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High-Severity Fire in Forests of the Southwest: Conservation Implications

Progress Report, August 2005

By Sandra Haire

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Cover photograph: Short-horned lizard (*Phrynosoma douglassii*) on a Field Map, Saddle Mountain Study Site, Spring 2005

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High-Severity Fire in Forests of the Southwest: Conservation Implications

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Introduction

The occurrence of large, severe fires in southwestern ponderosa pine (*Pinus ponderosa*) forests has resulted in concern that these forests may not persist under such an extreme disturbance regime. In our research, we are examining the outcomes of high-severity fire in ponderosa pine forests and their neighboring communities across an elevational gradient. One goal of our work is to contribute to understanding the resiliency of these systems, but we also want to investigate the conservation values intrinsic to the diverse communities that represent alternative successional trajectories after severe fire. One assumption of our research is that the spatial pattern of a disturbance becomes increasingly important when the disturbance is large and biological legacies are few and sparse. We ask, therefore, what spectrum of plant communities results from high severity fire, and what is their relationship to spatial patterns of severity mapped in early post fire timeframes? Also, do spatial patterns of older burns (1950–80) differ from recent burns (1998–present) in ways that make us expect successional changes years from now to differ from those we observed at our older burn field sites?

Here, we describe the first stages of our work in mapping burn severity at old and new burns as well as the work we have recently completed at our two field sites. The report is organized under our two main objectives with the purpose of summarizing the steps we have taken in working toward these objectives, as well as changes we have made in methodologies since the original study plan. We present some general observations and plans for the next steps in data analysis and product generation. This report, the study plan, a photograph gallery, slide presentations, and our contact information are available on the project Web site *http://www.umass.edu/landeco/research/swfire/swfire.html* .

Objective 1

Determine the persistent and ephemeral effects of the spatial heterogeneity of burn severity in areas affected by high-severity fire over decadal timeframes.

Mapping Burn Severity for the Field Sites

Last fall and winter, we obtained pre- and post fire aerial photographs for our field sites, delineated areas of high severity, and created GIS coverages of the burned areas. The first field site, La Mesa, burned in 1977. The burn is located primarily in Bandelier National Monument with some areas on the Los Alamos National Laboratory and also Santa Fe National Forest. La Mesa, thought to be a human-caused fire, burned across an elevational gradient, which generally increases from southeast to northwest, encompassing approximately 6,000 ha of pinion-juniper (*Pinus edulis-Juniperus* spp.), ponderosa pine, and mixed conifer forest. For this burn, we had access to aerial photographs taken in 1973, 1975, 1977, 1981, and 1983, courtesy of Kay Beeley, National Park Service. The photographs vary in scale from 1:6,000 to 1:24,000.

Our second field site is Saddle Mountain, a 4,000-ha burn that occurred in 1960. The fire started by lightning in Grand Canyon National Park and spread northeast across a similar range of forest types to that at La Mesa, with elevation increasing from northeast to southwest. The area is almost entirely within the Saddle Mountain Wilderness and is accessible by foot from dirt roads at the southwest, southeast, and northern wilderness boundaries. Aerial photographs taken before and after the fire (1957 and 1963; 1:15,840 scale) were purchased from the U.S. Department of Agriculture Aerial Photography Field Office.

The aerial photographs were interpreted in stereo and digitized with an Optem Digitizing Transfer Scope onto digital black and white orthophoto quads taken in the late 1990s and early 2000s. Mapping areas of high-severity burn was relatively straightforward where standing dead trees were visible in the photographs. In other cases, openings on the post fire photographs were compared to conditions on pre fire photographs to distinguish preexisting openings from new openings created by fire, although this was very rarely a source of confusion in our study areas. Moderate severity was mapped where a mix of dead and live trees was visible. In this case, standing trees commonly had brown needles but were too intermingled with live trees to delineate separate patches. The minimum mapping unit is defined by groups of two or more trees that survived the fire. These patches may have experienced low-severity (for example, surface) fire or may represent unburned islands.

