/library/gis/forest/road_snapshot.shp	Kiernan Holliday/Diane Taliaferro
		Trail_Route	Trails	
		TravelManagementArea	Empty (will have "areas" open to XC travel)	
SFE_VEGETATION.mdb	Vegetation	Base_Vegetation_Location	Compartments	
		Base_Vegetation_Site	1:24k scale veg polgyons with cover types	
		Invasive_Plant	Weeds	
		Mid_Level_Vegetation	empty	
		Potential_Natural_Veg	empty (can try TEU)	David Lawrence
SFE_WATER.mdb	Water	Flood_Plain	Derived from TEU query	
		Hydrologic_Unit_4th_Code		
		Hydrologic_Unit_5th_Code		
		Hydrologic_Unit_6th_Code		
		Riparian_area_TEU	Derived from TEU query (see metadata)	
		Riparian_buffer	Perennial streams and water bodies buffered 100 ft	
		Stream_arc	1:24k streams with CFF code (perennial, intermittent), no name	
		Stream_Road_Intersect	Points where streams and ML 2,3,4 roads intersect	
		Stream_Route	1:24k streams with names, no CFF code	
		Water_Body	Water bodies (polys)	
		Water_Point	Water points (springs, lakes, etc.). Water points may also be found in SFE_CONSTRUCT_FEAT.mdb (range improvements)	
		Watershed_Improvement_pl	empty	Carol VanDorn
SFE_WILDLIFE.mdb	Elk	Calving Areas	From NM Game & Fish and Esther Nelson in 2006	
		Crucial_Winter_Range	Source: Mary Orr	
		RMEF_Crucial_Summer_Range	From Rocky Mtn Elk Foundation	
		RMEF_Summer_Range	From Rocky Mtn Elk Foundation	
		RMEF_Winter_Range	From Rocky Mtn Elk Foundation	
	Goshawk	Goshawk_Foraging_Area		
		Goshawk_pl	Goshawk management areas	
		Goshawk_Replacement_Nest_Site		
		Goshawk_Survey		
	Jemez_Mountain_Salamandar	JMS_Conservation_Area		
		JMS_Occupied_Stands	UPDATED using the new ev_base vegetation layer & JMS_Survey_Positive	
		JMS_Survey_Negative		
		JMS_Survey_Positive		
	Mexican_Spotted_Owl	Mexican_Spotted_Own_pl	MSO PACs	
		MSO_Critical_Habitat		
		MSO_Nest_Roost_Site		
		MSO_Observations_89_05		
		MSO_Restricted_Area		

	Migratory_Bird	Migratory_Bird_Corridor	Important Bird Areas from 2001	
	Other	American_Marten_Survey		
		Black_Swift_Nest		
		Jumping_Mouse_Habitat	From Wayne Robbie query of TEU grassy wet meadows	
		Raptor_Observation		
	Peregrine_Falcon	Peregrine_Falcon_Nest		
		Peregrine_Falcon_Zone		
	Plant	TES_Plant	Includes Holy Ghost Ipomopsis, AZ Willow, etc	Charlie Gobar
	Rio_Grande_Cutthroat	RGCT_Occupied_Stream	From Sean Ferrell, 2006	
		RGCT_Restoration_Opp	From Sean Ferrell, 2006	Chantel Cook
	Wildlife	Wildlife_Feature_pl		
		Wildlife_Feature_pt		
		Wildlife_Historical_Feature_pl		
		Wildlife_Historical_Feature_pt		
		Wildlife_Observations_pl		
		Wildlife_Observations_pt		
		Wildlife_Survey_pl		
		Wildlife_Survey_pt	FAUNA Wildlife-* LAYERS HAVE NOT BEEN UPDATED SINCE 4/05	Charlie Gobar

Other GIS Data - some still in NAD27

GIS Layer	Related DB	Status	Location	Data Steward
Air - Airbasins		From NMED	J:\fsfiles\ref\library\gis\state\Airshed_ext_data.mdb\Airbasin	Jeanne Hoadley
Fire Aviation Hazards including Military Training Routes		MTRs downloaded May 2006 (can be updated every 28 days).	/fsfiles/office/gis/fire/aviation/hazards; J:/fsfiles/office/gis/arcgis/layer_files/aviation_hazards_military.lyr	Bob Skeen
