Section 13- Monitoring and Adaptive Management

Southwest Jemez Mountains Collaborative Forest Landscape Restoration Strategy

Proposal for Funding

Contents

Introduction

The Southwest Jemez Mountains (SWJM) landscape restoration strategy (project) will involve implementing a wide variety of coordinated and integrated treatments, including forest thinning, prescribed fire, management of natural fires, road closures and rehabilitation, riparian zone restoration projects, and fisheries and wildlife habitat improvement projects (see Landscape Strategy section of Proposal). These efforts will be undertaken over many ecosystem types, from grasslands to forests and from low elevation piñon-juniper woodlands to upper montane spruce forests (as shown in the diagram below). The majority of the projects, however, will take place in ponderosa pine and mixed-conifer forest types that dominate this landscape. Over the 10 years of the project, the 15 years of monitoring, and the many decades beyond, the ecosystem responses to this landscape-level treatment will continue to develop, and our restoration team has planned a comprehensive and spatially extensive monitoring program to assess these responses in a statistically robust and scientifically integrated fashion.

The forest restoration activities in the SWJM project area will incorporate both well-established and state-of-the-art approaches to restoration techniques and monitoring (Wilcove et al. 1986, USDA 1996, Sauer 1998, Friederici 2003, Mansourian and Vallauri 2005, Walker et al. 2007, Rietbergen-McCracken et al. 2008). The monitoring results will be used not only for evaluating the rate and extent of achievement for individual project goals and adaptive management, but also will be incorporated into analyses for cumulative effects at the landscape level (Council on Environmental Quality 1993, 1997).

The land management agencies in the Jemez Mountains have hosted an extensive array of scientific studies over the past two decades, and have developed a solid infrastructure of both place-based scientists and facilities. A large number of ecologists, biologists, botanists, foresters, wildlife biologists, range scientists, fisheries scientists, entomologists, hydrologists, climatologists, geologists and soils scientists are currently conducting a wide variety of grant-funded projects in the SWJM landscape area. In 2009, on the Valles Caldera National Preserve (Preserve), there were 39 permitted projects with more than $3.5 million in FY09 funding. The Santa Fe National Forest (Forest) and Bandelier National Monument (Bandelier) also hosted extensive scientific research and monitoring programs supported with both agency and extramural funding. In support of these science programs, the Preserve opened a new Science and Education Center in Jemez Springs (nearly in the center of the SWJM area) that provides laboratory space, archived voucher collections of flora and fauna, meeting and classroom space, residence housing, and food service. The Center is also ideal for educational groups to visit and stay in the project area, learning about the restoration programs and scientific methods for promoting science-based adaptive management for public lands. Thus, the SWJM project already has in place a vast network of personnel, facilities, intellectual knowledge, and field instrumentation to facilitate the monitoring program for the forest restoration activities.

Goals and Measures of Success

As defined in the Forest Landscape Restoration Act (PL 111-11, Sec. 4003(c)), the ecosystem monitoring program objectives for this SWJM project are to evaluate the degree to which restoration actions

(1) contribute toward restoration of pre-fire suppression old growth forest and other structural and compositional conditions representative of the historic variability within each ecosystem
(2) reduce the risk of uncharacteristic wildfire, and re-establish natural fire regimes
(3) improve fish and wildlife habitat, including endangered, threatened and sensitive species
(4) maintain or improve water quality and watershed function, and mitigate climate change impacts
(5) prevent, remediate, or control invasions of exotic species

(6) contribute woody by-products for social and economic community benefits

The success of the project's restoration actions will be determined based on the degree and direction of treatment-induced changes in the variables described in this section, for each of those objectives. Those variables used as monitoring indicators stem from the attributes identified in assessments of ecological departures, including those listed in the "out of whack" summaries of ecological departures for each ecosystem. Thus the monitoring and evaluation will focus on treatment-induced changes in forest structural/successional stages, species composition, fire regime conditions class and fuels, soil erosion rates, wildlife habitat for TES and selected indicator species, water quality and quantity, aquatic habitat structures and fish species, riparian vegetation conditions, and other key ecosystem attributes. These changes, in turn, will be gauged against the known current conditions within the area, which are supported by (1) the extensive available information within the Jemez Mountains for historic old-growth forest distribution, structure and composition, (2) documented detailed knowledge of pre-historic and historic fire regimes, (3) known and well-understood distributions and habitat requirements of Jemez Mountains plants and wildlife species, (4) long-term water quality and stream discharge data from project area watersheds, and (5) detailed knowledge of populations and distributions of native and non-native floral and faunal species in the Jemez Mountains. Restoration treatment effects and degree of success will be distinguished from normal "background" spatial and temporal variability through a carefully-designed network of replicated monitoring plots and untreated "control" areas, essentially creating a landscape "experiment" in which to evaluate the restoration program.

Science-Based Adaptive Management Approach

The overall approach to the SWJM project's monitoring program is to develop field monitoring activities in an "experimental" fashion, in which we establish statistically-replicated monitoring sites in both treated and untreated areas (equivalent to experimental "controls"), and measure the selected ecosystem variables prior to and after restoration treatments. The monitoring would continue for at least 15 years after treatments are completed, with some monitoring continuing thereafter for an indefinite period of time. Monitoring will use paired "control" areas for individual restoration activities that will allow the statistical separation of restoration treatment effects from normal ecosystem variability due to climate dynamics and other natural phenomena. This approach also will promote rigorous analyses and interpretations of results, and provide land managers with solid data with which to evaluate restoration success. In addition, implementation of the scientific method in designing the monitoring programs will engender public confidence in the restoration program, and increase the clarity and transparency of the project's results for managers, policy-makers, and the general public.

