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Historical and Current Fire Management Practices in Two Wilderness Areas in the Southwestern United States: The Saguaro Wilderness Area and the Gila-Aldo Leopold Wilderness Complex

Molly E. Hunter, Jose M. Iniguez, and Calvin A. Farris

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Abstract

Fire suppression has been the dominant fire management strategy in the West over the last century. However, managers of the Gila and Aldo Leopold Wilderness Complex in New Mexico and the Saguaro Wilderness Area in Arizona have allowed fire to play a more natural role for decades. This report summarizes the effects of these fire management practices on key resources, and documents common challenges in implementing these practices and lessons for how to address them. By updating historical fire atlases, we show how fire patterns have changed with adoption of new policy and practices.

Keywords: prescribed fire, managed wildfire, Southwest

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INTRODUCTION

Background, Purpose and Scope

Suppressing wildfires has been the dominant fire management strategy over most of the western United States for the last century. In forested systems adapted to frequent fire, this practice, in part, has resulted in contemporary forests with declining ecological conditions, large build-up of fuels, and increased potential for large, high-intensity and stand replacing wildfire (Covington and others 1994). However, in some areas managers have been able to adopt more flexible policies over the last few decades to allow fire to play a more natural role. Two of the most notable examples occur in the southwestern United States: the Gila and Aldo Leopold Wilderness Complex (GALWC) in the Gila National Forest (GNF) in New Mexico, and the Saguaro Wilderness Area (SWA) in Saguaro National Park (SNP) in Arizona (figure 1). Over the last 30 to 40 years, policies that facilitated the management of lightning and prescribed fires in these areas have resulted in the large-scale reintroduction of frequent fire as an ecological process. As a result, current forest conditions are strikingly different compared to long-unburned forests that can be found throughout the rest of Southwest.

Forest managers across the Southwest have long recognized the need to restore historical forest structure and reduce fuels following a century or more of fire exclusion. Mechanical treatments are often used to accomplish this goal in non-wilderness areas, but managers are increasingly relying on fire as a restoration tool for three main reasons: (1) the lack of a timber industry and local wood products manufacturing plants that can make mechanical treatments economically viable, (2) recent fire policy guidelines that now allow more flexibility in the use of fire, and (3) the need to work at landscape scales to effectively reduce the threat of large, high-intensity fires. Fire is often more efficient to implement than mechanical methods across large scales; the cost per acre of fire is typically lower and it is less restricted by access, topography, or legal challenges (Hunter and others 2007). Similar circumstances initially propelled the use of large-scale fires in wilderness areas within the GALWC and SWA. After several decades of fire management these two areas offer a wealth of knowledge that could aid managers who are now beginning to rely more on fire as a restoration tool in other forests throughout the western United States.

The purpose of this report is to document and synthesize the current and historical fire management practices in the GALWC and SWA, the effects of reintroduced fires on critical natural resources, and provide examples of how managers have addressed common challenges in implementing these fire programs. We culminate our findings with a discussion of key "lessons learned" from these unique programs. These lessons are broad concepts that are supported by the literature and conversations with managers and are applicable across both study areas. They represent what we have learned from these fire management programs that could be applicable to other areas where the practice of using fire as a restoration tool at landscape scales is in its infancy.

Figure 1—Location of the Saguaro Wilderness Area in Saguaro National Park (Arizona) and the Gila Aldo Leopold Wilderness Complex in the Gila National Forest (New Mexico).

Terminology

Terminology regarding the management of naturally ignited fire for restoration has changed numerous times since the practice was first adopted as official policy. When the policy was first implemented by a handful of National Park units in the late 1960s it was called a variety of things: "let burn," "natural prescribed fire," or "natural fire management" (van Wagtendonk, 2007). Over time, as policies were revised, the term "prescribed natural fire" took hold. A review and update of national fire policy in 1995 further reaffirmed the practice and introduced the term "wildland fire use for resource benefit," referred to as "wildland fire use" or often "fire use" (Philpot and others 1995).

The latest change in terminology came with the release of the 2009 Federal Interagency Implementation Guide (Fire Executive Council 2009). In the past, official policy distinguished three types of fire: wildland fire use, prescribed fire (intentionally ignited by managers), and wildfire (unwanted and suppressed fire). The most current guidelines recognized just two types of fire: wildfire and prescribed fire. This is an important distinction because under the former policy a fire resulting from a natural ignition had to be declared either a wildfire or "wildland fire use" and either suppressed or managed for resource objectives (but not both). With the new policy interpretation, a single wildfire can be managed for multiple objectives, allowing mangers to aggressively suppress areas of a fire where resources are threatened and apply minimal suppression strategies in areas where a fire is benefiting and/or posing minimal threat to key resources. A common terminology describing this practice has yet to be widely adopted and can include multiple labels, including, "minimal suppression," "contain," "confine," and "multiple objective fire."

For simplicity, throughout this report we use the term "managed wildfire" to describe all naturally ignited fires in GWALC and SWA that have been managed with a strategy other than full suppression. This would encompass any fires that in the past might have been labeled "prescribed natural fire," "wildland fire use," "multiple objective fire," or other related terms. Regardless of the specific terminologies used over time, these natural ignitions were managed with relatively similar overall strategies and objectives, and can be lumped into a single category. The term "prescribed fire" is used to describe any fire intentionally set by managers to meet specific resource objectives and "suppression fire" to describe any unwanted fire that was actively suppressed.

It should be noted that there is obviously overlap between managed, prescribed, and suppression fires. For example, a full suppression fire may involve indirect tactics such as utilizing natural barriers for safety. Conversely, managed wildfires often involve some level of direct suppression strategies such as line construction and firing operations to limit spread into undesirable areas or to manipulate fire intensity and effects (particularly in recent years due to more flexible policies). Moreover, some fires in the past started under one classification but were converted to another. For example, the 1994 lightning-ignited Rincon Fire in SWA was initially a "managed wildfire" (prescribed natural fire at that time) but was subsequently converted to full suppression fire when it burned outside of a specified area and acceptable fire behavior/weather parameters. Despite these ambiguities, this classification serves as a useful means of clarifying confusing terminology and examining how the use of fire has changed over time in the study areas.

METHODS

We used a combination of approaches to document and synthesize the historical role of fire and the effects of contemporary fire programs on critical resources in the GWALC and SWA. First, we conducted an extensive literature review of both peer-reviewed studies and grey literature regarding fire ecology and fire management practices in both study areas. Secondly, to identify challenges and keys to success in implementing the fire programs, we interviewed several managers (both current and retired) from a variety of disciplines in each study area. This included phone interviews, email discussions, and informal conversations on field trips and in other settings. Those interviewed represent over 200 years of cumulative fire management experience in these study areas; they provided invaluable insight into the challenges and processes of implementing innovative fire management strategies (see list of names in Appendix A). Results from that effort are documented throughout this report.

Third, to document the landscape scale patterns of fire occurrence over time resulting from changing management strategies, we updated previously published fire history atlases (Farris and others 2010; Rollins and others 2001) using data obtained from the National Park Service, The U.S. Forest Service, and the Monitoring Trends in Burn Severity database (www.mtbs.gov, last accessed 6/7/2013). Fire frequency maps encompassed the period from 1909 to 2013 at GALWC, and 1937 to 2013 at SWA, and included adjacent areas. Prescribed fires were not listed in the original fire history atlas for the GNF. However, using the Monitoring Trends in Burn Severity database (http://www.mtbs.gov/), we were able to update it to include prescribed fires over 1,000 acres in size that occurred after 1984. We also calculated cumulative area burned and proportion of area burned by each fire type (managed, prescribed, suppression) over time. In the SWA, this analysis was restricted to the greater Mica Mountain Study Area (MMSA). This area supports the primary coniferous forest belt in the wilderness, which has been the main focus of most managed and prescribed fires.

We conclude the report with some key "lessons learned" from the fire management programs in the GAWLC and SWA. These were the culmination of the work that went into producing this report (literature review, interviews with managers, and fire history analysis). The list of lessons learned is certainly not comprehensive, but it represents a set of recurring, core ideas that were conveyed independently by various managers across both of the study areas, and had strong support in the literature and in our own analyses. We chose lessons with multiple lines of corroboration, assuming that they would be more likely to be applicable across broad geographic areas, including non-wilderness, and potentially most useful where using fire as a large-scale restoration tool is at an earlier stage of development. We also present these lessons as a starting point in hopes that managers in other areas will add to them based on their own experience.

STUDY AREAS

Geography

The GALWC in central New Mexico encompasses 558,014 acres and is composed of two main mountain ranges (figure 2). The Mogollon Mountains dominate the western half of the study area. They rise to an elevation of 10,742 feet and fall abruptly toward the west and south and more gently toward east and north. The Black Range is a smaller range that runs south to north along the eastern part of the GALWC. These two main mountain ranges are the headwaters for the Gila River. Between them the land is dominated by steep canyons and large expansive mesas. The entire landscape was formed by volcanic activity in the Cretaceous Era (USGS 1965).

The SWA in southern Arizona is 70,905 acres and encompasses most of the Rincon Mountains, which are part of the Basin and Range Province that dominates the landscape across southern Arizona and the northern state of Sonora in Mexico. These mountain ranges were uplifted during the mid-Tertiary Era (Baisan 1990). The main mass of the Rincon Mountains is composed of granite gneiss although limestone outcrops can also be found throughout. The Rincon Mountains rise abruptly from the Sonoran Desert to an elevation of 8,432 feet above sea level. The two main physical features of the Rincon Mountains are two peaks, Mica Mountain and Rincon Peak to the south (figure 3). Mica Mountain

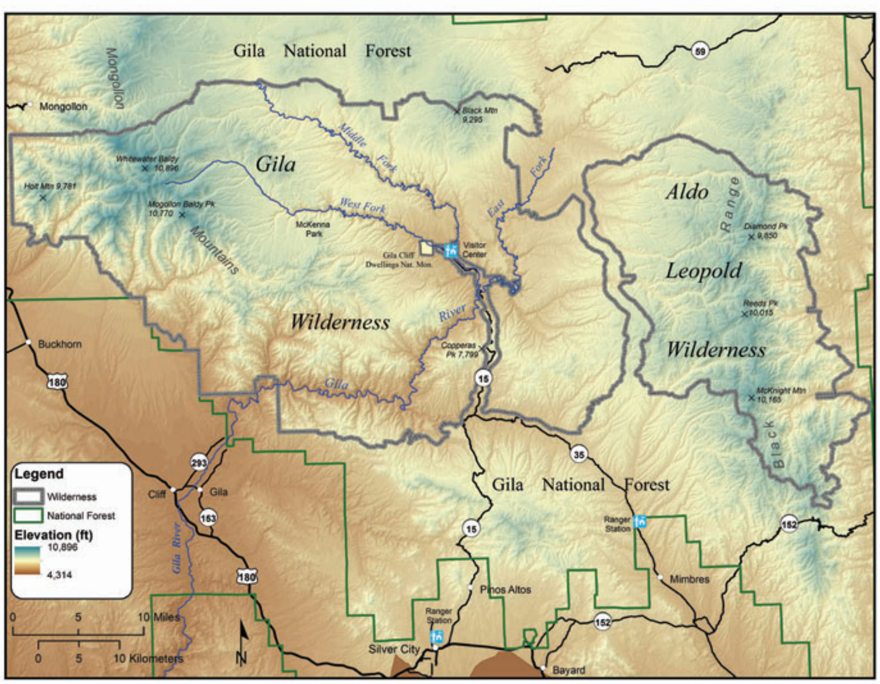

Figure 2—Detailed map of the Gila Aldo Leopold Wilderness Complex and surrounding lands in the Gila National Forest. The main physical features of the Gila Wilderness are the Mogollon Mountains in the northwest along with the three forks of the upper Gila River. The main physical feature of the Aldo Leopold Wilderness is the north-south running Black Range.