Fire Closure Areas/Restrictions		For when fire restrictions go into effect, done summer 2005 - CONTACT AL FOR QUESTIONS	J:/fsfiles/office/gis/fire/restrictions/layers	GIS
Fire Dispatch Zones			/fsfiles/ref/library/gis/state/dispatch	GIS
Fire LANDFIRE Biophysical Settings/Potential Veg	LANDFIRE	Feb. 2008. See metadata for more info	J:\fsfiles\office\gis\fire\landfire\layers\bps	GIS
Fire LANDFIRE Canopy Cover	LANDFIRE	Feb. 2008. See metadata for more info	J:\fsfiles\office\gis\fire\landfire\layers\can_cov	GIS
Fire LANDFIRE Canopy Height	LANDFIRE	Feb. 2008. See metadata for more info	J:\fsfiles\office\gis\fire\landfire\layers\can_ht	GIS
Fire LANDFIRE Canopy Bulk Density	LANDFIRE	Feb. 2008. See metadata for more info	J:\fsfiles\office\gis\fire\landfire\layers\cbd	GIS
Fire LANDFIRE Canopy Base Height	LANDFIRE	Feb. 2008. See metadata for more info	J:\fsfiles\office\gis\fire\landfire\layers\cbh	GIS
Fire LANDFIRE Existing Veg Height	LANDFIRE	Feb. 2008. See metadata for more info	J:\fsfiles\office\gis\fire\landfire\layers\ev_ht	GIS
Fire LANDFIRE Fire Behavior Models (13)	LANDFIRE	Feb. 2008. See metadata for more info	J:\fsfiles\office\gis\fire\landfire\layers\fbfm13	GIS
Fire LANDFIRE Fire Behavior Models (40)	LANDFIRE	Feb. 2008. See metadata for more info	J:\fsfiles\office\gis\fire\landfire\layers\fbfm40	GIS
Fire LANDFIRE Fire Regime Condition Class	LANDFIRE	Feb. 2008. See metadata for more info	J:\fsfiles\office\gis\fire\landfire\layers\frcc	GIS
Fire LANDFIRE Succession Class	LANDFIRE	Feb. 2008. See metadata for more info	J:\fsfiles\office\gis\fire\landfire\layers\sclass	GIS
Fire Preplan Areas			J:/fsfiles/office/gis/fire/preplan/wildcad/layers/preplan_sf.shp	GIS
Fire Regime Condition Class		DRAFT Jemez Mountains, from TNC	j:/fsfiles/office/gis/fire/layers/frcc_west	GIS
Fire Structures, Driveways, fire hydrants		Polys from Sandoval & Los Alamos Counties; points from Mora & Santa Fe Counties under /fsfiles/ref/library/gis/county	/fsfiles/ref/library/gis/forest/SFE_OTHER.mdb structure_pt and /fsfiles/ref/library/gis/forest/county	GIS
Forestry Old Growth - Designated		Areas from 1987-1992 NEPA assessment that ID'd potential areas to manage for OG	/fsfiles/office/gis/forestry/old_growth/layers/dsog	David Lawrence
Forestry Old Growth - Possible		RSAC/Jessica/Lisa effort using remote sensing to ID possible OG areas. NOT GROUND TRUTHED	/fsfiles/office/gis/forestry/layers/east_ogp	David Lawrence
Forestry Old Growth in Surveyed Stands		Based on Regis Cassidy's RMRIS query for high productivity sites, revised for FSVeg tables; only available in stands that have had a stage 2 stand survey	/fsfiles/office/gis/forestry/old_growth/layers/survstand_oldgrowth_hiprod.shp	David Lawrence
Forestry Pest Damage		1998 - 2007 GIS layers from aerial detection	/fsfiles/ref/library/gis/forest/pest_survey	David Lawrence
Geology - volcanic vents		1:500k from USGS/NMBM	/fsfiles/ref/library/gis/state/geol_vents	Larry Gore
Geology 24k & faults		5 quads on Jemez available (draft)	J:/fsfiles/office/gis/minerals/geology_quads/NMBGMR-2005	Larry Gore