In addition to the analyses of individual monitoring programs (i.e. taxon or topic-specific), the project team will undertake large-scale analyses to determine if the cumulative effects of all the treatments together create a desired landscape outcome that is "greater than the sum of the parts" (Turner et al. 2001, Turner 2005). As demonstrated in many previous studies, the cumulative landscape response (in terms of watershed function, hydrologic processes, wildfire size, fire intensity and return interval, wildlife movements and home ranges, biodiversity, etc.) to multiple treatments of thinning and burning will likely be amplified in a non-linear fashion, due to scale changes from catchments to watersheds to basin (Block et al. 2001, Allen et al. 2002, Peters et al. 2004, Turner and Chapin 2005, Wagner and Fortin 2005, Peters et al. 2006, Allen 2007, Bestelmeyer et al. 2009). As such, our cumulative effects analyses will employ continually-updated remote-sensing landscape GIS data layers (e.g. MODIS, TM and future NASA satellite platforms scheduled for deployment in 2012), coupled with topographically-scaled hydrology models (tRIBS, see Hydrology section below), landscape connectivity models based on fauna and flora distributions, and wildlife telemetry data and home range/habitat-use models. Landscape patterns will be analyzed with indices that characterize patches (e.g. patch size, patch density, connectivity, landscape leakiness; see references above). Cumulative effects monitoring will utilize statistical approaches recommended by the Council on Environmental Quality (CEQ 1997), in evaluating changes in biodiversity patterns, invasive species, and protected species abundances and distributions. The data will be spatially linked through GIS maps, models and pattern-based metrics established for the monitoring program.

Data Management, Analysis and Dissemination

The data generated from the monitoring program will be used in a continuous feed-back loop, allowing for project modification in terms of technique, spatial extent, location and timing of treatment actions. Dissemination of results from the monitoring will be accomplished in annual reports to all stakeholders, as well as in peer-reviewed scientific journal articles. There will be annual workshops involving all restoration monitoring partners, to review and evaluate monitoring results and determine the appropriate adaptive management adjustments to be made. In addition, results of the monitoring program will be made available on all the web sites of the collaborating organizations, as well as being used in public education programs on the Forest and Preserve. Through publicly-open and easily-accessible monitoring data sets and monitoring reports, the collaborating agencies and organizations will implement the science-based adaptive management process throughout the project's duration, thereby demonstrating the highest possible level of the adaptive management concept (Johnson et al. 1999, Sexton et al. 1999, Szaro et al. 1999, Stankey 2005)

The actual data management and interagency/collaborators web site management will be conducted by The Nature Conservancy (TNC) with assistance from New Mexico Forest and Watershed Restoration Institute. A data manager will facilitate monitoring data compilation from all the collaborators, coordinate data entry and Quality Assurance/Quality Control (QA/QC), conduct the database management, data analysis and distribution to partners, as well as hosting the annual monitoring symposium to present/discuss monitoring data and management implications. TNC would provide an in-kind contribution of supervision of the data manager and office space.

Project managers will contract with a data manager and statistician, possibly the one we've been using from University of New Mexico, to assist the monitoring team with data analysis. The data manager and statistician will work together with place-based scientists and the monitoring team to review existing monitoring protocols, with the goal of increasing their statistical power to detect change and increase efficiency (reduce costs). Where necessary, the statistician will make recommendations for locating additional monitoring plots, determining sampling intensity and frequency and consulting on data analysis methods. Where appropriate, the statistician will conduct the statistical analyses and assist with interpretation of findings for the collaborators and the public; otherwise these functions will be carried out by the data manager in consultation with the monitoring team and place-based scientists.

Monitoring Ecosystem Change

Climate

As previously described in the Ecological Context section of this Proposal, the climate of the project area is reflecting the regional climate changes in the southern Rocky Mountains, in that temperatures are increasing and precipitation is decreasing. We anticipate that these patterns will continue as forecasted through both the 10 years of the project period and the future years of the monitoring program. As such, detailed site-level and landscape-level meteorological data will be required to understand and interpret ecosystem responses to the project's activities.

There are currently 5 Campbell-style meteorological stations operating on the Preserve, along with a NOAA Climate Reference Network (CRN) station (Fig. 13.1). The Preserve's climate stations all collect year-round precipitation (rain and snow), air temperature, wind speed and direction, relative humidity, total solar radiation, and soil temperature and moisture (TDR probes) at three soil depths (data on-line at Preserve web site). There is one RAWS meteorological station operating in the SW corner of the Preserve. Bandelier, on the east side of the project area, also operates a weather station, along with a National Atmospheric Deposition Network (NADP) site (for precipitation chemistry). We will establish an additional 3 new meteorological stations in the Jemez Ranger District to obtain weather data from the mid- and lower elevations of the restoration program area, and will upgrade the existing RAWS station to measure winter snow precipitation (currently, this station only collects summer data for rainfall). In addition, in collaboration with NRCS scientists, we will install a SNOTEL site in the Preserve (high elevation) to provide snow water equivalent (SWE) data within the Jemez River watershed. Lightning strike location data (from the BLM website) will be archived in the project database, along with landscape-level NEXRAD storm precipitation data, to allow large-scale multi-year analyses of meteorological patterns and their effects on ecosystem responses (e.g. plant biomass production, wildfire ignitions, snow depths, and hydrologic modeling). Collaborators on climate monitoring include USFS, VCT, NRCS (SNOTEL data), BLM (lightning data), and the Desert Research Institute (RAWS data).

Figure 13.1 NOAA CRN meteorological station on the Preserve.

Hydrology

Watershed hydrologic functioning before and after restoration treatments will be assessed by monitoring the quantity and quality of stream water discharged from the watersheds of the restoration area. Departures in hydrologic regimes in stream and riparian ecosystems, along with associated monitoring indicators, are described in the landscape assessment documents and specialist reports.

Figure 13.2. Flume gauging station on Redondo Creek

Stream discharge quantities will be monitored in a series of replicated, nested-catchments with flumes and gauges (pressure transducers in stilling wells; Fig. 13.2). The existing network of flumes and gauges will be expanded from the current system of five 1st-order flumes, four 2nd-order flumes, two 3rd-order gauging stations, and one 4th-order USGS gauging station to include 4 additional 1st- and 2nd-order flumes on the remaining perennial streams within the restoration area, and 6 flumes on paired catchments with ephemeral streams having different levels of forest treatments (including non-treated "control" catchments). This network will permit the testing of the hypothesis that forest canopy thinning to optimal levels will decrease winter snowpack sublimation and increase snow-water equivalent, resulting in enhanced stream discharge during the spring snowmelt (either in peak flows and/or duration) (Parmenter 2009). Figure 13.3 displays the network of climate stations and stream flow monitoring gauges on the Preserve. An additional stream gauge lies below the Preserve near Cañon.