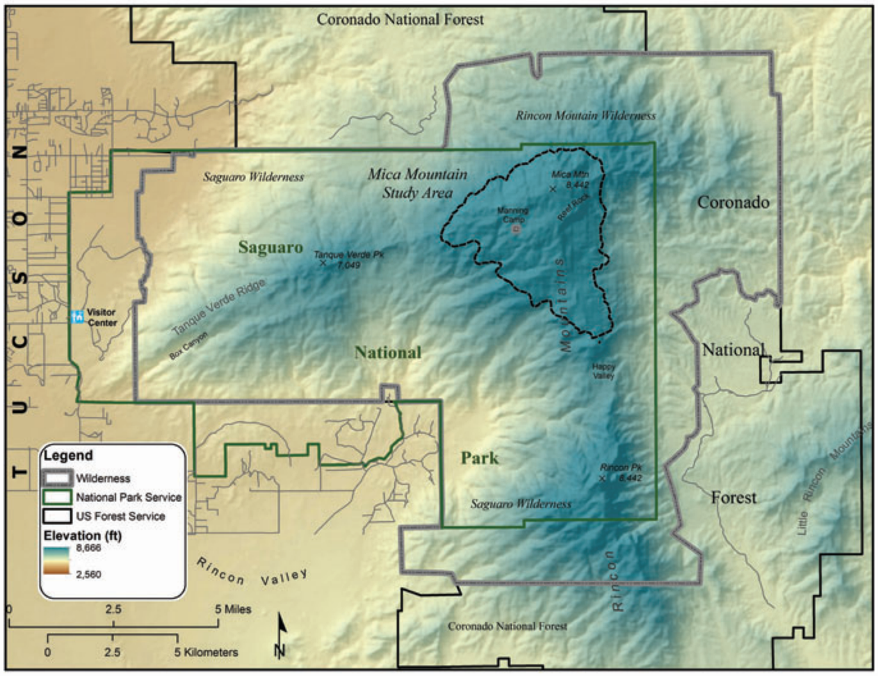

Figure 3—Detailed map of the Saguaro Wilderness Area in Saguaro National Park and the adjacent Rincon Mountain Wilderness Area in the Coronado National Forest. The outlined Mica Mountain Study Area represents a 6,870 acre area on Mica Mountain where the prescribed fire and managed wildfire program has been focused. It is also where most fire history studies have been conducted.

slopes gently along the top but drops off abruptly on three sides towards the desert. Rincon Peak is steeper and dissected. The two high points are connected by Happy Valley saddle, which supports a stand of ponderosa pine at 6,234 feet elevation (figure 4).

Both study areas have a seasonally bimodal precipitation pattern. In the winter (November to March), frontal storms bring snow to higher elevations and rain to the lower elevations. In the mid- to late-summer (July to August), moisture from Mexico creates a “monsoonal” weather pattern with thunderstorms. The arid “foresummer” period (April to June) preceding the “monsoonal” moisture is typically very hot and dry and is when most large fires burn. Annual precipitation varies greatly by elevation. In the GAWLC, averages range between 12 to 28 inches from roughly 4,500 to 11,000 feet in elevation. In the SWA, average annual precipitation ranges from about 13 inches at the base of Mica Mountain (~2,500 feet) to 27 inches at the summit (8,666 feet).

Both study areas represent very remote and inaccessible areas, making them ideal places to experiment with managed wildfire. While there are some towns on the outskirts of the GALWC and GNF (Silver City, New Mexico, and Reserve, New Mexico) and private inholdings throughout, the human population density in the region is relatively low. Although SWA and SNP is located next to a major metropolitan area (Tucson, Arizona), its rugged, roadless terrain, difficult access, and surrounding unburnable fuels (desert) resulted in functional isolation for fire management purposes (figure 5). While there are some historical structures and significant cultural sites in both study areas, there are

Figure 4—View from the top of Rincon Peak looking north across Happy Valley Saddle to Mica Mountain in the background (photograph by Michael Crimmins, University of Arizona).

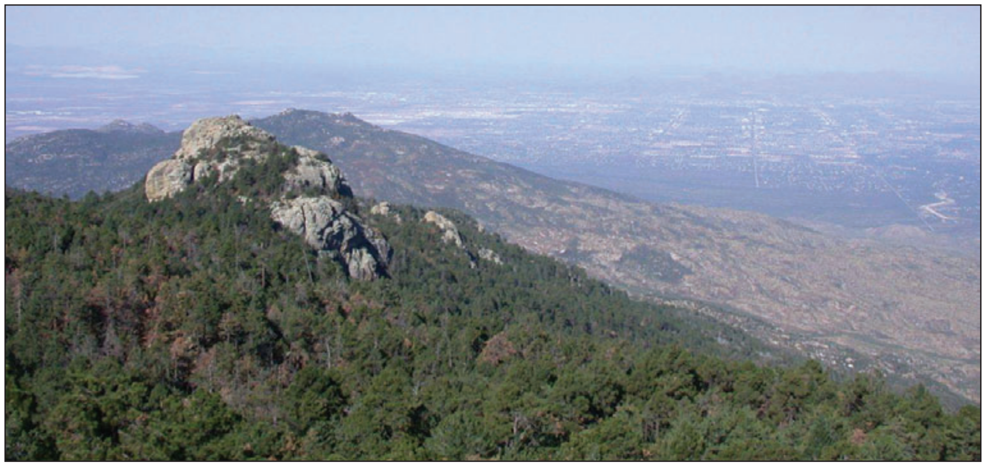

Figure 5—View of ponderosa pine and mixed conifer forests in the Mica Mountain Study Area (Helens Dome in foreground), looking west across desert vegetation and the city of Tucson Arizona in the background (photograph by Calvin Farris, National Park Service).

very few modern human developments directly adjacent to the wilderness areas.

Vegetation Communities

Both study areas are located at the junction of two major biomes. From the north there is a Rocky Mountain Cordillera influence and from the south there is a Madrean influence. The sharp vertical relief and unique geographic position of these mountains combine to create a diverse mosaic of vegetation assemblages stratified along elevation/moisture gradients (Niering and Lowe 1984). Plant communities at higher elevations (above 6,000 feet) are closely related to the Cordilleran/Rocky Mountain floristic province. Plant communities in lower elevations (below 6,000 feet) are primarily influenced by the Madrean floristic province (McLaughlin 1995). For the sake of simplicity, however, we have identified three broad vegetation communities that this report will focus on: pinyon-juniper woodlands, ponderosa pine forests, and mixed-conifer forests (figure 6).

Pinyon-juniper woodlands typically occur in areas below 6,500 feet elevation although they can also be found at higher elevations on drier south-facing aspects (figure 7). The dominant tree species within the pinyon-juniper plant community include alligator juniper (*Juniperus deppeana* Steud.), Rocky Mountain juniper (*Juniperus scopulorum* Sarg.), one-seed juniper (*Juniperus monosperma* (Engelm.)Sarg.), pinyon pine (*Pinus edulis* Engelm.) and border pinyon (*P. discolor* D.K. Bailey and Hawksw). Three general pinyon-juniper vegetation types have been identified across the western United States: persistent pinyon-juniper woodlands, pinyon-juniper savannas, and wooded shrublands (Romme and others 2009). The persistent woodland and wooded shrubland types are generally characterized as having higher tree and shrub density and lower grass cover in the understory compared to the savanna type. Both the persistent woodland and savanna types occur in the GNF, although the savanna type was historically much less prevalent (Miller 1999). Various pinyon and juniper species can be found at lower elevations in the pine/oak woodlands in SWA, which also includes a number of Madrean oak species.

Ponderosa pine forests are generally found at mid-elevations between 6,500 and 8,500 feet elevation (figure 8). The dominant tree species in these forests are ponderosa pine (*Pinus ponderosa* C. Lawson) and sometimes Gambel oak (*Quercus gambelii* Nutt.). In SWA, pine forests also includes Madrean species such as Apache pine (*Pinus engelmanii* Carr.), Chihuahua pine (*P. leiophylla* Schiede & Deppe), Arizona pine (*Pinus arizonica*), silverleaf oak (*Quercus hypoleucoides* A. Camus), Arizona white oak (*Q. arizonica* Sarg.), and Emery oak (*Q. emoryi* Torr.) (figure 9).

Mixed conifer forests are generally found between 8,500 and 10,000 feet elevation (figure 10). Common tree species within mixed conifer forests include Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Fanco), white fir (*Abies concolor* [Gord. & Glend.] Hildebr.), southwestern white pine (*Pinus strobiformis* Engelm.) quaking aspen (*populus tremuloides* Michx.) and ponderosa pine. Forest structure and composition generally changes dramatically along an elevation-temperature-moisture gradient between warmer, drier ponderosa pine and colder, wetter spruce-fir forest types. Mixed-conifer can be further separated into warm/dry and cool/moist subtypes that occupy each end, respectively, of the elevation-temperature-moisture gradient (Evans and others 2011) (figure 11). The cool/moist type occurs at the highest elevations but can also be found on north-facing aspects at lower elevations (figure 11a). The main distinguishing feature of this type is that although ponderosa pines maybe present they are not usually dominant. The warm/dry type occurs at the lower elevations or on south-facing slopes at higher elevations. This type can