Selection of Field Plot Locations

In our analysis of the maps to determine field site selection, we used a simplified map with high and low/unburned classes. Moderate areas in which live trees were too scattered to delineate were included in the high category. Before the field season, we devised a scheme for selecting sample locations with the goal of capturing variation in gradients of (1) distance from within high-severity patches to an edge of lower severity and (2) landscape context of forest cover/potential seed sources. The variation in ponderosa pine cover at La Mesa was modeled using percent cover values from a map created soon after the fire by Craig Allen for his dissertation work. For Saddle Mountain, we estimated percent cover of ponderosa pine from the post fire aerial photograph in a buffer zone around each high severity polygon. Using the cover values, we developed a surface that represented potential for seed dispersal within the high severity polygons using kernels (Worton, 1989; figs. 1 and 2). Local peaks in distance within high-severity patches were identified, and a subset of these locations was chosen to represent variation in kernel values. Approximately 60 priority locations were chosen at each site; extra points that could be substituted or added were available to use if needed.

Field Data Collection

We collected data at 68 plots at La Mesa and 80 plots at Saddle Mountain between May 16 and June 30, 2005. Plots were located throughout the burns (figs. 3 and 4), except where access was limited by private ownership (for example, Los Alamos National Laboratory properties). We also avoided locations where tree planting was documented, for example, on the Mesa del Rito (New Mexico). According to our contacts at the Forest Service, trees were planted at Saddle Mountain; however, we had no information on the specific location of the planting. Therefore, we continually looked for evidence of planting and found none in our plots (that is, no trees near in age to the burn). The plots were circular with a 25-m radius; data collected at each plot include physical characteristics, point-intercept cover estimates, tree species, size, age, and shrub and understory species lists (table 1; fig. 5).