Numerical watershed models are useful tools to address the impacts of land use change scenarios on water resources. We will utilize a well-tested distributed hydrologic model (the TIN-based Real-time Integrated Basin Simulator (tRIBS) model [Ivanov et al., 2004; Vivoni et al., 2007]) to provide predictions of the impact of forest thinning on water supply in the project area's basins. This work would follow on prior work by Mahmood and Vivoni (2008), Rinehart et al. (2008) and Mahmood et al. (2010) using the tRIBS hydrological model in the Preserve and the Jemez Mountains. In particular, we will apply the model for snow conditions and spring discharge in the project area using past and ongoing data records in the Preserve and the Jemez River in the Jemez Ranger District (USGS gauge in Cañon, NM). For this project, we will use a distributed approach that represents the basin and vegetation characteristics, climate forcing and streamflow forecast points at a high-resolution. The tRIBS modeling effort applied to the project monitoring effort will involve (1) characterizing the selected sub-basins in the project area upstream of gauging stations (topography, land use, soils – these GIS databases already exist), (2) analysis of meteorological data of rainfall, snow, temperature, wind, streamflow, soil moisture and other ongoing meteorological observations, (3) generation of the modeling domain and establishing a baseline set of model parameters; and (4) model testing against available monitoring data of snow depth, snow-water equivalent, and streamflow observations. The tRIBS has been successfully tested in the Preserve's La Jara catchment and the Jemez Mountains Quemazon Snotel site (Rinehart et al. 2008), Preserve's Redondo Creek (Mahmood and Vivoni 2008) and in the ponderosa pine Hillslope in Parajarito Plateau (Mahmood et al., 2010), and applied to other mountain regions of the southwestern U.S. and northern Mexico (e.g., Vivoni et al, 2010a). Furthermore, the model can be used in long-term simulations (years to decades) and within an ensemble (Monte Carlo) framework due to its high performance computing capabilities (Vivoni et al. 2010b). Figure 13.4 shows a climate monitoring Flux Tower in the spruce-fir forest. Other flux towers are located in ponderosa pine and grassland ecosystems.

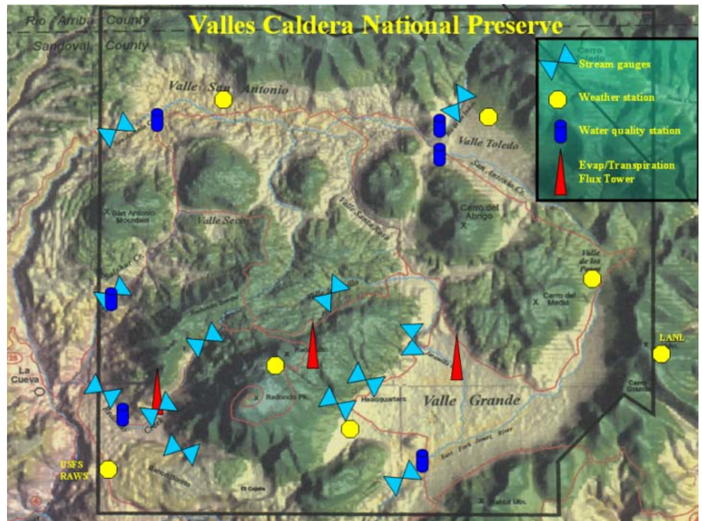

Figure 13.3 Hydrologic and meteorologic stations in the upper Jemez River watershed. A stream gauge not shown is below the Preserve, near Cañon, NM.

In parallel with the modeled stream discharge predictions, we will use the project's forest restoration actions to address the impact of forest thinning on snow accumulation and melt, and its subsequent effects on streamflow discharge (which is expected to increase, and is one of the stated goals of the restoration action). Prior work at the Preserve's La Jara catchment by Veatch et al. (2009), Molotch et al. (2009) and Musselman et al. (2008) will be used to help parameterize effectively the impact of vegetation structure on snow accumulation, such that an imposed thinning "experiment" will effectively be transmitted through the model physics related to

Figure 13.4. A climate monitoring Flux Tower in spruce-fir forest; other towers are in ponderosa pine forest and open grassland.

snow interception, sublimation and melt water delivery to the soil surface. The forest thinned catchments will be compared against the "control" (no-treatment) catchments, and tested with available snow and streamflow monitoring data. Subsequently, the model predictions in the treated sites will be compared to post-thinning monitored observations.

In addition to stream discharge quantities, stream water quality will be monitored using Hydrolab or Sonde recording instruments deployed through the ice-free seasons (usually mid-April through November). Variables recorded will include temperature, dissolved oxygen, pH, conductivity, and turbidity at 15 minute intervals. In addition, monthly bulk samples of stream water will be collected, and analyzed by the State of New Mexico's Scientific Laboratory Division in Albuquerque; these variables will include analyses for nutrients (total phosphorus, total nitrogen, nitrate, nitrite, ammonia), ions (sodium, calcium, magnesium, fluoride, sulphate, chloride), hardness, alkalinity, carbonate, bicarbonate, ion balance, color, pH, total dissolved solids, and total suspended solids. This stream water quality monitoring program has been in place since 2005 on the Preserve (Fig. 13.3), and will be expanded to include the remaining perennial streams in the restoration area.

In addition, collaborating university scientists from across the United States are participating in a long-term hydrologic study in the Jemez River watershed funded by the National Science Foundation. This project, the "Critical Zone Observatory" (CZO), is one of six national sites that have been extensively instrumented to examine the role of climate change on the "critical zone" of life's processes (essentially the top of the tree canopy to the bottom of the groundwater table). This project operates two forest flux towers (Fig. 13.4) to measure precipitation, evapo-transpiration, energy and CO_2 exchange, with additional instrumentation to quantify tree sap flow, water infiltration into soil, and runoff. Los Alamos National Laboratory also operates a grassland flux tower (part of the Ameriflux Network) on the Preserve. Collectively, these studies will assess long-term changes in the hydrologic functioning of these forested sites as restoration treatments are applied on the nearby landscape.