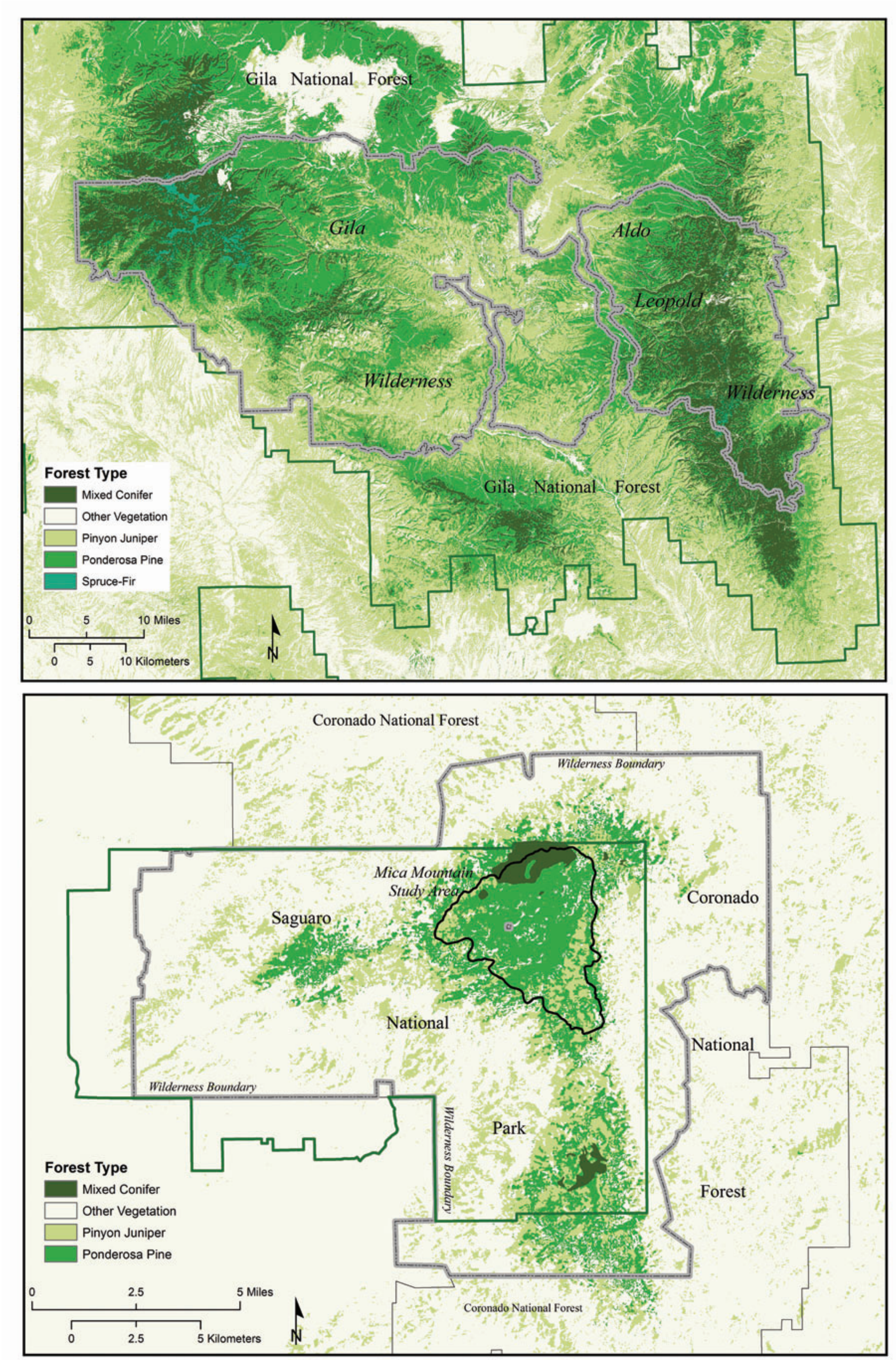

Figure 6—Maps of vegetation communities in (a) the Gila and Aldo Leopold Wilderness Complex and surrounding lands, and (b) Saguaro National Park. Vegetation categories are derived from Landfire Data (www.landfire.gov; last accessed 1/21/14).

Figure 7—Typical unburned pinyon-juniper vegetation in the Gila National Forest. This vegetation community tends to occur at lower elevation within these mountain ranges (photograph by Molly Hunter, Northern Arizona University).

Figure 8—Southwest ponderosa pine forest in the Gila National Forest. Although ponderosa pine can be found with other species at its lower and higher elevation limits, it often forms large stands or pure ponderosa pine. Historically, such stands were open and dominated by large trees due to frequent fires; however, due to logging and fire suppression, stands such as this one in the Gila wilderness are relatively rare in the Southwest (photograph by Jose Iniguez, USDA Forest Service).

Figure 9—Ponderosa pine forests in Saguaro National Park often include a number of Madrean oak species in the understory. Rincon Peak is in the background (photograph by Calvin Farris, National Park Service).

Figure 10—Mixed conifer forests are limited to a few isolated locations on north aspects in Saguaro National Park, but occur extensively across higher elevations in the GALWC. This scene is in the Mogollon Mountains taken prior to the 2012 Whitewater-Baldy fire that burned much of the landscape (photograph courtesy of USDA Forest Service).

Figure 11—Mixed conifer in the two study areas can be divided into (a) cool/moist and (b) warm/dry types. The cool/moist mixed conifer forests are distinguished by a general absence of ponderosa pine. The closed canopy and abundant coarse woody debris in the cool/moist mixed conifer forest make it ideal habitat for Mexican Spotted Owls (photographs by Calvin Farris, National Park Service).

contain the same mix of associated species as the cool/moist type but ponderosa pine is often still dominant or co-dominant (figure 11b).

Cultural History

The two study areas share many cultural history similarities. Prior to European settlement both areas were home to various Native American groups. The earliest known inhabitants in the greater GNF landscapes were the Mogollon culture. They were followed by the Pueblo Indian Cliff Dwellers who occupied the area in the 13th and 14th centuries and, like other native cultures, abruptly abandoned the areas for unknown reasons (Cordell 1997). In SNP the oldest known inhabitants to the general area were the Hohokam who, as farmers, mainly occupied the desert valley bottoms near reliable water sources. By the 13th century, the Apaches began migrating to the Southwest from northern regions. Unlike prior inhabitants of the Southwest, the Apaches primarily hunted and gathered and thus utilized both valley bottoms as well as upland forested areas.

Spanish settlers began moving into the Southwest in the 16th and 17th centuries (Clemensen 1987). Early Spanish explorers were mainly interested in finding gold and silver. By the 1600s, settlements developed around mining camps near what is now the GNF and around missions near the Rincon Mountains. These activities had a great impact on the land in the form of timber harvesting, which was needed both for construction and fuel. However, significant impacts were mostly confined to areas in close proximity to settlements. Moreover, through the 1800s the presence of

Apache groups restricted Euro-American settlement in and around high elevation forests (Bigelow 1968). By 1856 both the Gila and the Rincon Mountains became part of the United States territory. Around the same time, the area saw the arrival of the railroad in 1880 and the capture of the last Apaches (Bigelow 1968). These two events allowed greater Euro-American settlement and brought about significant ecological changes throughout southwestern forests (Cooper 1961; Weaver 1951).

By the close of the 19th century, both areas had been declared part of the National Forest Reserve system and off limits to new settlement. By 1906 they became part of the newly created National Forest system. In 1924, due to the efforts of many including Aldo Leopold, the Gila Wilderness was set aside and became the first wilderness areas in the world (Roth 1990). In 1933 the Rincon Mountains were taken out of the National Forest system and designated a National Monument (Clemensen 1987). By 1976 the Saguaro Wilderness Area and the Gila Wilderness Area were officially designated with the passage of the Wilderness Act. The Aldo Leopold Wilderness Area was designated in 1980; in 1994 Saguaro was named the 52nd National Park.

HISTORY OF FIRE REGIMES AND MANAGEMENT

With an abundance of ignition sources, receptive fuels, and frequent intra- and inter-annual drought, forested landscapes in the Southwest are some of the most fire-prone in the United States. These two study areas are no exception, yet fire occurrence has fluctuated a great deal over the past 120 years due to human influences. Thus, we divided the discussion of fire history in our study areas according to major human-caused changes in the fire regime. The *Pre-Euro-American Settlement Era* includes years prior to 1900, which is approximately when the arrival of Euro-Americans dramatically changed the role of fire in these landscapes. The *Fire Exclusion Era* encompasses the period of about 1900 to 1970 when fire was virtually eliminated from the landscape due to fire suppression and land use changes (heavy grazing, logging, etc.). The *Fire Management Era* begins around 1970 and continues into the beginning of the 21st century. This represents the time when fires were reintroduced through prescribed fire and managed wildfire. We end the discussion with the present day as we enter the *Megafire Era* in the Southwest. This time period is characterized by the increasing incidence of large and intense wildfires concurrent with rising global temperatures and intensifying drought conditions (Stephens and others 2014; Westerling and others 2006).

Pre-Euro-American Settlement Era (Prior to 1900)

Prior to Euro-American settlement, the fire regime in each of these landscapes varied by vegetation type, reflecting the significant differences in rates of fuel accumulation and fire-season length. Within the pinyon-juniper woodlands, live and dead fuels accumulate relatively slowly due to limited moisture and high temperatures. Fire history studies in these woodlands in both SWA and the GALWC are lacking, but inferences can be made from studies in pinyon-juniper woodlands throughout the Southwest. Although the fire season is relatively long and ignitions are plentiful, widespread fires were likely infrequent historically. That is, the mean fire interval (MFI), or the average number of years between fires, was likely greater than 100 years due to slow rates of plant growth and the discontinuous nature of fuels (Romme and others 2009). When fires did occur, most were likely either very small (impacting one or a few trees) and with variable intensity, or large (several hundred acres) high-intensity crown fires. More frequent, low intensity fires likely occurred in some juniper savannahs or woodlands that supported a dense and continuous grass fuel bed on the order of every 20 to 30 years (Margolis 2014).

Mid elevation pine forests have relatively high rates of fuels accumulation and a long fire season. Thus, they historically supported a fire regime dominated by frequent, low-severity surface fires prior to the 20th century. In the MMSA in SWA for example, Farris and others (2013) found that the Natural Fire Rotation (NFR), or the time required on average to burn an area equivalent to size the entire study area, during the 19th century was only 10 years. Between 1630 and 1900, a large fire (at least 25 percent of the study area) burned somewhere within MMSA every 7 to 8 years, on average (Baisan and Swetnam 1990; Farris and others 2013). The MFI within small stands or groups of stands ranged from 6 to 13 years in the GALWC prior to Euro-American settlement (Swetnam and Baisan 1996) (table 1). Fires of this frequency would have mainly consumed surface fuels and had relatively minimal impacts on the overstory. Most fires in both study areas occurred during the hot, dry arid foresummer between May and early July, prior to the onset of "monsoonal" moisture moving into the region (Abolt 1997; Baisan and Swetnam 1990).

Table 1: Summary of published pre-20th century Mean Fire Return Intervals (MFI) in the Gila wilderness and Mica Mountain study areas (MMSA). Vegetation type sampled includes ponderosa pine (PIPO), mixed conifer (MC), and spruce-fir (SF). For blank values, the statistic either was not reported or not applicable because of stand size.

Vegetation	Elevation (feet)	Fire-scar samples	Area (acres)	MFI_{all}	$MFI_{10\%}$	$MFI_{25\%}$	Time period
			——Gila Wilderness——				
PIPO/MC[a]	8,400-9,290	27	~740	3.0	5.8	13.1	1700-1900
PIPO[a]	8,300	10	~110	4.5	8.3	8.7	1700-1900
PIPO[a]	7,600-7,800	12	~860	3.5	6.3	6.9	1700-1900
PP[b]	7,810	18	590	5.1	5.5	8.4	1700-1900
MC/PIPO	8,640	1	n/a	10.8	—	—	1700-1900
MC[b]	10,100	9	50	12	—	—	1700-1900
MC/PIPO[b]	8,690	16	60	7	—	—	1700-1900
MC[b]	8,860	4	32	15	—	—	1700-1900
SF/MC[b]	9,510	4	7	42	—	—	1700-1900
MC[b]	9,020	6	10	8	—	—	1700-1900
			——Mica Mountain——				
PIPO[c]	8,304	4	3[d]	7.3[e]	—	—	1631-1900
PIPO[c]	8,055	7	6[d]	6.7[e]	—	—	1631-1900
PIPO[c]	8,219	4	3[d]	6.9[e]	—	—	1631-1900
MC[c]	8,241	4	6[d]	9.9[e]	—	—	1631-1900
PIPO/MC[a]	7,005-8,488	12 sites	6,870[g]	—	6.1	7.3	1631-1900
PIPO/MC[f]	7,005-8,488	60 sites	6,870[g]	—	6.2	8.0	1800-1900

[a] From Swetnam and Baisan 1996.
[b] From Abolt 1997.
[c] From Baisan and Swetnam 1990.
[d] Approximate size of area individual trees were sampled from; estimated from maps in Baisan 1990.
[e] Only includes intervals between fires that scarred more than one tree at a collection site.
[f] From Farris et al. 2013.
[g] Size of the entire MMSA study area.