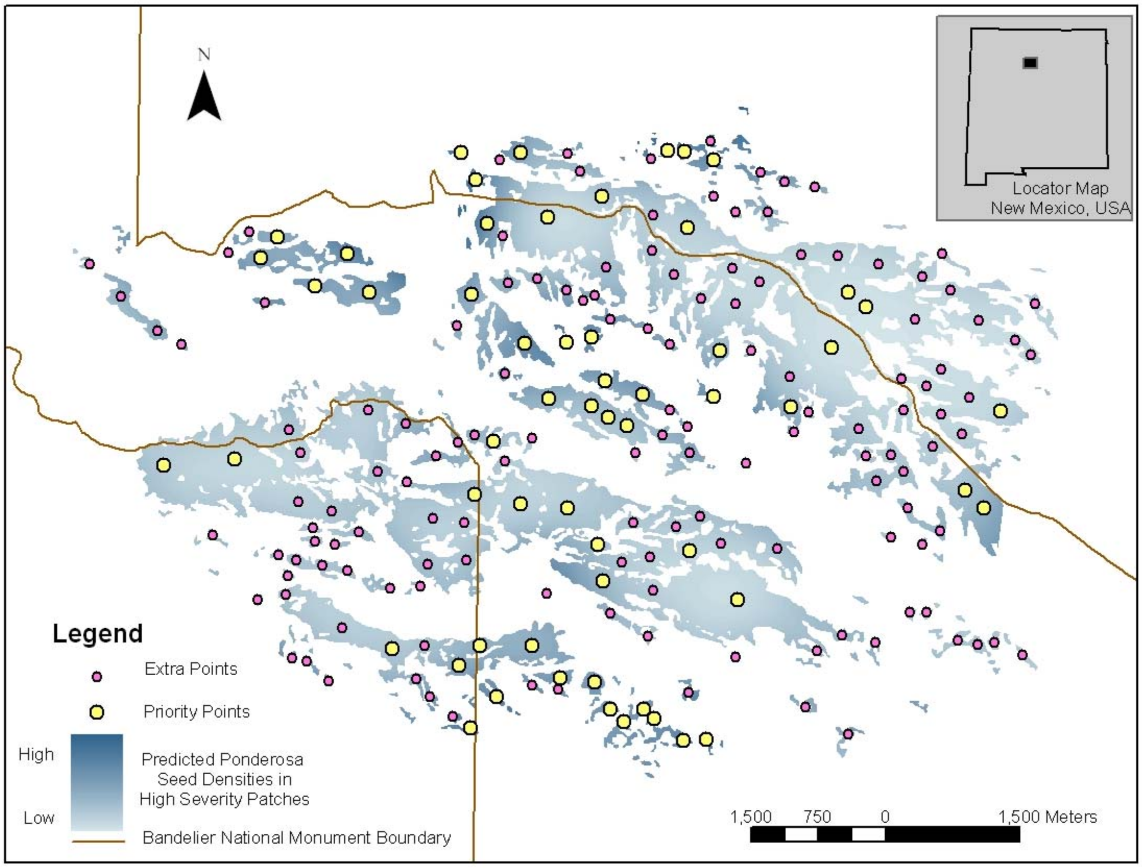

Figure 1. The field map of potential plot locations at La Mesa chosen relative to (1) distance from high severity (blue areas) to nonhigh and (2) variation in ponderosa pine seed sources outside the high-severity patches (represented by shades of blue). A large portion of the burn is located within Bandelier National Monument, but parts of the Santa Fe National Forest to the southwest and Los Alamos National Laboratory property to the northeast also burned in the fire.

Some changes were made in the data-collection procedures from our original proposal. We made a complete survey of woody species at all plots; however, due to several factors (visibility of flowers because of season, time constraints, and limitations of our expertise in botany) we could not realistically identify all herbaceous and grassy species at the plots. Instead, we identified the most visible species (that is, those that were flowering) at a subset of the plots and added a narrow belt along the line transects in which to quantify presence/absence of high-priority "invasive" plants. Some of the invasive species of interest, identified by local managers, were cheatgrass (*Bromus tectorum*), smooth brome (*Bromus inermis*), mullein (*Verbascum thapsus*), sheep fescue (*Festuca ovina*), Kentucky bluegrass (*Poa pratensis*), and diffuse knapweed (*Centaurea diffusa*), among others.

Objective 2

Determine the differences in spatial heterogeneity in older and newer burns of similar and different sizes and, using our findings from Objective 1, evaluate the cumulative effects of high-severity burns on biodiversity within the broader regional landscape.

Study Site Selection and Mapping

We have identified a set of fires that meet our criteria in the older and newer timeframes (table 2). The fires are distributed among three regions: Jemez Mountains in New Mexico, Gila Mountains in New Mexico, and the Kaibab Plateau (including Grand Canyon North Rim) in Arizona. In the older burn category, mapping is in progress for the Lookout Canyon, Little Creek, and McKnight burns, and we are working with cooperators