Finally, scientists from the six major New Mexico universities have begun a long-term study under the National Science Foundation's EPSCoR program to monitor the impact of climate change on water quantity and quality in the mountains of northern New Mexico. This $15 million effort is measuring hydrologic parameters in three experimental watersheds, including the upper Jemez River watershed (the other two are the Rio Hondo near Taos, NM, and a tributary to the Rio Chama near the Colorado state line). Scientists working on this project are deploying a wide array of instruments to measure surface- and groundwater dynamics, landscape-scale stream temperature changes, and continuous measures of annual stream water nutrient cycles. The data from these studies and the CZO will be included in the long-term monitoring of the Jemez Mountains restoration area.

Soil

Soil erosion throughout the restoration area will be monitored through the use of sequential high-resolution LIDAR imagery. A LIDAR GIS data layer is being acquired in summer of 2010 on the upper watershed (Preserve), and will be augmented for the entire project area by 2011. A second LIDAR data layer will be acquired in 2019 for comparative analyses. Current resolution of LIDAR imagery is 20-30 cm horizontal and 5-8 cm vertical, sufficient for assessing soil erosion events. Movements of headcuts, gullying from ephemeral streams, stream-road crossings, slumping of road cuts, and sheet-flow erosion from spring snowmelt and summer thunderstorms will be documented for at least 15 years after treatment activity, and these data layers will provide a baseline for future monitoring for many decades.

Vegetation and Fuels

Forest condition has been assessed for the entire restoration area through USFS Common Stand Exam plots. Initial forest treatment effects will be monitored through interagency agreements (USFS-NPS) according to existing agency protocols for inventories of forest stand conditions and fuels. Prescribed fire monitoring will include area burned, flame heights, flame rate of spread, percentage of litter depth consumed, and tree mortality. For monitoring the long-term response of trees in both treated and untreated stands, we will adopt the field methods of the H. J. Andrews Experimental Forest Long-Term Ecological Research Program (LTER). A series of plots will be established, and all trees, snags, stumps and logs within each plot will be tagged and mapped, and measured for diameter and height (length for logs), along with the health status and condition (data forms and methods for these field measurements have already been established, and Dr. Parmenter (Preserve) has extensive experience in these methods, plot establishment and monitoring in New Mexico). Plots will be monitored annually to determine health and mortality, and sampled every 4 years for diameter and height.

Understory vegetation (shrubs, forbs and grasses) will be monitored annually using replicated 100 meter point-transect lines in forests, meadows and riparian areas (Preserve already has 40 such monitoring plots established, and have been sampled annually since 2001; this system will be expanded onto the rest of the restoration area). These data provide species-specific cover and height measures, along with bare ground and litter cover. From these measures, plant diversity, richness, evenness and vertical architectural indices will be calculated among treated and untreated areas (Griffis et al. 2001, Roni 2005). Invasive and non-native plants will receive particular attention during the monitoring, so that control measures can be taken if necessary (Cronk and Fuller 1995). The Science and Education Center in Jemez Springs houses a complete herbarium of all plant species found within the Preserve and Forest.

Biomass production and utilization of herbaceous vegetation (critical to wildlife and livestock) will be monitored semi-annually (spring and late summer) using replicated clip-plots and portable exclosures. Production measures are derived from differences within exclosures between spring and late summer biomass measures, and percent forage utilization is calculated from the ratios of biomass outside and inside the exclosures. Exclosures are then moved a short distance and reset following sampling to begin the next season's monitoring (winter use or summer use). Since 2002, there has been a network of 75 such plots on the Preserve, Forest, and Bandelier lands (Fig. 13.5). This system of plots will be expanded to include treated and untreated areas of the restoration area.

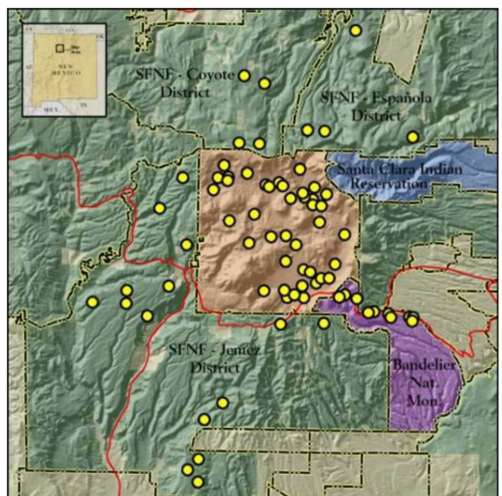

Figure 13.5. Vegetation monitoring sites for plant biomass production and forage utilization.

Wildlife and Fish

Mammals

Vertebrate wildlife, and many mammals in particular, are particularly responsive to habitat manipulations due to their mobility and relatively specific habitat requirements (Cody and Smallwood 1996, Thompson et al. 1998, Holthausen et al. 2005, Morrison 2008), and therefore constitute excellent taxa (both large and small species) for assessments of long-term trends in landscape-level forest ecosystem restoration (Wilson et al. 1996, Bissonette 1997, Barrett and Peles 1999, Maehr et al. 2001, Converse et al. 2006, Morrison 2009).

Large mammal use of restored forest habitat will be monitored on both treated and untreated areas. The major large mammal species of interest in the Jemez Mountains is elk (*Cervus elaphus*), due to their large size, population density, economic value, and potential for ecological damage through overgrazing (Cooperrider 2005). In response to local elk-human-ecosystem interactions, a citizens/agency group, "Seeking Common Ground", has been active for the last decade in the Jemez Mountains to deal with complaints and issues with the elk herd; the Forest and Preserve are members of this consortium. Elk, and to a greater extent mule deer, exhibit highly variable patterns of movements and habitat use in ponderosa pine and mixed conifer forests (Skovin et al. 2002, Ager et al. 2005), and would be expected to change their movements and use patterns following restoration activities (see Toweill and Thomas 2002, Wisdom 2005, and references therein). Thinning in ponderosa pine/mixed conifer forest has been shown to shift elk movement and habitat use patterns, and increase hunter success percentages (Lyon and Christensen 2002, Wisdom et al. 2005). In addition, bears emerging from hibernation have been found to cause feeding damage to trees (particularly Douglas fir), and thinned stands are particularly attractive to bears due to higher sap flows in the spring(Ziegltrum and Nolte 2001, Lowell et al. 2010). In our SWJM restoration area, monitoring will be used to determine the patterns of large mammal use and movements in response to forest restoration, because only a few studies have addressed manipulation of forests on the restoration of carnivores or ungulates, and absolute site-specific predictions on their responses are not possible (see Long et al. [2008] and Van Dyke and Darragh [2007] for mule deer responses to habitat manipulations). This is particularly important in the Jemez Mountains, as much of the area contains WUI areas with human residences, setting the stage for potential human-wildlife conflict interactions.