Fuels also accumulate at relatively rapid rates in the mixed conifer forests, but the length of the fire season is shorter compared to ponderosa pine forests because snow can remain on the ground into the early summer months. Historical fire regimes in mixed conifer forests were highly variable ranging from relatively frequent low-severity surface fires in transition areas between pine and mixed conifer forests to infrequent high severity fires at higher elevations where mixed conifer forests transitions to spruce-fir. The extent of mixed conifer forests in the SWA is limited, covering less than 400 acres. These stands are generally found adjacent to pine forest but in cooler north-facing slopes and ravines and historically experienced surface fires of variable intensity at 15- to 30-year intervals (Baisan 1990; Iniguez and others 2009). In the GALWC, similar dry mixed conifer forests experienced a fire every 13 years on average (table 1), although individual intervals ranged between 3 and 30 years at the stand level (Abolt 1997; Baisan and Swetnam 1990).

Although absent in the SWA, the GAWLC, also contains the wet/cool mixed conifer type on north-facing aspects that transition into spruce-fir forests. Winter snowpack tends to persist well into the summer in these forests and they are also the first to receive the summer rains, resulting in a relatively short fire season. As a result, these forests tended to experience relatively infrequent (every 30 to 400 years), mostly high severity fires (Abolt 1997; Margolis and others 2011). Although fires likely ignited somewhere on these landscapes on an annual basis, in most years fuels would have been too wet to support fire spread and fires would burn only a few acres. During very dry years, however, the wetter mixed conifer sites would support large stand-replacing fires of 500 to 1,200 acres in size (Margolis and others 2011).

Widespread fires across ponderosa pine and mixed conifer forests tended to be synchronized with inter-annual climate cycles that controlled broad-scale patterns of fuel production and drying (Swetnam and Baisan 1996). In the GALWC for example, Swetnam and Baisan (2003) identified at least 26 widespread fire years between 1605 and 1904 across a gradient of elevation and vegetation ranging from ponderosa pine to spruce-fir. Not surprisingly, most years with widespread fires were drier than average and most years with small fires were wetter than average. A closer examination of fire-climate relations reveals important lagging relationships during the years preceding fires: most of the largest fire years occurred during a drought year that was preceded by 1 to 3 years of significantly wetter/cooler conditions. These wet periods resulted in an abundance of fine fuels (especially grasses) across the landscape and set the stage for extensive fires when the next dry year occurred. Small fire years were preceded by relatively dry years that inhibited build-up of grasses and needles. These lagging relationships were weaker or absent in cool/wet mixed conifer forests dominated by woody fuels where drying was the most important factor (Swetnam and Baisan 1996, 2003).

Fire Exclusion Era (1900-1970)

The cultural changes brought about by the arrival of Euro-Americans at the end of the 19th century significantly altered the natural fire regime and ecology of these landscapes. After 1910, total annual area burned decreased dramatically in both the SWA and GALWC. For example, despite high rates of 20th century burning compared to other pine-dominated forests in the West, the NFR in the MMSA increased from 10 years in the 19th century to 31 years for the period 1937 to 2013 (Farris 2009; updated using data described in the methods section). A similar pattern occurred in GALWC fire history datasets (Swetnam and Baisan 1996). This was probably due to a number of factors but mainly the influx of intensive livestock grazing with the arrival of the railroad. Another contributing factor was that these areas were now under management of the U.S. Forest Service and active fire suppression was encouraged. The great numbers of livestock that moved into the Southwest with the establishment of the railroad significantly decreased grass cover and subsequently limited the capacity of the landscape to sustain frequent, low intensity fires (Cooper 1961; Weaver 1951). Furthermore, organized fire suppression began around 1910, and became increasingly effective with the use of mechanized equipment and aircraft in the 1940s and 1950s (Pyne 1997).

During this Era, however, fire exclusion was certainly not ubiquitous across these landscapes; their relative remoteness and rugged terrain sometimes limited effective fire suppression. In particular, starting in the late 1940s and 1950s both areas saw the return

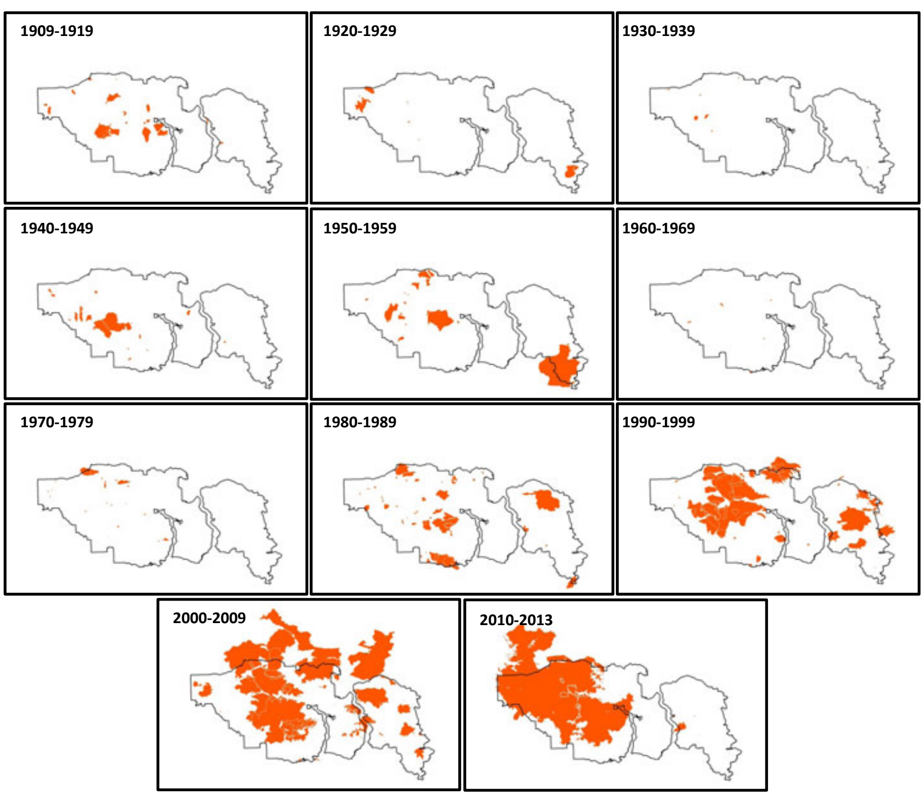

Figure 12—Decadal fire perimeters for the Gila and Aldo Leopold Wilderness Complex and vicinity. Fire perimeters include managed and suppression fires for the entire period in addition to prescribed fires adjacent to the wilderness areas after 1984. Only fires that intersected wilderness lands are shown.

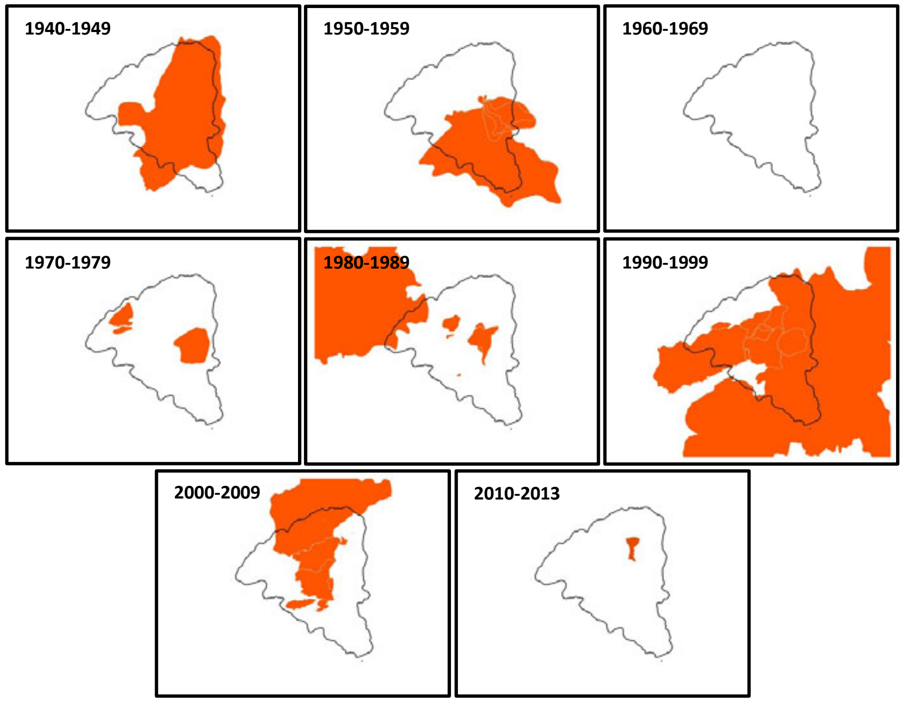

Figure 13—Decadal fire perimeters in the Mica Mountain study area and vicinity. Fire perimeters include managed wildfire, suppression wildfire, and prescribed fires. Only fires that intersected wilderness lands are shown.

of some relatively large fires (figures 12 and 13). In the SWA, the first major fire in 1943 burned approximately 4,500 acres and by 1959 almost 8,000 acres had burned in total. What is particularly notable is that the major fires on Mica Mountain during this Era overlapped spatially, resulting in numerous reburns within a relatively short amount of time (figures 13). In the GALWC, several large fires occurred in the 1950s, including the McKnight Fire in 1951, which burned over 48,000 acres in the southern end of the Black Range. Although these were large fires compared to earlier decades in the Era, they were not as large as the frequent fires that burned across these landscapes prior to 1900. Still, between 1909 and 1969, a total of 134,000 acres burned in the GALWC; by 1970, approximately 25 percent of the wilderness area had experienced at least one fire since 1900 (figure 14). These mid-century fires reduced accumulated fuels and reduced tree densities, thereby making it more feasible to initiate managed wildfire programs in the 1970s (figure 15).

Managed Fire Era (1970 – 2010)

The managed wildfire program in SWA began in 1971 following the development of a fire management plan approving the practice. It was the second national park in the country to adopt such a policy. Managed wildfire was first officially implemented in the Gila Wilderness in 1975 (Boucher and Moody 1998). The initial fire management plans, which were relatively conservative and simple by today's standards, described several

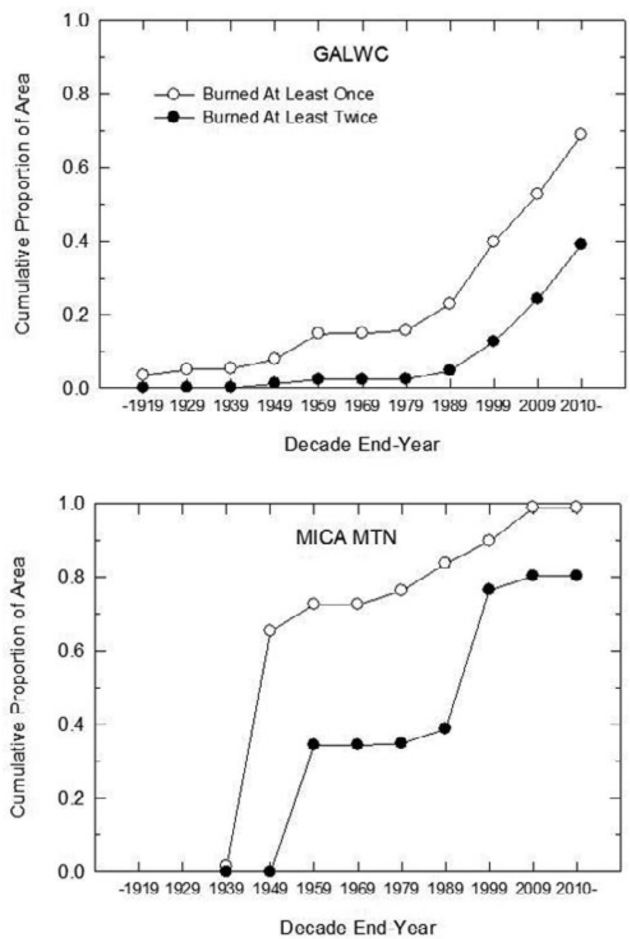

Figure 14—Cumulative proportion of area burned at least once and at least twice over time in the Gila Aldo Leopold Wilderness Complex (GALWC) and Mica Mountain Study Area (MICA MTN). Data include all fire types.