GIS Ref 1935 Air Photo		Flown in 1935, roughly georeferenced	/fsfiles/ref/library/rs/airphoto_1935_east or west.img	GIS
GIS Ref 24k softcopy quads MOSAIC		Mosaiced for east and west sides	/fsfiles/ref/library/gis/quad/mosaics	GIS
GIS Ref 24k, 100k, 250k softcopy quads			/fsfiles/ref/library/gis/quad/24k (100k & 250k also)	GIS
GIS Ref 24k, 100k, 250k quad boundaries			/fsfiles/ref/library/gis/state	GIS
GIS Ref- aspect (0-360 degrees)		Generated from 30 meter DEM	/fsfiles/ref/library/gis/forest/aspect	GIS
GIS Ref Digital Elevation Model 10 meter		10 meter	/fsfiles/ref/library/gis/forest/elevation	GIS
GIS Ref Digital Elevation Model 30 meter		30 meter	/fsfiles/ref/library/gis/forest/elev_30m	GIS
GIS Ref Digital Ortho Quads 1996 - MOSAIC		East, west, and central mosaics; MrSID format	/fsfiles/ref/library/rs/doq	GIS
GIS Ref Digital Ortho Quads (DOQs), 1996 & 2005/2006		1 meter resolution	/fsfiles/ref/library/rs/doq_1996 and doqq_2005	GIS

GIS Ref Forest Service Shield		Shapefile shaded green and yellow	J:/fsfiles/office/gis/carto/fsshield.shp; j:/fsfiles/office/gis/arcgis/layer_files/fsshield*.lyr	GIS
GIS Ref forest visitor map (2005)		Forest Visitor Maps, east and west	/fsfiles/ref/library/gis/forest/visitor_*.tif	GIS
GIS Ref Region 3 Data		Regionwide data (R3 forests, etc.)	J:/fsfiles/ref/library/gis/r3	GIS
GIS Ref Satellite Imagery		2000 - 2002 images	/fsfiles/ref/library/rs	GIS
GIS Ref Slope		Percent slope grid from 30 meter DEM	/fsfiles/ref/library/gis/forest/slope_percent	GIS
GIS Ref State Data		Statewide data (states, rivers, lakes, ownership…)	J:/fsfiles/ref/library/gis/state	GIS
GIS Ref USA Data		Nationwide data (states, rivers, lakes, fed lands…)	J:/fsfiles/ref/library/gis/usa	GIS
GIS Ref Zip Codes		From 2000	/fsfiles/ref/library/gis/usa	GIS
Heritage Resource Survey Areas	INFRA	See Mike Bremer	Sensitive	Mike Bremer
Heritage Sites (lines, pts, polys)	INFRA	See Mike Bremer	Sensitive	Mike Bremer
Lands BLM Wilderness		Wilderness and wilderness study areas	J:\fsfiles\ref\library\gis\state\Land_ext_data.mdb\BLM_wild_study_areas	GIS
Lands Indian Reservations			J:\fsfiles\ref\library\gis\state\Land_ext_data.mdb\Indian_Reservations	GIS
Lands Land Grants			J:\fsfiles\ref\library\gis\state\Land_ext_data.mdb\Land_grants	GIS
Lands Mineral Ownership		From BLM (subsurface ownership)	J:\fsfiles\ref\library\gis\state\Land_ext_data.mdb\Mineral_Ownership	GIS
Minerals Mines Sites	INFRA	Abandoned and active (also in GNIS)	/fsfiles/ref/library/gis/state/mines	Larry Gore
Minerals Oil-Gas Lease Areas	INFRA		J:/fsfiles/office/gis/minerals/layers/oil_gas_leases.shp	Larry Gore
Physical Surface Geology		1:500k scale	J:\fsfiles\ref\library\gis\state\Physical_Surface_ext_data.mdb\GEOLOGY	Larry Gore
Physical Surface LULC		Land Use Land Cover from USGS	J:\fsfiles\ref\library\gis\state\Physical_Surface_ext_data.mdb\LULC_GENERAL	GIS
Physical Surface Soils		1:1,000,000 scale	J:\fsfiles\ref\library\gis\state\Physical_Surface_ext_data.mdb\SOILS	GIS
Rec. Sites, Dispersed		Working on w/Districts in 2007	/fsfiles/ref/library/gis/(district name)	Diane Taliaferro