Therefore, as part of the restoration project, large ungulates and carnivores, specifically elk and mule deer (*Odocoileus hemionus*), along with black bear (*Ursus americanus*) and mountain lion (*Felis concolor*), will be monitored to examine responses to habitat restoration. Global Positioning System collars will be deployed on elk, deer, bear and mountain lion, and resource selection functions will be developed for collared individuals to detect responses to forest restoration (Long et al. 2009). Analyses will be conducted using resource selection functions to better assist managers in implementing ongoing and future habitat restorations. Collaborators in this aspect of monitoring include staff from the Preserve, Forest, and New Mexico Department of Game and Fish.

Additionally, changes in small mammal communities will be monitored using mark-recapture methods on replicated trapping webs in treated and untreated stands (Parmenter et al. 2003), and population density estimates (number per hectare) will be calculated using Program DISTANCE for each species(Laake et al. 1993). Species population density, richness, diversity, evenness, biomass (kg/ha) and population demographics will be analyzed for forest treatment effects through time (using Repeated-Measures Analysis of Variance statistical techniques; e.g. see Parmenter et al. 1999).

Selected threatened, endangered and sensitive (TES) small mammal species will be specifically monitored and evaluated during the restoration program to determine if restoration actions help to restore habitat suitable for sustaining or increasing these species. For example, the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) is endemic to moist meadow habitat in New Mexico, Arizona, and a small area of southern Colorado (and is undergoing review for Federal Endangered Species status). Only 16 jumping mouse localities are known, including the SWJM area. During the 10-year restoration project, we will undertake riparian restoration treatments and mouse transplant/reintroduction programs to restore jumping mouse populations in previously occupied habitat in the area. Mark-recapture live-trapping inventories and monitoring of post-reintroductions will be conducted using methods in Frey (2007). Collaborators in this aspect of monitoring include biologists from the Preserve and Forest along with New Mexico Department of Game and Fish, New Mexico State University, WildEarth Guardians, and The Nature Conservancy.

Monitoring for other small mammals listed as “sensitive” species will consist of replicated transects sampled before and after forest treatments (in treated and untreated stands) using visual observation counts and home range measures. Small mammal populations in the project area are expected to increase in numbers as high-density ponderosa pine and dry mixed conifer forests are restored to more open, uneven stands, with clusters of even-aged groups connected by canopy corridors. Such forest structure will provide the foods required by squirrels, mice, and other rodents, including canopy cover necessary for fungi production, nesting, and escape (Keith 2003). Restoration of these forest stands is predicted to result in recolonization and expansion of small mammal populations. This will in turn provide additional prey species (food) for important raptors in the area such as Mexican spotted owl, peregrine falcon, northern goshawk, and others (see Birds).

Beaver (*Castor canadensis*) is an important riparian/aquatic mammal whose population in the upper Jemez River watershed was extirpated in the 20th Century. Beavers have returned in relatively small numbers along certain stream reaches in the SWJM area. However, the historic heavy grazing by livestock coupled with past and current grazing by large elk populations in the upper Jemez River watershed, have annihilated the streamside willow stands and prevented full recovery of the beaver population. Several ongoing and proposed treatments to re-establish willow and aspen stands in riparian stream areas within the proposed restoration area will help develop sustainable habitat for beaver. Monitoring beaver population migration and numbers will augment the overall monitoring of riparian and aquatic restoration treatments for this project.

Birds

Forest habitat structure and seral stage conditions are primary factors determining the composition and abundances of forest bird communities (Dickson et al. 1979, Newton 1979, Wiens 1989, Newton 1998, Block and Finch 2000, Medin et al. 2000). Bird populations in coniferous forests respond quickly to timber harvesting (e.g., Franzreb 1977, Scott 1983) and fire-induced habitat changes (Kreisel and Stein 1999), and therefore serve as excellent monitoring taxa for assessing restoration success. If successful, the planned restoration projects should promote the reestablishment of avian assemblages typical of old growth ponderosa pine, mixed conifer, and spruce-fir forests. To monitor the bird community response to forest restoration, we will conduct general bird population monitoring (see methods below) across the different forest types and treatments (thinning, fire, and non-treated “controls”) to assess species composition and density each breeding season. In addition, we will assess population structure and conduct demographic analyses through live-capture mark-release studies using mist nets, especially targeting TES species. Finally, we will perform standardized surveys for TES species in this area such as Mexican spotted owl, goshawk, and peregrine falcon (bald eagle uses the area in winters but does not breed in this area).

General bird community monitoring will be documented through replicated, timed standard 10-minute point counts at selected monitoring sites in treated and untreated stands. It will be conducted by field ornithologists in multiple visits to each monitoring site during the breeding season to compare species diversity, evenness, and richness among sites. These counts will document any observed breeding activities as territorial songs, courtship, nest building, and feeding of young. We anticipate approximately 20 monitoring sites superimposed onto both treated and “control” forest stands.

Demographic data on forest birds will be determined using a nationally-recognized protocol that involves bird banding and mist netting during the breeding season at each of approximately six monitoring sites (DeSante et al. 2007). A variety of light-weight mist-net systems are available and suitable for this project (Dejohghe and Cornuet 1983; Meyers and Pardieck 1993).

Northern goshawk will be the primary bird species monitored as an indicator of sustainable ponderosa pine ecosystem conditions, although we may also use Grace's warbler as another indicator. Grace's warbler populations in decline (Butcher and Niven 2007, Norris et al. 2005), and it is a bird of conservation concern (U.S. Fish and Wildlife Service 2002, 2008, Rich et al. 2004, Norris et al. 2005, NMDG&F 2006). The steepest declines in this bird species population is in New Mexico (Rustay and Norris 2009). Bird monitoring will include three primary products: (1) adult population index and productivity estimates; (2) trends in adult population size and productivity; and (3) survivorship analyses. The analyses of data to get these results is likely to closely follow the methods used to determine demographic rates of birds at Yosemite National Park (Siegel et al. 2007), Sequoia and Kings Canyon National Parks (DeSante et al. 2005), and Devil's Postpile National Monument (Gates and Heath 2003).