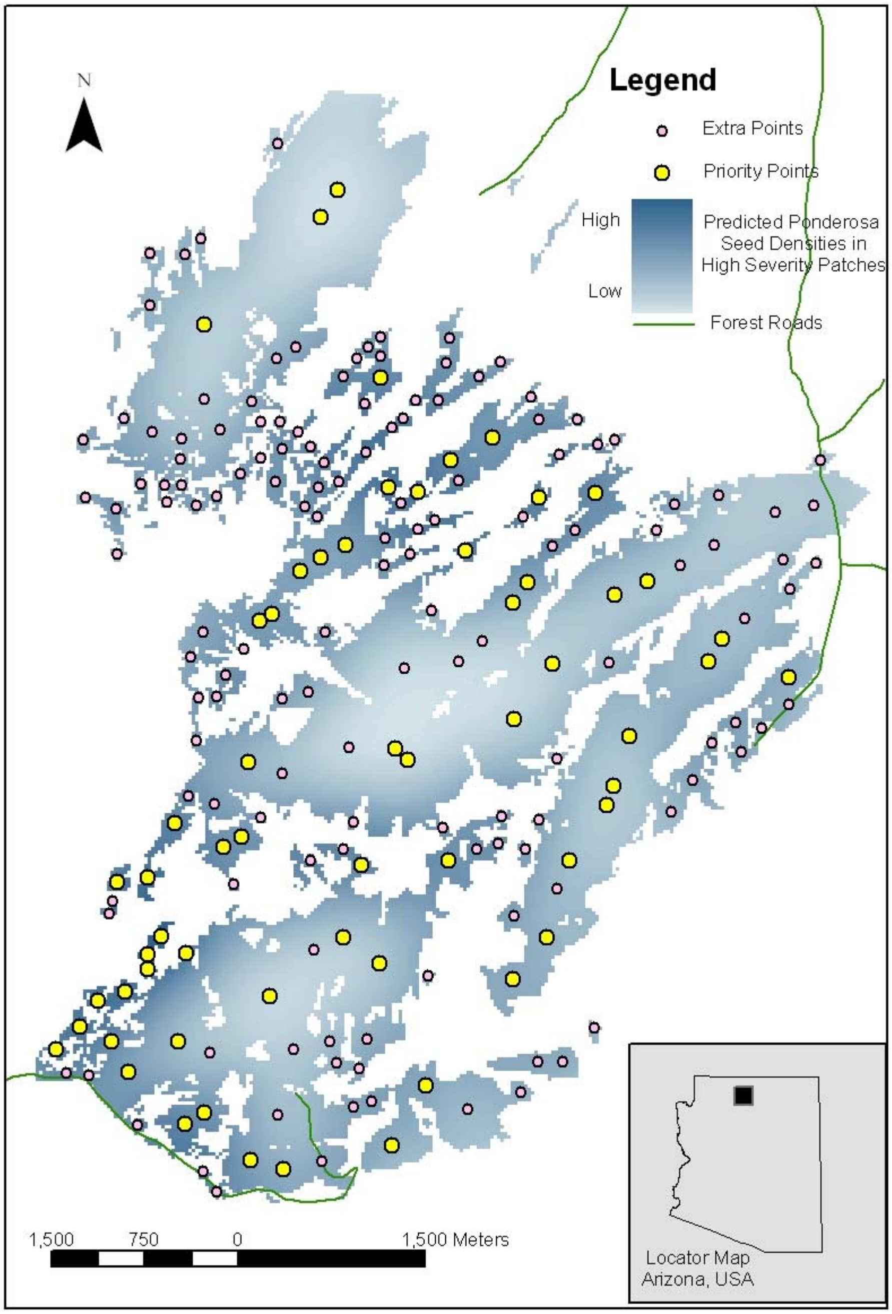

Figure 2. The field map of potential plot locations at Saddle Mountain, chosen relative to (1) distance from high severity (blue areas) to nonhigh and (2) variation in ponderosa pine seed sources outside the high-severity patches (represented by shades of blue). The southern edge of the high-severity patches borders on Grand Canyon National Park (Forest Road 610 of the Kaibab National Forest). The majority of the burn is in the Saddle Mountain Wilderness, North Kaibab Ranger District.

at the Los Alamos Laboratory to obtain photographs for American Springs. The size of the McKnight fire may prevent its completion in the timeframe and budget of our project, but we will optimistically keep it in the plan until the work on the other burns is near completion. There are many possibilities for newer burns, and we may yet substitute one for another in some cases. For example, several large burns have recently been mapped in the Gila Mountains. Burn severity maps are available for all of the recent fires either through the National Burn Severity Mapping Project (*http://burnseverity.cr.usgs.gov/fire_main.asp*) or from collaborators (for example, at the local National Forest).

Table 1. Data collected at La Mesa and Saddle Mountain field plots. Plots were 25-meter radius, with transects running north-south and east-west.