Roads Areas with motorized restrictions		Includes closure orders (seasonal & permanent closures), non-motor areas from IRAs, Forest Plan, etc.	J:/fsfiles/office/gis/roads/ohv/layers/geographic_areas - existing_direction	GIS
Roads Mileposts		For state and interstate roads	/fsfiles/ref/library/gis/state/mileposts.shp	GIS
Roads RAP - districts		Coyote, Cuba, Espanola draft as of Jan. 2005	J:/fsfiles/office/gis/roads/rap/layers/(district)	Henry Gallegos
Roads RAP - forestwide levels 3&4		For the most part final as of Jan. 2005	J:/fsfiles/office/gis/roads/rap/layers/forest/rap_levels_3_4.shp	Henry Gallegos
Transportation Airports		Statewide	J:\fsfiles\ref\library\gis\state\Trans_ext_data.mdb\Airports	GIS
Transportation Major Roads		Statewide	J:\fsfiles\ref\library\gis\state\Trans_ext_data.mdb\Major_Rds	GIS
Transportation Railways		Statewide	J:\fsfiles\ref\library\gis\state\Trans_ext_data.mdb\railway	GIS
Transportation Road Crashes		Statewide 1996-2005 (also see LEIMARS database)	J:\fsfiles\ref\library\gis\state\Trans_ext_data.mdb\Road_Crashes	GIS
Transportation Traffic		Statewide		GIS
Utilities PNM Transmission Lines, Conductors, Transformers, etc.		Statewide	J:\fsfiles\ref\library\gis\state\PNM_	GIS
Water Acequias/conveyances		From the NM State Engineer's Office	J:\fsfiles\ref\library\gis\state\acequia.shp	GIS
Water Aquifers		Statewide	J:\fsfiles\ref\library\gis\state\Water_ext_data.mdb\AQUIFER	GIS
Water Evaporation		Annual evaporation from shallow lakes	/fsfiles/ref/library/gis/state/evaporation	GIS
Water Impaired Waters (303d, 305b, lakes and streams		From NMED (2006), entire state of NM	J:\fsfiles\ref\library\gis\state\Water_ext_data.mdb\Impaired_*	GIS
Water NMED Benthic Sites			/fsfiles/ref/library/gis/state/benthic_sites	GIS
Water NMED fish monitoring sites			/fsfiles/ref/library/gis/state/fish_sites	GIS
Water NMED geomorphic monitoring sites			/fsfiles/ref/library/gis/state/geomorph_monitoring_sites_nmed.shp	GIS
Water NMED Surveyed Reaches			/fsfiles/ref/library/gis/state/wq_reaches	GIS
Water NMED water qual monitor. Sites			/fsfiles/ref/library/gis/state/chem1_sites	GIS
Water NMED water qual monitor. Sites			/fsfiles/ref/library/gis/state/chem2_sites	GIS
Water Precipitation 1931-1960		Annual in inches, 1931-1960	/fsfiles/ref/library/gis/state/precip_hist (lines)	GIS
Water Precipitation 1961-1990		Annual in inches, 1960-1991	/fsfiles/ref/library/gis/state/precip.shp (polys)	GIS
Water Riparian Vegetation Pecos & Rio Grande		From National Wetlands Inventory - draft as of 9/04	/fsfiles/office/gis/water/layers/	cvandorn
Water Stream-Road-TEU erosion prone areas analysis		Contact Danielle Montes for specific questions	/fsfiles/office/gis/water/layers/	dmontes
Water Wells		From University of NM	/fsfiles/ref/library/gis/state/water_well	GIS
Water Wells		From Office of State Engineer	J:\fsfiles\ref\library\gis\state\Water_ext_data.mdb\OSE_Wells_jan03	GIS
Wildlife Game Management Units		2006 statewide hunting units	J:\fsfiles\ref\library\gis\state\Wildlife_ext_data.mdb\GMU_2006	GIS