Adult population indices will be generated from the number of newly banded birds, recaptured birds, and birds released unbanded. For productivity estimates, procedures used by Siegel et al. (2007) will yield yearly reproductive index from the number of young and adult birds captured. For survivorship analyses will follow White (1983) and Hines et al. (2003) to calculate the maximum-likelihood estimates and standard error for adult survival probability, adult recapture probability, and the proportion of residents among the newly captured adults using a between- and within-year transient model.

Monitoring for northern goshawk and Mexican spotted owl will follow standard Forest Service protocols, described in agency directives and policies. Peregrine falcon is another raptor species with historic and occupied nesting sites in the area that will be monitored. Hawks Aloft and other raptor specialists in the area will work with Forest and Preserve biologists to monitor these raptor species in the area. Mexican spotted owl surveys will be conducted according to Forest Service Region 3 protocol (USFWS 2003). Surveys include night surveys with daytime follow-up surveys when spotted owls are located, using standard methods (Forsman et al. 1984). Survey protocols include visits to determine nest occupancy and reproductive success of confirmed pairs. Northern goshawk monitoring will likewise follow Forest Service Region-3 protocol, as currently described in the Northern Goshawk Inventory and Monitoring Technical Guide (Woodbridge and Hargis 2006). This protocol requires up to two surveys each year in potential goshawk habitat during the nestling and fledging/early post-fledging periods. Surveys include determination of nest occupancy and reproductive success of confirmed pairs.

Reptiles and Amphibians

The impact of forest restoration on reptiles and amphibians is not well understood, although two species of amphibians are of concern in New Mexico and in this SWJM area: Jemez Mountain salamander and northern leopard frog. Monitoring surveys for these will be undertaken using special protocols described below, while general observation surveys for reptiles and other amphibians will be conducted during other monitoring programs in the restoration project area (Heyer 2007). Reptile populations in the project area are relatively low (due to the area's high elevation), and sightings of reptiles are unpredictable and spotty. However, general presence/absence and sighting numbers collected over repeated field days may provide indications of general abundance and distribution of some species. Hence, during field monitoring for vegetation, mammals, birds, fish, and invertebrates, field technicians will record all sightings of reptiles encountered during the course of their work.

The Jemez Mountain salamander occurs only in the Jemez Mountains at elevations between 7,200 to 9,500 feet. It lives under rocky soils and rotting logs primarily in mixed conifer and spruce-fir stands (Degenhardt et al. 1996). It is a State-endangered species and is being reviewed for Federal listing under the Endangered Species Act. Presence-absence surveys for Jemez Mountain salamander will be conducted within the project area using the established survey and monitoring protocol (Protocol A) developed by the inter-agency New Mexico Endemic Salamander Team (2000). Salamanders found will be tested for chytrid fungus using genetic PCR techniques by Pisces Molecular in Boulder, Colorado, or a lab with similar capabilities.

Presence-absence surveys for northern leopard frogs will be conducted within lentic and lotic aquatic habitats within the project area using the U.S. Fish and Wildlife Service survey protocol adapted from Arizona Game and Fish Department guidelines (Blomquist et al. 2002). Northern leopard frogs (and other amphibians found coincidentally) will be tested for chytrid fungus using genetic PCR techniques by Pisces Molecular in Boulder, Colorado, or a lab with similar capabilities. In New Mexico, this frog species is associated with streams, marshes, and waterbodies, and has been found along the Rio Grande in New Mexico (Degenhardt et al. 1996). Populations appear to be declining in New Mexico (C. W. Painter and R. D. Jennings *unpubl. data; in* Christman 2009; Lanoo 2005) and in the Jemez Mountains (*pers. obs.*, Cummer et al. 2002; *in* Christman 2009).

Fish

The restoration project area has a relatively small fish community, composed of several species of native non-game fish (long-nose dace, Rio Grande chub, Rio Grande sucker, and fathead minnow), along with two species of non-native trout (rainbow and German brown trout) (Sublette et al. 1990). The native Rio Grande cutthroat trout species was extirpated from the project area during the 20th Century primarily by the introduction of the brown and rainbow trout species. Monitoring of fisheries within the restoration area will be conducted using permanently marked 100 m reaches of stream, and utilizing a triple-pass electrofishing sampling method with blocking nets. All fish specimens will identified to species, measured and weighed, and released back into the stream after sampling. Fish density, biomass, and body condition will be calculated, and monitored through time as restoration projects occur on the watershed. Fisheries have been monitored using these methods on the Forest and Preserve since 2003 at 6 permanent sampling sites, and this network of sites will likely be expanded to 9 to-12 sites along perennial streams in the restoration area. Collaborators in this monitoring will include biologists from the Forest, Preserve, New Mexico Dept. of Game and Fish, New Mexico Trout and Trout Unlimited.

Invertebrates

Insects and other invertebrates are important ecosystem components, contributing what land managers view as “beneficial” and “detrimental” (pest) impacts on ecosystem structure and function. Beneficial activities include pollination of plants (by bees, butterflies, moths, flies), decomposing litter and aiding nutrient cycling (beetles, springtails, earth-worms), and preying on “pest” insect species (parasitoid wasps, ground beetles, spiders). Detrimental pest species may cause widespread death of trees (e.g., bark beetles, tip moths, budworms), reduction of cone or acorn crops (beetles, moths), loss of forage for wildlife and livestock (grasshoppers, aphids), and spread of disease (flies, mosquitoes). Many invertebrates also serve as food for vertebrate wildlife in both terrestrial and aquatic ecosystems.