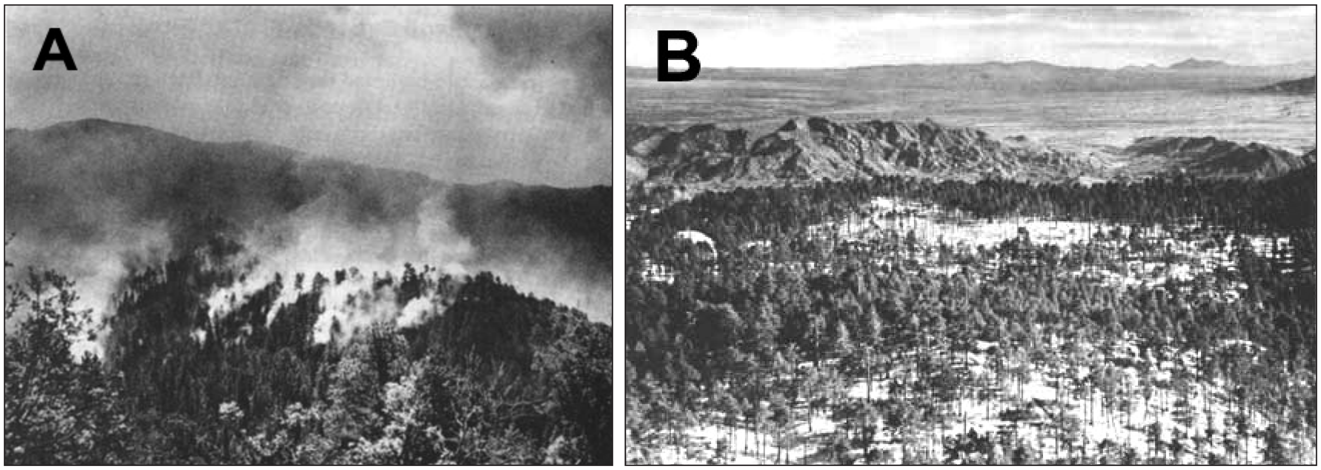

Figure 15—Evidence and legacy of mid-1900s fires. Despite aggressive fire suppression policies, several fires still grew large in the Saguaro Wilderness Area and Gila Wilderness in the mid-1900s. Panel (a) shows a major fire burning in the Gila Wilderness in 1951. Panel (b) shows the effects of a 1943 wildfire near Mica Mountain in the Saguaro Wilderness (photo taken before 1957) (photographs courtesy of: (a) the Forest History Society, Durham, N.C., and (b) the National Park Service (from Dodge 1957)).

conditions required to consider managing a wildfire, such as specific calendar dates and a range of values for fire danger indices under which a wildfire could be managed. Additionally, early fire management plans in SNP highlighted the need for prescribed fire in the wilderness area to reduce fuels. With mechanical thinning not being an option in the Park or in wilderness areas, it was thought that prescribed fire in strategic locations would eventually allow for more use of managed wildfire. Prescribed fire was first implemented in the Park in 1984. Conversely, prescribed fire has not been implemented within the GALWC (although prescribed burning has occurred along the borders outside the wilderness), and managers have instead relied on natural ignitions to achieve their objectives.

Because the programs were initially conservative with respect to allowable burning conditions, acreage burned by managed wildfire and prescribed fire was modest in the early years (~1970-1990) (figure 16 and 17). From 1970 to 1989, a combination of all fires in the GALWC covered a total of 88,805 acres, 90 percent of those acres burned between 1985 and 1989

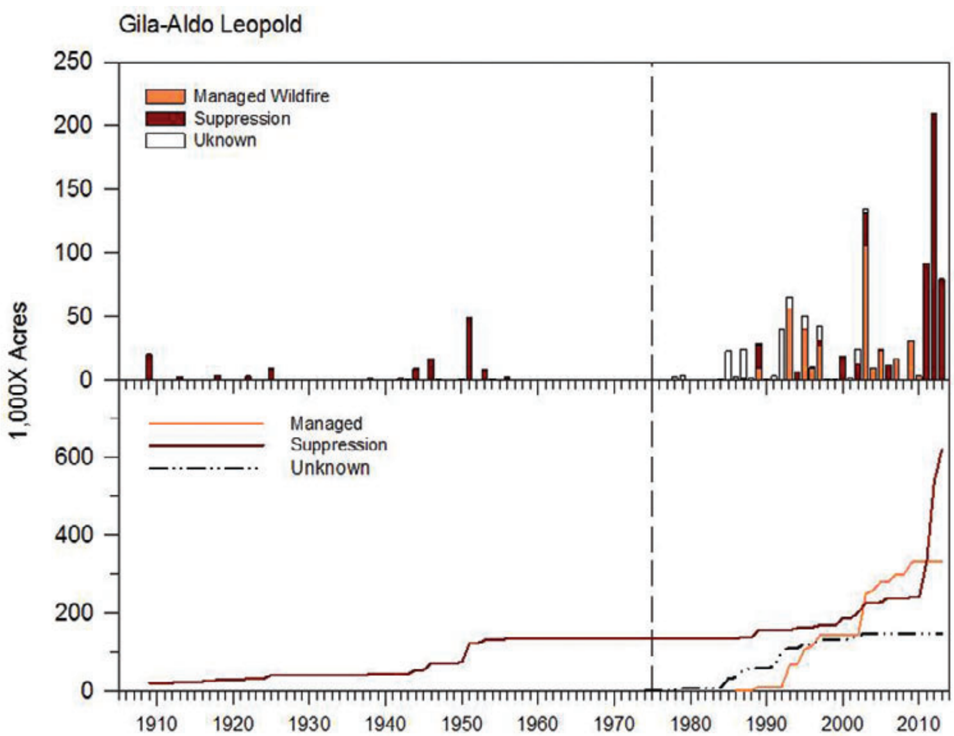

Figure 16—Area burned per year in the Gila and Aldo Leopold Wilderness Complex since 1909. The top panel shows annual area burned, and the bottom panel shows cumulative area burned in managed wildfires, suppression fires, and fires of "unknown" status (fires in which there was no information available in the database). Vertical dashed line indicates first year of managed wildfire in 1975. Prescribed fires have not occurred within these wilderness areas. The graph includes only fires greater than 100 acres.

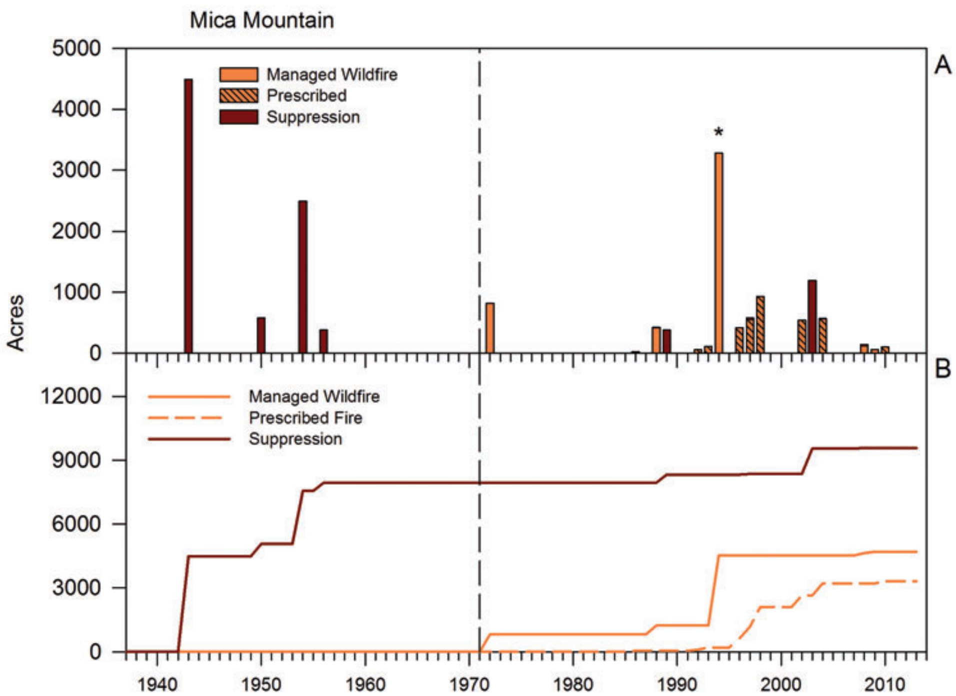

Figure 17—Area burned per year in the Mica Mountain Study Area of Saguaro National Park since 1940. The top panel shows annual area burned, and the bottom panel shows cumulative area burned in managed wildfires, prescribed fires and suppression fires. Vertical dashed line indicates first year of managed wildfire in 1972. The graph includes only fires greater than 100 acres. *The 1994 Rincon Fire was initially a managed wildfire, but was converted to a suppression fire after it spread toward the Park boundaries.

(figure 12). The largest managed fire during this period was the 1989 Shelley Fire that burned over 10,000 acres mostly within the wilderness boundary. Between 1971 and 1989, several managed wildfires occurred in the SWA, but the vast majority were relatively small (figure 17). The two exceptions were managed wildfires in 1972 and 1988 that burned 820 and 420 acres, respectively on Mica Mountain. These fires were particularly important because they reburned areas east of Reef Rock that had already experienced four overlapping fires in the 1940s and 1950s, and which would burn again multiple times in the future (figure 18). Additionally, the 1989 Chiva Fire was a suppression fire that started on Forest Service land but burned nearly 400 acres on Mica Mountain. In total more than 1,600 acres burned on in the SWA between 1971 and 1989.

Large increases in prescribed fire and managed wildfire in both wilderness areas were not realized until the early 1990s and high rates of burning continued into the early 21st century. There are numerous reasons that this pattern developed. By 1998, policy and fire management plans were updated to allow for managed wildfire outside of wilderness areas in the GNF and managers began utilizing managed wildfire in other parts of the GNF, mostly in the Black Range Ranger District. Increased Federal investment in fuels treatments and fire management in general, including the adoption of the National Fire Plan (2000) in the early 2000s, gave both units greater capacity to manage both

Figure 18—View of the east side of Reef Rock on Mica Mountain in the Saguaro Wilderness showing a small lightning fire that was suppressed in 2007. The relatively open forest structure of ponderosa pine forests in the foreground reflects the influence of 5 to 9 repeated fires in this area since 1943 (photograph courtesy of the National Park Service).

wildfire and prescribed fire. This included more funding for planning and implementing prescribed fire and access to Fire Use Modules (teams of fire professionals who specialized in implementing managed wildfire). Greater investment in prescribed fire ultimately provided more opportunities to utilized managed wildfire. For example, the Indian Peaks project in the GNF, in which 40,000 acres were treated with prescribed fire between 1999 and 2006, is seen as playing a pivotal role in allowing for the expansion of managed wildfire outside of the wilderness area in the Black Range. Prescribed fires on Mica Mountain in the SWA played similar roles. In addition, the accumulated experience with managed wildfire over decades allowed the organizations overall to be more comfortable and accepting of the practice.

In the GALWC, more than 219,000 acres burned between 1990 and 1999 with over 60 percent of these acres burning as part of managed fires. By the end of the 1990s more than 40 percent of the area within the GALWC had burned at least once since 1910 and more than 20 percent had burned multiple times (figure 14).