Field data collected	Description of methods
Plot characteristics Location GPS error Slope Aspect Topographic position	Navigated to point using Garmin 12 GPS, map, and compass, then marked the location in the GPS unit and recorded error. Slope of the land in degrees. Aspect in compass degrees describing the predominant direction face. Classified relative to the local condition: summit or mesa top, flat side-slope, shoulder, toe, or bottom.
Cover data Grass Forb Soil Rock Organic Shrubs (by species) Trees (by species)	Point intercept recorded at 100 1-m intervals along North-South and East-West line transect through center of plot.
Live trees Diameter (or seedling, sapling class) Species Age if ponderosa pine (whorl count and coring) Health rating **Downed wood** Length in belt Average diameter in belt Decay class **Stumps and snags** Diameter Species if identifiable	Trees and dead wood were measured in a belt along either side of the line transect. At each plot, width was chosen to optimize number of coniferous trees while maximizing efficiency in areas with dense trees. Width of the belt varied from 2 to 10 meters. Trees were cored selectively (approximately 20-30 per site) to determine confidence in age estimates based on whorl counts. Health of trees was rated on a scale of 1 (healthy) to 3 (unhealthy). Downed wood and stump decay class was rated using a standard scheme, considering state of bark and stems and softness of wood. Diameters were measured at 1.5-meters up from the ground.
Soil data Stoniness Development Texture	Soil was characterized onsite using categories of stoniness, degree of development, and texture based on properties when wet.
Plant species diversity and abundance Woody species identification Herbaceous and grassy species identification “Invasive” species abundance	All woody plants were identified to genus and in most cases, to species. Herbaceous and grassy species were identified at a subset of plots as time and expertise allowed. Presence/absence of priority “invasive” species, specified by local managers, was quantified in 200 1-m^2 plots, which were located along the line transects.
Photographs	Digital photographs were taken from plot center, one in each cardinal direction.

For the newer burns, a change detection index called the Normalized Burn Ratio (deltaNBR) provides a template for modeling burn severity. Landsat Thematic Mapper or Enhanced Thematic Mapper imagery band 4 and band 7 are used in a normalized ratio; then, the prefire NBR and postfire NBR are differenced to calculate the deltaNBR (Key and Benson, 2005). The method incorporates bands Showing substantial change from pre to postfire in a change detection algorithm with the objective of providing a clear distinction between burned and unburned areas while mapping burn severity as a gradient of values representing increasing degree of change on the burned landscape. The deltaNBR has been related to a field measure that represents a composite of effects across vertical strata of vegetation and soils (Key and Benson, 2005). We are using burn severity ratings and (or) fire-effects data (Kotliar and Haire, unpubl. data (USGS 2001); Omi and Martinson, 2002, unpubl. data) from several recent fires (Outlet, Pumpkin, Cerro Grande, Viveash) to determine the expected accuracy of severity maps that are derived using the deltaNBR alone (that is, without field data).