Forest Service Regional Office entomologists conduct aerial surveys of insect and disease damage on the Forest and Preserve (NFS) lands each year (Fig. 13.6). These on-going surveys will continue to be used to evaluate changes resulting from the restoration project. Changes in defoliation and mortality in each forested ecosystem will continue to be entered into the monitoring database for this SWJM restoration project and evaluated. In particular, changes will be detected in prevalence of western spruce budworm, a native moth inhabiting conifer forests throughout the Rocky Mountains and this SWJM area (Powell and Opler 2009), known for its explosive population outbreaks and degree of defoliation damage (Campbell 1993, Cain and Parker 2004). Figure 13.6 shows results from aerial surveys of western spruce budworm that indicate increasing impacts from 2003 to 2009. Changes in prevalence of bark beetles will also be monitored, as these beetles have caused increased defoliation and mortality in the ponderosa pine forests and piñon-juniper woodlands that dominate the project area. Aerial surveys conducted for the past decade by the Forest Service show the extent of conifer tree defoliation and mortality caused by these insect pests (refer to maps on the SWJM website). Changing forest structure and tree health through thinning and prescribed fire activities will influence the abundance of these pest species.

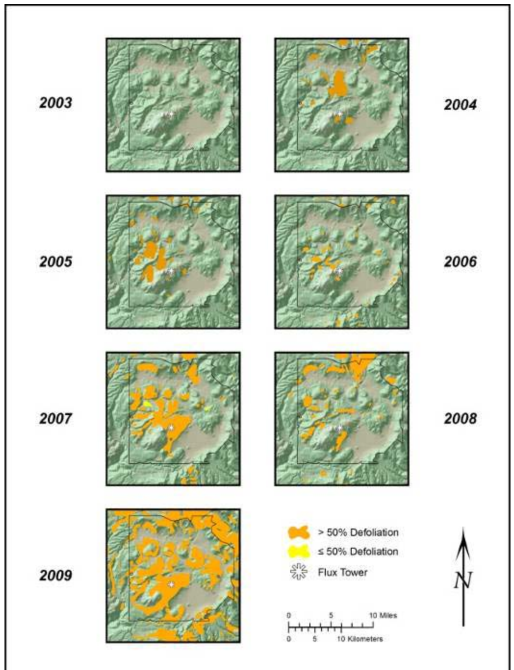

Figure 13.6. Aerial surveys show spruce budworm impacts increased from 2003 to 2009.

Terrestrial forest and meadow invertebrate species, including both pest species and beneficial insects (pollinators, predators, parasitoids) will be monitored in treated and untreated areas by entomologists from the Preserve, the USDA Systematic Entomology Laboratory (SEL) and Smithsonian Institution (SI) using malaise traps, light traps, pitfall traps, grasshopper density rings, and sweep nets (Leather 2005). Inventories and identifications of these species have been conducted in the Jemez Mountains by entomologists from those organizations during 2004-2010, and archival reference specimen collections are available at SEL/SI and in the Preserve's Science and Education Center in Jemez Springs.

Aquatic invertebrates known to be beneficial and indicative of healthy aquatic ecosystems will be monitored in the project area's perennial streams using permanent sample locations (co-located with the fisheries monitoring sites described above). Quantitative replicated samples for invertebrate density, species richness, diversity and evenness, will be taken using standardized area samples (Surber bottom samplers). Specimens will be identified to species and counted. Inventories of Jemez Mountains streams have already been conducted (Vieira and Kondratieff 2004), and species identifications will be verified using reference specimens archived in the Preserve's Science and Education Center in Jemez Springs.

Monitoring Social and Economic Change

Heritage Resource Preservation

Monitoring historic and prehistoric (archaeological) sites will be conducted through pre-implementation and post-implementation surveys, following standard protocols established by the Forest Service and State Historic Preservation Office. While pre-treatment surveys will be used predominately, up to 25% of treatment areas will be subject to post-treatment surveys. Results will be evaluated and used to adjust out-year treatment prescriptions as needed. Cultural resource sites are typically identified and avoided during implementation activities. If avoidance is determined to be infeasible, other mitigation measures are used to preserve the cultural resource site data.

Potential negative effects of forest restoration activities include disturbance of surface features (e.g., fieldhouses, cairns, grid gardens) from heavy equipment and tree-felling, ground disturbances from heavy equipment, vehicle use, and roadwork, loss of or damage to combustible historic features (e.g., cabin foundations, corrals, fencelines), heat alteration and damage to prehistoric artifacts and features, and intentional removal or unintentional damage to historic water control features (e.g., dams, spring heads, irrigation and drainage ditches). Long term and cumulative effects to otherwise protected subsurface archaeological deposits can occur with surface erosion, stream downcutting/arroyo formation, and development of rills. The cumulative effects of increased access during and after project implementation are less obvious and less predictable, but nonetheless harmful. These include loss of surface artifacts and damage to alterable or detachable components of historic and prehistoric features, construction of new features (e.g., rock cairns), and increased knowledge of the location and contents of high-value archaeological deposits (e.g. rockshelters).

To assess the success of mitigation measures designed to avoid those impacts, monitoring activities will include observer oversight during a sample of activities such as tree-felling and roadwork, repeat site visits at a sample of all sites, repeat photo monitoring at selected site locations, pre-and post-fire condition assessments at selected archaeological sites, and use of temperature-probe installations to measure heat-exposure during burning. Over longer periods (over 5 years), comparison of aerial photography will be used to assess intended versus actual outcomes (e.g. project boundaries) to evaluate if protective measures were of appropriate scope. Because so many of the archaeological sites in the project area are cultural soil deposits, more subtle effects such as erosion can be tracked by LIDAR, non-archaeological soil, vegetation change, and water monitoring activities

Social and Economic Values

Wood utilization values from implementing this project is expected to benefit local economies. Staff from the Forest and Preserve together with other restoration partners will track and annually report the economic activities resulting from forest thinning and wood removal activity. This includes tracking and reporting the types of products and ultimate market destinations of the wood removed from the restoration project area. This will permit evaluation of economic stimulus into local economies, as well as employment rates and capital investment in businesses.

Evaluating the reduction in uncharacteristic wildfires and restoration of natural fire regimes will include analysis of associated social and economic values. The Proposal Section 4-Wildfire describes the reduction in economic costs and social impacts expected to result from this restoration strategy. Thus, the costs for wildfire suppression, burned-area rehabilitation, human injury and death, and other wildfire-related costs will be tracked and evaluated to help determine the effectiveness of treatments in reducing these economic and social costs.