The new millennium brought even more fire and the increase in area burned can be summarized in three distinct types of fires. The first type was a continuation of managed wildfires inside the wilderness area, the largest of which was the 2003 Dry Lakes Fire Complex that burned nearly 114,000 acres. The second fire type was large managed wildfires outside the wilderness. Examples of such fires include the 2005 Black Range Complex (74,274 acres), 2005 Fork fire (14,869 acres), and the 2007 HL fire (10,784 acres). The third fire type was large-scale prescribed fires outside the wilderness. The largest of these fires was the 2003 Boiler fire (56,695 acres) that burned in pine forests just north of the Aldo Leopold wilderness. As in prior decades, there were also a small number of fires that burned within high elevation mixed-conifer forests.

Patterns of severity of these fires varied, but fires in ponderosa pine forests tended to burn mostly with low severity while fires in mixed conifer forests tended to include more areas of high severity. For example, the 1992 Creel fire (17,240 acres), 1993 Brush fire (39,348 acres), 1993 Iron fire (5,825 acres) and 1997 Lilly fire (18,507 acres) all burned in ponderosa pine forest within the Gila wilderness and included less than 4 percent high severity within their perimeters (Iniguez 2014). These fires contained occasional patches of crown fire that created treeless patches as large as 300 acres. On the other hand the 1995 Bonner fire (26,380 acres) and the 1996 Lookout fire (14,200 acres) contained 18 percent and 11 percent high severity, respectively. These latter fires burned in higher elevation mixed-conifer forests; hence the mixed severity fire pattern was likely similar to historical fires in this landscape.

In the SWA, a total of 5,374 acres burned on Mica Mountain between 1990 and 1999 (figure 17). More than half of this total was from the 1994 Rincon Fire (3,281 acres) that was initially a managed wildfire; it was later converted to a suppression fire when it exceeded resource capabilities and burned toward U.S. Forest Service lands where management options were more limited. While most acreage occurred in suppression status, we classified it as a managed fire for the purpose of this report because it would have been suppressed at <1 acre had policy not been in place to allow lightning fires to burn. The rest of the acreage burned during this period was from prescribed fires, most of which were implemented in areas that had been burned in the prior decades. By the end of the decade nearly 80 percent of the MMSA had burned at least two times since 1937 (figures 14). From 2000 to 2010 a total of 2,500 acres had burned on Mica Mountain, of which about half was in the form of managed wildfires and the other half as suppression fires. The largest of the suppression fires was the Helens II fire in 2003, which burned mainly on the north slope of Mica Mountain through mixed conifer stands that had not burned during the last century.

Beginning in the mid- to late-2000s, a number of factors resulted in a decline in acreage burned in managed wildfire and prescribed fire in both the GAWLC and SWA (figure 16 and 17). This was driven in part by growing concern for the potential negative impacts of managed wildfire on valued resources, particularly under persistent drought conditions. Several suppression, managed, and prescribed fires during this period resulted in undesirable effects on habitat and populations of listed or sensitive species, including the Mexican spotted owl (*Strix occidntalis lucida* Nelson), the lowland leopard frog (*Lithobates yavapaiensis* Platz and Frost 1984), and the Gila trout (*Oncorhynchus gilea* (Miller)). In addition, some fires across the greater SWA spread into lower elevations in vegetation types not well adapted to fire; several saguaro cacti (*Carnegiea gigantean* (Engelm.) Britton & Rose), an iconic species and the namesake of the Park, were burned, along with other Sonoran desert species. There was also increasing concern about the spread of invasive grasses in the Sonoran desert, which might further encourage fire spread. In the GNF, there was growing concern for the impacts of fire on livestock range that was being impacted by severe drought. The capacity to implement prescribed fire in remote areas had also

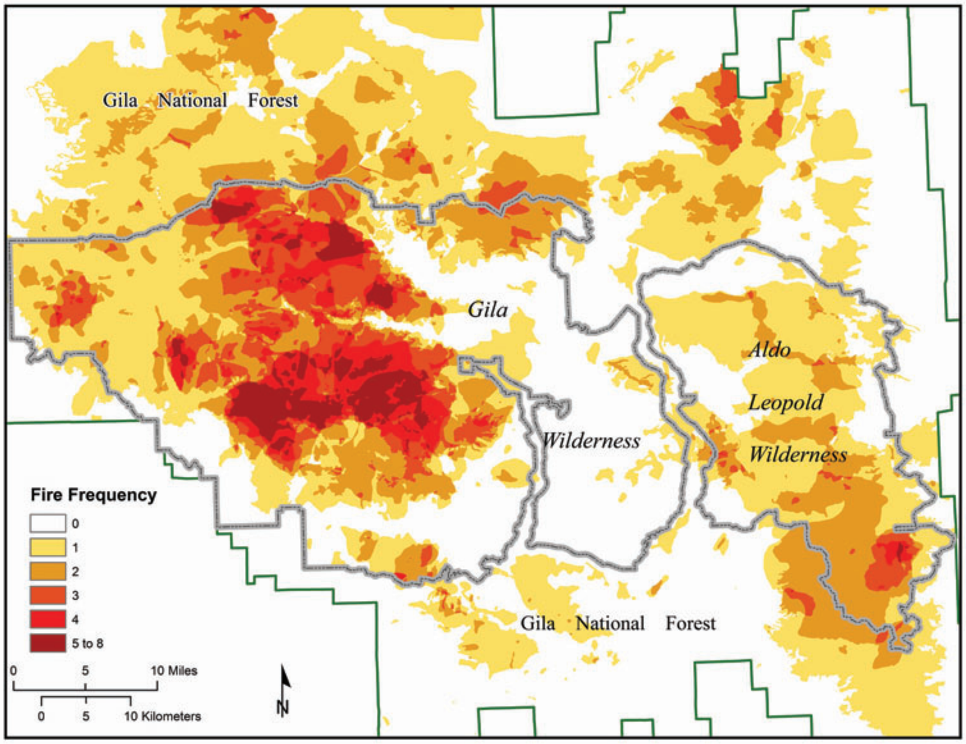

Figure 19—Fire frequency in the Gila Aldo Leopold Wilderness Complex from 1909 to 2013. Most of the pine and mixed conifer forest in the GALWC have burned at least once; hence, most of the unburned areas are dominated by pinyon-juniper. Some areas in the interior of these two wilderness areas have burned as many as eight times since 1909.

declined substantially toward the end of the 2000s; the cost of such projects had increased dramatically over the years and agencies directed most funds for fuels treatments to areas near the wildland urban interface. The last prescribed fire conducted in SWA was the 2010 Mica Mountain prescribed fire. Only 114 acres of the 423-acre project area were burned because conditions became too dry, yet the burn cost approximately $300,000. Finally, managers in both study areas had found difficulty in expanding managed wildfire and prescribed fire programs to the "hard acres," the steeper terrain and mixed conifer forests with heavy fuel loading where fires have greater potential to burn severely and have detrimental impacts to critical resources. Such areas comprised most of the remaining long-unburned areas by the beginning of the 21st century.

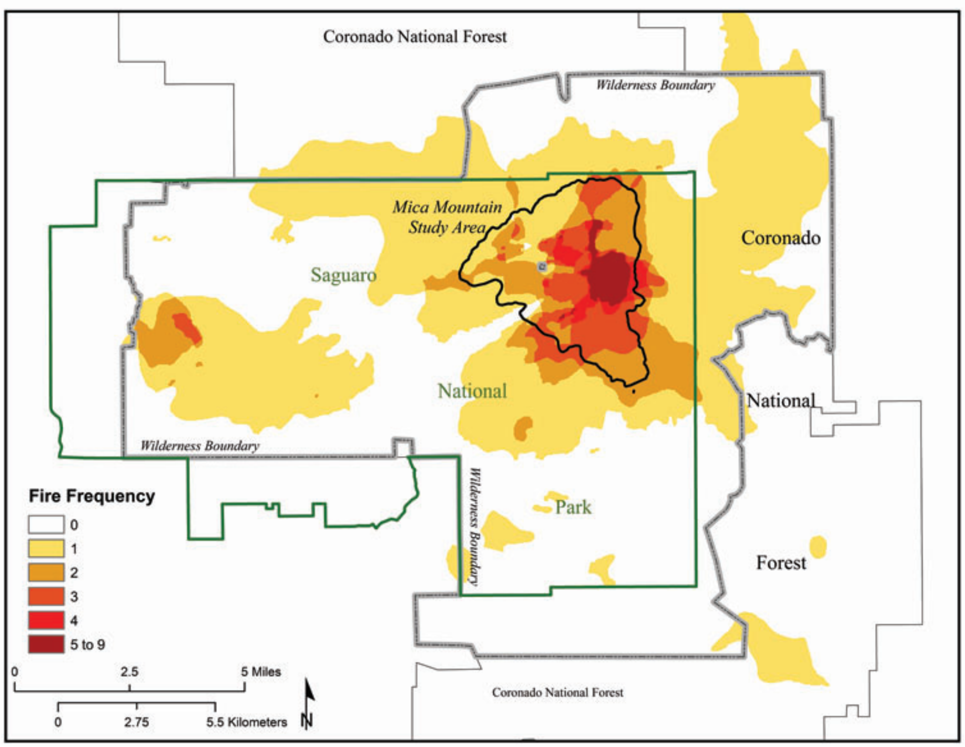

Figure 20—Fire frequency in the Saguaro Wilderness Area in Saguaro National Park from 1937 to 2013. Most of the area within the Mica mountain study areas has burned at least one and some areas have burned as many as nine times since 1900.

Figure 21—View from Rincon Peak looking west toward the X-9 Ranch development. The steep terrain, accumulated fuels, and neighboring developments hamper fire managements in the Rincon Peak portion of Saguaro National park (photograph by Jose Iniguez, USDA Forest Service).

Despite the successful reintroduction of prescribed fire and managed wildfire during this Era, there remain many areas within the SWA and the GALWC that have not burned in a century or more (figures 19 and 20). The most notable in the SWA includes much of the area on Rincon Peak, which historically had fewer natural ignitions and slightly longer fire return intervals than Mica Mountain, and has had no prescribed fire (Iniguez and others 2009). More conservative approaches to fire management (suppressing more natural ignitions) on Rincon Peak have been taken in part because limited access and heavy fuels provide few options for managers to prevent fires from spreading to neighboring private property (figure 21). In addition, there has been resistance from resource staff in managing fires in Rincon Peak where there are sensitive resources, such as spotted owl populations. By 2010, long-unburned areas in the GALWC included the upper elevation mixed conifer, aspen, and spruce-fir forests in the Mogollon Range, which by the end of the 20th century, still hadn't burned in over 100 years. Managers often attempted to utilize managed wildfire in these areas, but when lightning fires occurred they often burned during the monsoon season and remained small before going out on their own. Many wildfires were also suppressed in this system because of concerns about detrimental fire effects on Gila trout and Mexican spotted owl habitat. In addition, unlike at the SNP, fire managers have not utilized prescribed fire within the GNF wilderness area. Thus, mixed conifer forests have experienced relatively low rates of contemporary burning and may be more susceptible to larger, high intensity fires compared to what these forests would have experienced historically.