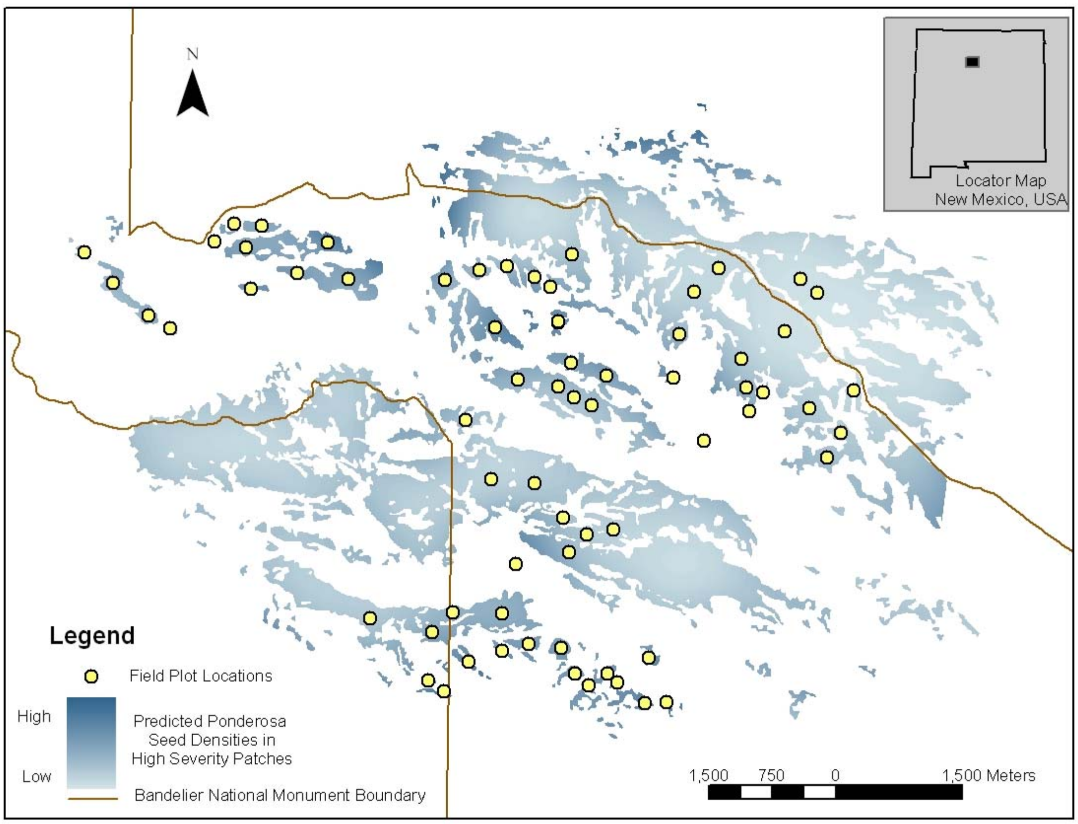

Figure 3. Sample plot locations at La Mesa (n = 68). Mesa del Rito (southwest) and areas near the Ponderosa Campground (north-central) were avoided due to known tree plantings after the fire. Two plots were located on Los Alamos Laboratory properties, with permission from the local authorities.

General Observations

The past year of work on the project has increased our enthusiasm for the original ideas in the proposal. Initial uncertainty regarding the availability of historical photographs, taken at the desired place and time, was replaced by excitement when we acquired the photographs and began to work out the protocols for severity mapping. Our field season, with all its logistical challenges, was endowed with extreme good luck in terms of weather (the monsoons only began in the last week), an amiable and compatible field crew, and equipment (GPS and palm pilots, especially) that got through the season without incident. We continually looked for verification and (or) problems with the burn severity maps as we hiked to the plots, but found only a few places where adjustments were needed. We often used the severity maps for navigation because the patterns of trees that survived the fire were clearly visible on the landscape. As expected, we observed a wide spectrum of vegetation communities in high-severity areas at both sites (see the Web site Photograph Gallery for a sample). Dense shrub communities with manzanita (*Archtostaphylos* spp.), oak (*Quercus* spp.), New Mexico locust (*Robinia neomexicana*), grassy meadows, and aspen (*Populus tremuloides*) with conifers in the understory/openings and ponderosa pine in varying densities and stages of growth were all represented in the suite of successional outcomes.