Livestock production and grazing management changes before and after restoration treatments will be monitored, evaluated and reported. Forest thinning and burning activities will promote understory recovery of grasses, forbs and shrubs. Increased herbaceous forage (grass and forbs) may allow for changes in annual livestock grazing plans for affected allotments. Monitoring the increase in herbaceous forage availability and resulting changes in stocking rates or weight gains of cattle within the restoration project area will help us to evaluate the economic benefits to the local ranching economy.

Wildlife and fish habitat will be enhanced through restoration treatments, which will have economic and social benefits to locals and visitors. Elk hunter success is expected to increase with forest thinning and the creation of more open forest habitats, and will potentially translate into greater demand by hunters and wildlife enthusiasts to visit and recreate in the SWJM area. Revenues from hunting and fishing specifically, and tourism in general, constitute some of the major sources of income for the local rural economy. In addition, with habitat modification and redistribution of elk, the region may experience lower complaints of elk damage to private properties and livestock grazing allotments. Hunter data (applicants, success rates, financial expenditures while on hunt trips, etc.) from the New Mexico

Department of Game and Fish in the hunt units within the project area will be analyzed for these trends. Large predators (bears and mountain lions) may exhibit different predation success rates on livestock and elk calves within more open forest stands. Distributional data from the elk herd also will permit assessments of forage consumption within grazing allotments, which in turn will have economic impacts on local ranchers due to competition for forage between elk and cattle. Livestock stocking levels are controlled and monitored by Forest and Preserve personnel, allowing detailed economic evaluations of elk impacts on ranch operations. Elk monitoring data will also be used to evaluate economic impacts of these large game animals.

There will be an increased *ecosystem services* value from improved watershed function and water production, as another social and economic value that will be monitored and reported. Forest restoration treatments can result in increasing surface water production during spring snowmelt, and this "restored" water production has an obvious economic value. For each forest stand of a given age, size, and density structure on a known slope, aspect, and elevation, there is a unique solution to optimize open space (allowing snow to reach the ground) and still provide shade to reduce moisture loss through sublimation. Thinning treatments should increase the amount of water available to the hydrologic cycle, enhancing growth of trees, shrubs, grasses, and forbs for wildlife food and habitat, and providing additional streamwater discharge during spring snowmelt for downstream users. Preliminary estimates by the University of Arizona hydrologists working in the Jemez Mountains suggest that implementing these forest thinning prescriptions could reduce snow sublimation by up to 50 percent, thereby increasing Jemez River stream discharge by approximately 10 to 20 percent.

This enhancement of ecosystem service to society in the Rio Grande valley has significant monetary value. The headwaters streams in this SWJM area produce around 20,000 acre-feet of water each year: a 10 percent increase in stream discharge would equal 2,000 acre-feet. At current water rights prices (the City of Rio Rancho, New Mexico, recently purchased water rights for $11,000 per acre-foot), the capital value of 2,000 acre-feet would equal $22 million. If leased at 10 percent of capital value per year, this would equal an annual water benefit worth $2.2 million to downstream farmers, ranchers, and urban residents. Concomitantly, the financial benefit of reduced fire risk and increased forage for wildlife and livestock from forest thinning further enhances the collective value to society. Thus, the hydrologic monitoring data of the watershed during the restoration project will be translated into economic models to track the economic benefits of increased discharge and improved watershed functioning.

Recreational uses, scenic values, and tourism will be enhanced by restoration activities in the area that increase plant and animal diversity, reduce roads and rehabilitate denuded areas. The influence of restoration activities on recreational uses and values in the project area have economic benefits to the local economy that will be monitored. The project area is heavily used for recreation by local, regional, national and international populations, and tourism is a major input to the New Mexican economy. The Forest and Preserve staff will continue to monitor recreational use within the project area using standard National Visitor Use Monitoring protocols and database systems to determine any changes in recreational use by visitors. Changes in visitor use will be evaluated in terms of social and economic effects on local businesses and community services.

Recreation and Vehicle Use in Riparian Areas

Human activity such as camping, parking, driving and trash-dumping in riparian areas has resulted in significant degradation of riparian vegetation, wildlife habitat, water quality and fish habitat. Monitoring changes in those activities in the riparian area is important in evaluating the success of the riparian restoration treatments. Hydrology and fisheries staff from the Forest, Preserve, New Mexico Environment Dept, and non-government organizations will monitor the changes in these activities within riparian areas undergoing restoration. Monitoring will evaluate the effectiveness of travel management regulations that prohibit driving off designated roads, and closures, signs, barriers, and regulatory controls designed to limit those uses in riparian zones. It will also help evaluate the success of on-going public environmental education programs in this area, and the degree that visitors comply with the restrictions and assist in protecting and restoring these sensitive ecosystems.

Training, Education and Employment Opportunities

Staff from the Forest and Preserve will monitor changes in providing training, education, and employment opportunities to local communities. This restoration project will provide an enormous opportunity to school students, scouts, Youth Conservation Corps, student conservation association, Pueblo youth and others in this area. Students from public schools, universities, and other groups will be educated in field-based programs and science camps at the new Science and Education Center in Jemez Springs, with emphasis on how to restore large-scale ecosystems. Topics will include management principles and techniques for forests, rangelands, watersheds, soils, wildlife, fisheries, cultural resources, climate change, biodiversity, fire ecology, forest products, and economic interactions also will be included. Youth and adult groups including volunteers working on restoration activities will continue to learn about complex natural resource issues. These training and educational activities will be monitored and tracked to help assess the overall social effects of this restoration project. The project will employ a substantial number of people from local and regional communities (both career professionals and students) to conduct restoration treatments as well as monitoring activities. This employment in industry, government and collaborating groups will contribute to professional training and building a capable natural resource workforce in the region. This capacity-building will help accelerate other restoration projects on surrounding lands in the region. The Preserve and Forest managers employ people of many ethnic backgrounds, and will continue to strive to recruit a wide diversity of people for restoration projects and science-based monitoring of resources. The restoration project should particularly increase job opportunities for Native American and Hispanic communities that currently have high unemployment and poverty rates, and employ a highly diverse workforce to conduct and monitor this ambitious restoration project in the coming years.