Megafire Era (2011 – present)

Very large and severe fires (~100,000+ acres) are projected to occur more frequently in the western United States as the climate becomes warmer and drier (Dillon and others 2012; Westerling and others 2006). There is overwhelming evidence that many types of fuels treatments can be effective in mitigating the severity of wildfires (Fulé and others 2012). However, the degree to which fuels treatments (including managed wildfire and prescribed fire) will be effective in making forests more resilient to wildfire under future climates remains an open question and an important topic in need of additional research (see Appendix B). After more than a quarter century of reintroducing wildland fire in the GALWC, this landscape has been "tested" by a series of large wildfires since 2011. These fires have highlighted the benefits and potential limitations of the managed and prescribed fire program under relatively warm and dry climatic conditions. In particular, the 2011 Miller Fire (88,835 acres), the 2012 Whitewater Baldy Complex (297,845 acres, currently the largest wildfire in New Mexico State history), and the 2013 Silver Fire (133,625 acres) burned during severe and prolonged drought conditions through forests previously treated with prescribed fire and managed wildfire and through long-unburned forests.

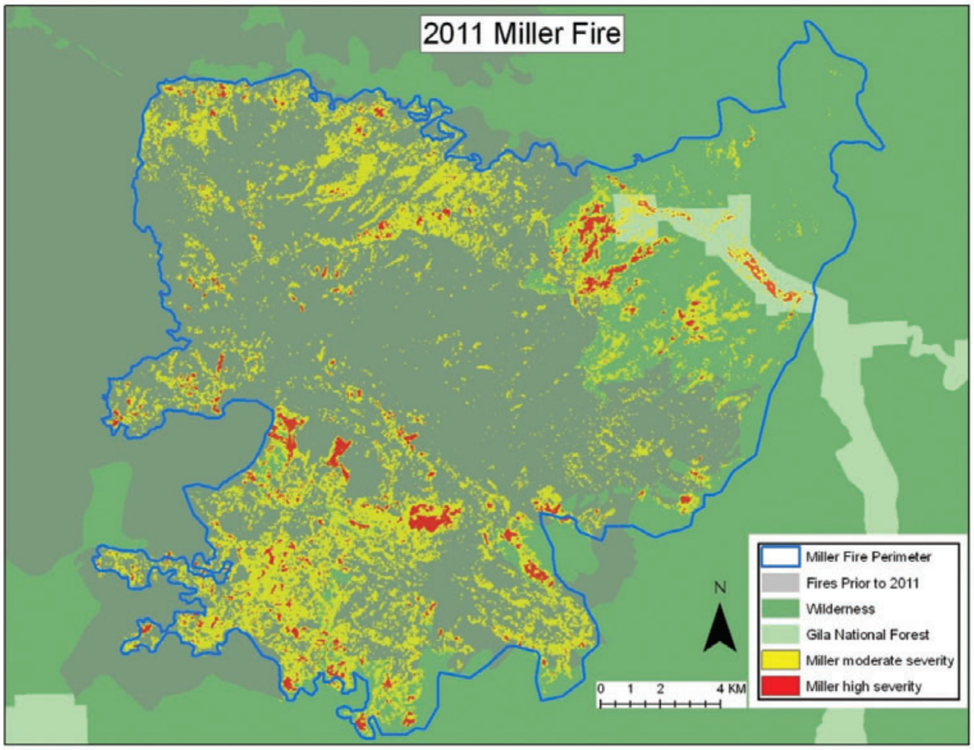

Figure 22—Map showing fire history and severity of the 2011 Miller Fire in the Gila National Forest. Most of the fire was low to moderate severity particularly within areas that had burned prior to 2011. Some of the areas that did experience high severity fires were pinyon-juniper stands that had not burned in the last century. Fire severity was derived from the Monitoring Trends in Burn Severity database (http://www.mtbs.gov/).

One thing that is evident from these fires is that the landscape mosaic created by previous prescribed, managed, and suppression fires provided options and opportunities to firefighters during suppression operations and that without that fire history, these suppression fires would have been much larger and more severe. For example, the spread of the Whitewater Baldy Complex (WWBC) was halted on the northeast by the 2006 Bear Fire and on the south by the Miller Fire. Firefighters were able to stop advancement to the north at the Eckleberger prescribed fire project area, an 18,000-acre burn on the Reserve Ranger District. Fewer resources were devoted to suppression on the eastern flank of the WWBC when it spread into Iron Creek Mesa, Jerky Mountain, and Lilly Mountain, where the WWBC was the third or fourth fire in the last 3 decades and was burning with low intensity. Similarly, the Silver Fire burned through previous fires with both low and high intensity, but it slowed and stopped to the north when it reached previous managed and suppression fires. The onset of "monsoon" conditions also helped stop the Silver Fire from spreading further.

Managed wildfire and prescribed fire can increase the resiliency of these forests to wildfire, even under severe drought conditions. In maps that overlay fire history and burn severity (figures 22 and 23), one can see that most of the areas that had previously experienced managed wildfire reburned with low to moderate severity in the Miller Fire and the WWBC. Overall, more than 64,000 of the 88,000 acres burned in the Miller Fire experienced at least one fire in the previous few decades. Most of the area classified as high severity had not burned in over a century; this included pinyon-juniper woodlands, pine stringers, and riparian areas that burned as the Miller Fire approached the West Fork of the Gila River. The WWBC and Silver Fire resulted in severe effects mostly in upper elevation mixed conifer forests that were also long unburned.

While the history of fires clearly impacted the spread and intensity of these suppression fires, it is also evident that previous fires were not always effective in mitigating fire severity. From the fire history and burn severity maps, it is clear that some areas classified as high severity had burned previously in managed wildfire (figures 22 and 23). Moreover, managers mentioned that all these fires seemed to result in fairly high tree mortality even as it passed through previously burned forests (figure 24). It is unclear, however, if the tree mortality is directly related to fire intensity, drought, or perhaps a combination of the two. Ultimately, the effects of subsequent fires likely depends on a large number of factors: how a fire burns into a stand, terrain and landscape context, fraction of total landscape treated, daily weather, seasonal drought, and fire management operations and tactics. More research into these and other factors that contributed to the high severity patches in these fires would further shed light on

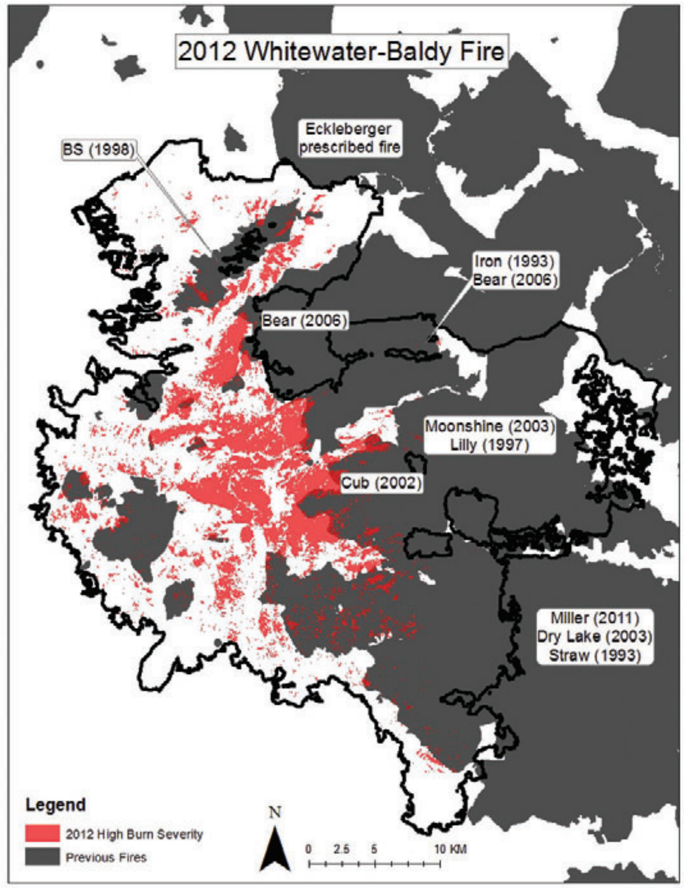

Figure 23—Map showing fire history and severity of the 2012 Whitewater Baldy Complex in the Gila National Forest. Fire severity was derived from the Monitoring Trends in Burn Severity database (http://www.mtbs.gov/).

Figure 24—Aerial view of the 2011 Miller fire burning mostly as a low intensity wildfire within forested areas. The Miller fire also burned within and around non-forested patches (yellow/grass) created by prior more severe fires including the 2000 Bloodgood Fire and the 2003 Dry Lakes Complex. Patches of previous severe fires are now dominated by standing snags and grasses (photograph by U.S. Forest Service).

the benefits and limitations of managed and prescribed fire under a changing climate (see Appendix B).

The fire program in SWA has not been recently tested in the same manner, because total area burned has been very low over the past several years. We speculate that a similar pattern might emerge should a fire start under severe drought conditions. In the areas where previous prescribed fires and managed wildfires have occurred, subsequent fires should be more likely to spread with lower intensity compared to long-unburned areas. However, unlike the GAWLC where burned area is increasing, about 10 years has passed since the last major fire in SWA. Given that prescribed burning has also declined substantially in the Park, it remains unclear if resource management objectives will continue to be maintained in this landscape in the future with managed wildfires alone.

EFFECTS OF MANGED WILDFIRE AND PRESCRIBED FIRE

Over the last several decades, many research and monitoring studies have been conducted in these study areas in an attempt to understand the effectiveness of managed wildfire and prescribed fire in meeting management objectives and the effects of the practices on critical resources. This section summarizes what has been reported in the literature and sheds light on areas in need of further research (see Appendix B). Much of the existing literature focuses on the effects of these practices on (a) fuels, forest structure, and potential fire behavior, and (b) wildlife populations and habitat.

Fuels, Forest Structure, and Potential Fire Behavior

The effects of reintroduced fire on fuels, forest structure, and potential fire behavior vary by vegetation type and historical fire regime. For example, widespread low intensity fires would likely have occurred every 10 to 30 years in juniper savannas (Margolis 2014). These areas have declined during the 20th century as a result of grazing and fire suppression. However, pinyon-juniper woodlands historically made up a much greater portion of the landscape (Miller 1999). In the woodlands, fires historically either burned very small areas (1-2 trees) or burned large areas as crown fires. This also appears to be how managed wildfires currently behave in this system (figure 25). In two recent wildfires in the GNF (2006 Martinez and 2005 Johnson Fires), pinyon-juniper woodlands mostly burned as high intensity crown fires with almost complete overstory mortality (Hunter and others 2011). Even in pinyon-juniper woodlands that were classified as low severity in burn severity maps, often no evidence of fire was detected or if it was, it appeared that the fire impacted only 1 to 2 trees and logs in their immediate vicinity (Molly Hunter, personal observation of 2006 Martinez and 2005 Johnson Fires). Broadcast burning is not a common practice in these woodlands because fuels are generally not conducive to fire spread. Indeed, fire managers in the GNF often use pinyon-juniper woodlands as fuel breaks to slow or stop fire during prescribed fire and managed wildfire operations (Toby Richards, personal communication). However, recent wildfires have shown that many of these woodlands will support high intensity crown fire following a century of fire exclusion. While such fires may not be outside of the historical range of variability of fire behavior, it is unclear what the post-fire successional trajectories will be under current or future climates. Pinyon-juniper woodlands in other parts of the Southwest have shown the potential for novel successional trajectories due to spread of invasive species (Floyd and others 2006) and widespread mortality overstory induced by climate change (Breshears and others 2005).

The severity of managed wildfire and prescribed fire in ponderosa pine forests has tended to be more moderate. Studies in both the GWALC and SWA have shown that managed and prescribed fires were effective at reducing surface fuels and density of small trees while

Figure 25—High severity burn in pinyon-juniper woodlands in the 2011 Miller Fire. Many of these woodlands tend to burn during periods of high winds and drought resulting in higher severity fires (photograph by Jose Iniguez, USDA Forest Service).