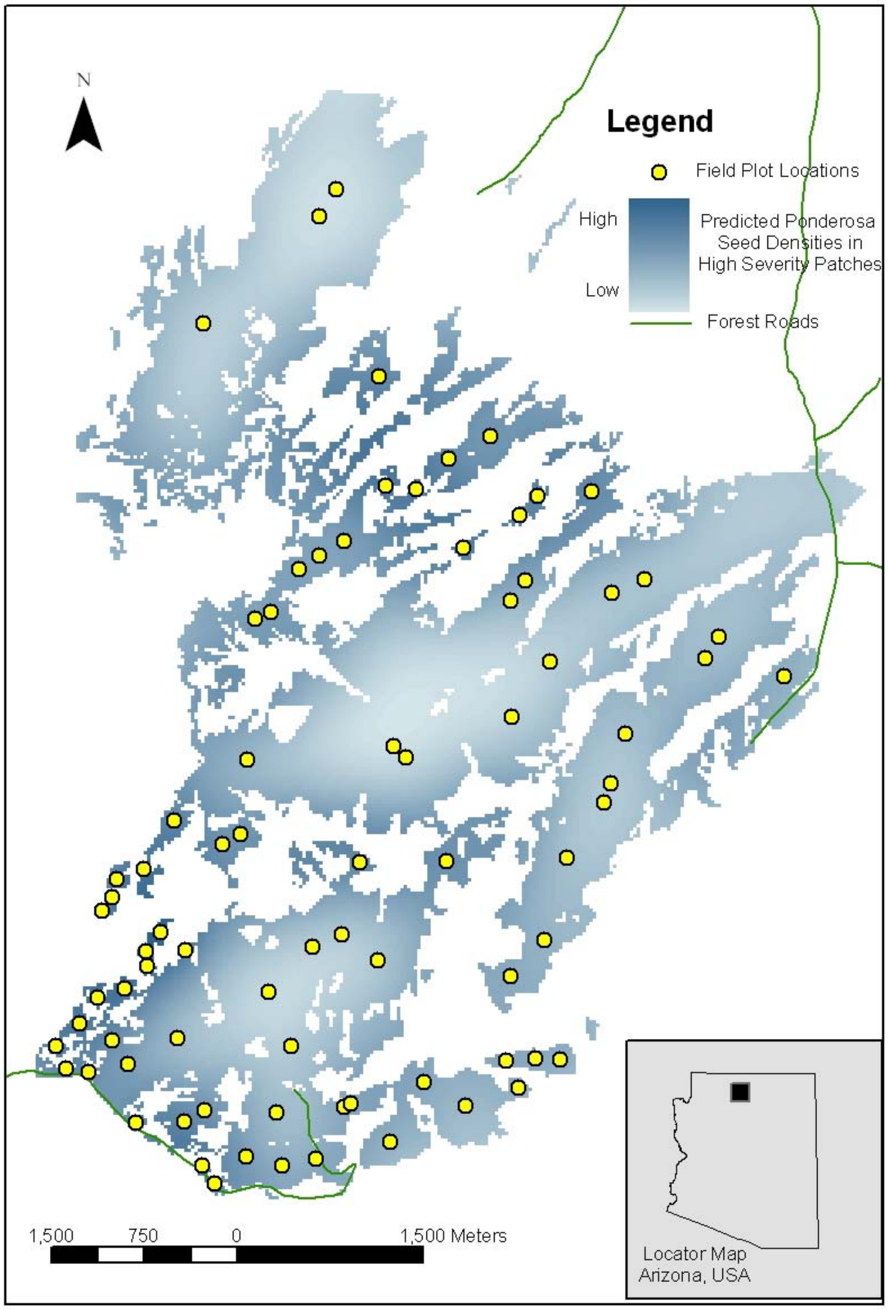

Figure 4. Sample plot locations at Saddle Mountain (*n* = 80). The plots were accessed by hiking from forest roads (primarily Road 8910 on the north and Road 610 on the south) that border the Saddle Mountain Wilderness.

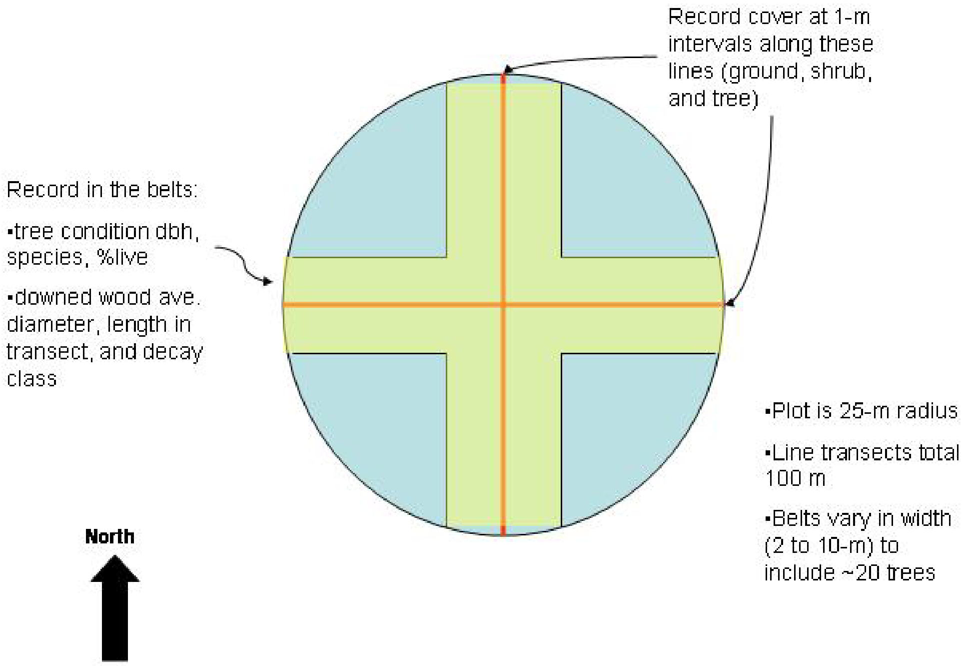

Figure 5. Diagram of plot layout. At each plot location, two 50-meter line transects were oriented in cardinal directions, and ground cover was recorded at 1-meter intervals. Tree and downed wood data were collected within in a belt varying in width from 2 to 10 m along the line transects. Photographs were taken, and physical characteristics of each plot were recorded at plot center.

Table 2. Burns in the older and newer timeframes from the three regions: Jemez, Gila, and Kaibab (including Grand Canyon North Rim).

Fire name	Region	Approximate size (ha, hectare)	Date	Status of mapping/comments
American Springs	Jemez	600	1954	Working with Los Alamos National Laboratory to obtain photographs.
Jerky #5	Gila	700	1956	Photographs acquired.
Lookout Canyon	Gila	2,400	1951	Photograph interpretation and mapping in progress.
Saddle Mountain	Kaibab	4,000	1960	Mapping complete (field site).
Little Creek	Gila	6,000	1951	Photographs acquired.
McKnight	Gila	16,000	1951	Photographs acquired; may be too large to complete.
La Mesa	Jemez	6,000	1977	Mapping complete (field site).
Oso	Jemez	2,000	1998	Landsat burn-severity map available.
Vista	Kaibab	1,500	2001	Landsat burn-severity map available.
Outlet	Kaibab	6,000	2000	Landsat burn-severity map available.
Pumpkin	Kaibab	3,500	2000	Landsat burn-severity map available.
Cerro Grande	Jemez	17,000	2000	Landsat burn-severity map available.
Dry Lakes	Gila	26,000	2003	Landsat burn-severity map available for this and other recent burns in the Gila Mountains.

Data Analysis and Products

We are in the process of determining the best ways to present the results of the project. Our current plans include several peer-reviewed publications, and we will maintain the project Web page as a way to distribute reports, photographs, and presentations, in addition to data products (for example, maps).

Here are a few ideas for working titles of manuscripts we hope to develop as the data analysis progresses:

1. "Plant community diversity decades after high-severity fire: Assessing conservation value." Possible journal outlet: *The Southwestern Naturalist*
2. "A characterization of plant communities relative to spatial patterns of high-severity fire in the Southwestern U.S." Possible journal outlet: *Forest Ecology and Management*
3. "Spatial patterns after high-severity fire and their implications for long-term successional changes at broad temporal and geographic scales." Possible journal outlet: *Landscape Ecology*
4. "A spatial model of ponderosa pine regeneration after high-severity fire." Possible journal outlet: *Conservation Biology*

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