Figure 26—Many ponderosa pine stands that have burned one or more times have more heterogeneous, open stand structures with lower densities of small trees. Stands such as this one in the Gila Wilderness should now exhibit a reduced probability of high severity fires in near future (photograph by Jose Iniguez, USDA Forest Service).

maintaining large trees (Holden and others 2007; Hunter and others 2011) (figure 26). This has resulted in stands that more closely resemble historical forest structure and are at lower risk of stand-replacing crown fire (Holden and others 2010; Hunter and others 2011). Areas that have previously burned in managed wildfires in the GAWLC tended to reburn with lower severity compared to previously unburned areas (Parks and others 2014). Furthermore, the cited studies show that those conditions can be effectively maintained after multiple managed wildfires have impacted an area (figure 27). One study showed that managed wildfire is slightly more effective

Figure 27—Open pine forests in the (a) Gila-Aldo Leopold, and (b) Saguaro Wilderness following multiple surface fires. Open forests in Iron Creek Mesa in the Gila Wilderness have experienced three surface fires since 1970 (1985, 2003, and 2012) including burning most recently in the 2012 Whitewater-Baldy fire. In Mica Mountain, this ponderosa pine stand (b) did not burn between 1893 and 1942, but has since burned six times (two wildfires and four prescribed fires). Following a large increase in tree density during the fire exclusion gap in the early 1900s, the post-1942 fires significantly reduced tree density and increased structural diversity and understory herbaceous cover (photographs by Jose Iniguez, USDA Forest Service (a) and Calvin Farris, National Park Service (b)).

than prescribed fire at reducing fuels and potential fire behavior (Hunter and others 2011). However, this study focused on first entry prescribed fires, which managers tend to ignite with cooler prescriptions to minimize detrimental effects and improve control. While no study has specifically examined the effects of multi-entry prescribed fire, managers in both areas are confident that they have achieved fuels objectives with repeated prescribed fire (figure 28).

Managed wildfires have been much less common in mixed conifer forests; when they have burned, they have tended to burn with higher severity compared to pine forests (Holden and others 2010). This may not be inconsistent with the historical fire regime, especially in the wetter, cooler mixed conifer types (Margolis and others 2011). In general, studies on the effects of prescribed fire and managed wildfire in mixed conifer forests in these areas are lacking in this region. However, Fulé and others (2004) found that a high intensity prescribed fire in mixed conifer forests in Grand Canyon National Park effectively reduced tree density and produced forest structures more closely resembling historical conditions. While studies on the effects of prescribed fire and managed wildfire on fuels, forest structure, and potential fire behavior have been studied in other parts of the country (for example, California), more studies in the Southwest are clearly needed (see Appendix B).

Figure 28—Examples of managed and prescribed fires in the Gila National Forest and Saguaro National Park. The 2002 Cub Fire (a) is an example of a managed fire in the Gila National Forest. Panel (b) shows a ponderosa pine stand near the summit of Mica Mountain immediately following a prescribed burn in 2010. The burn was conducted as a maintenance burn in an area that had experienced four previous fires since 1943 (photographs by the U.S. Forest Service (a) and National Park Service (b)).

Threatened, Endangered, and Sensitive Species

In the last few decades, several local populations of the threatened Gila trout in the GALWC have been extirpated as a result of ash and debris flows following wildfires with large high severity patches on steep slopes (figure 29). Some examples include the 1989 Divide Fire, the 1995 Bonner Fire, the 1996 Lookout Fire and more recent wildfires (Brown and others 2001). Many populations of the Gila trout are geographically isolated, and opportunities for the fish to seek refuge and reestablish in recovered habitat after fires are limited. This has been exacerbated by low water levels during drought conditions. Thus, it has become common practice for fish to be removed from impacted streams when possible, and reintroduced when the habitat improves (Wood and Racher 2010). While widespread severe wildfire is known to be detrimental to the species, low intensity managed and prescribed fire may actually make Gila trout populations more resilient, especially if these fires result in reduced fuel loading and reduced risk of stand replacing wildfires in the future (Brown and others. 2001).

Aquatic Habitat and Species

Fires have also impacted aquatic species and habitat in the SWA. There are few perennial water sources in the SWA, and aquatic species rely in part on tinajas, or ephemeral pools that form in bedrock depressions. The lowland leopard frog, classified as a species of concern by the Arizona Game and Fish Department, is one of the species that relies on these pools (figure 30). Several tinajas filled with ash and sediment following the 1999 Box Canyon Fire and the 1989 Chiva Fire (Parker 2006). While water and frogs returned to some pools after a few years, some pools remained filled with sediment for up to 20 years. Severe fires have the greatest long-lasting impact on stream dynamics, sedimentation, and frog habitat. Thus there is concern that should fire spread through long-unburned portions of the SWA where fuel loading is uncharacteristically high, there could be further impacts on lowland leopard frog habitat.

Figure 29—The Gila trout is an endangered species found in streams within the Gila National Forest and is threatened by high intensity wildfire (photograph by R.C. Helbock, New Mexico Department of Game and Fish).

Figure 30—The lowland leopard frog is listed as a species of concern by the State of Arizona and is found in Saguaro National Park. The perennial pools that supply their habitat can fill with sediment following wildfire, but habitat and frogs have been found to return to some effected areas (photograph by Jim Rorabaugh, U.S. Fish and Wildlife Service).

Mexican Spotted Owl

The threatened Mexican spotted owl is adapted to fire-prone forests and uses a variety of forest conditions for feeding, nesting, etc. (figure 31). However, they rely particularly on closed forests with complex structure for nesting (USFWS 2012). These critical habitats exist both in pine forests within canyons and in denser mixed conifer forests. In the past, both managers and researchers have debated about using prescribed fire to reduce fuel loads within nesting areas as there was concern that fire could diminish key habitat features. However, some reduction in fuel loading is often desirable because stand replacing fires are seen as one of the biggest threats to the species (USFWS 2012). Extensive surveys have shown that low intensity prescribed fire

Figure 31—The threatened Mexican spotted owl is found in pine/oak and mixed conifer forests in both the Gila National Forest and Saguaro National Park. In some instances, managers have been successful in allowing spread of prescribed fire and managed wildfire in their habitat with minimal to beneficial effects. In other instances, managed wildfire and suppression fires have been detrimental to their habitat (photograph by Bill Radke, U.S. Fish and Wildlife Service).

and managed wildfire have minimal short-term impact on Mexican spotted owl occupancy or reproduction (Jenness and others 2004). However, several recent wildfires, such as the 2002 Helen's II Fire in the SWA and the 2012 Whitewater-Baldy Complex in the GNF have burned severely in core owl habitat, particularly in mixed conifer forests (figure 32). Mexican spotted owls have high site fidelity so they will likely return to these sites particularly if patches of live forest remain (Willey 1998). However, there are fears because of low prey productivity and increased temperatures that the habitat will not be used by subsequent generation of Mexican spotted owl.

Wildlife Habitat and Populations

The fire programs in SNP and the GNF have had mostly positive or neutral impacts on non-listed wildlife species and their habitat. In the past, there have been concerns that frequent fire might deplete the snag population, which is a critical habitat feature for many wildlife species (Boucher and others 2000). Despite a decline in snag densities following a moderately intense fire in the Santa Catalina Mountains, they remained sufficient for wildlife habitat and bird populations remained stable (Ganey and others 1996). Snag densities also remained within recommended guidelines in areas that have burned multiple times in managed wildfire in the GALWC (Holden and others 2006).

There is also evidence that some species in particular have benefited from managed wildfire programs. For example, the buff-breasted flycatcher (*Empidonax fulvifrons*) is common in Mexico but its numbers declined in the mountains of southern Arizona and New Mexico starting in the late 1800s; some research suggests that fire exclusion may be partly responsible for the trend. Surveys have found the buff-breasted flycatcher associated with areas that recently burned in surface fire in the Rincon Mountains while they were not found on other mountain ranges in the region that had little to no evidence of recent fire (Conway and Kirkpatrick 2007). In addition, abundance of many other forest birds found in southwestern mountain ranges has been found to be higher in recently burned areas (Kirkpatrick and others 2006).

Figure 32—High severity burn patches following the 2002 Helens 2 Fire on the north slope of Mica Mountain. Historically, widespread fires burned across these north-slope warm/dry mixed conifer forests every 10-20 years prior to 1886, but the area did not burn between 1886 and 2002. The north slope of Mica Mountain was habitat for Mexican spotted owls. Although the fire severity was relatively heterogeneous, the long term impacts on the owl habitat are still unknown (photograph by National Park Service).

CURENT CHALLENGES TO IMPLEMENTING MANAGED WILDFIRE

Their relative remoteness, inaccessibility, and history of frequent fire makes both of these study areas ideal for using fire as a restoration tool across broad landscapes. However, managers in both study areas still faced significant challenges managing wildfire and implementing large scale prescribed fire over the several decades of these programs. These challenges, which would likely be faced in other parts of the Southwest and the country, are described briefly here. In addition, we give examples of how managers in these study areas have worked to overcome these challenges.

Threatened and Endangered Species

There are several threatened and endangered species within SNP and the GNF that could be impacted by wildfire or prescribed fire: Mexican spotted owl, the lowland leopard frog, the Gila trout, and other species. Fire managers need to consider how their actions will affect these species. Managers often need to alter fire management practices during prescribed fire and managed wildfire to reduce potential threats to such species. Changed strategies and tactics could include altering the timing or intensity of fire, or restricting fire all together in sensitive areas. Managers in the GNF and SNP have overcome some of these challenges in particular by collaborating across disciplines and implementing rigorous monitoring programs.

Managers in the GNF for example have been successful in allowing fire to spread through Mexican spotted owl nesting habitat in pine forests with minimal and even beneficial effects to the species. In other parts of the Southwest, the default management strategy has been to avoid these areas altogether, which may ultimately be detrimental to the species if their core habitat cannot be made resilient to wildfire. The success in the GNF is partly attributed to collaboration between the fire staff and the natural resource staff that work closely together and recognize the importance of meeting objectives for both fuels and wildlife. Before every fire season both fire and non-fire personnel participate in a meeting where they strategize about where they might allow for managed wildfire in the upcoming fire season. Because of this close working relationship, fire managers understand what kind of fire and effects are desirable in sensitive areas and they can help achieve those effects. As a result, fire managers can make more informed decision on where, when, and how to manage fires.

SNP has invested a great deal in long-term monitoring to document the effects of fire on habitat and populations of lowland leopard frog to better understand the short- and long-term effects of fire on the species. Through these efforts, they have learned that leopard frog habitat can be severely degraded in the years following a high intensity wildfire and populations can subsequently disappear (Parker 2006). However, after several years frog populations have returned to some affected watersheds, indicating that refuge areas exist within the landscapes. Ultimately the monitoring results have provided further justification for the managed wildfire program; it has shown that fire management practices have likely increased resilience of frog populations in the long run.

Public Support for Fire Programs

Public support for fire programs is vital for their long-term success and there are many factors that can influence public opinion. For example, the public may not be supportive of fire programs if the inevitable smoke significantly impacts populated areas. However, the public is more likely to tolerate smoke if they recognize the benefits of less severe fires in the future. Other unintended consequences of prescribed fire and managed wildfire, such as escapes or impacts to recreation areas, can also influence public support. While some impacts to the public from fire are inevitable, minimizing impacts, engaging the public, and communicating the importance of fire can increase public support. Maintaining an active fire program is also important.

Managers in both study areas have invested a great deal in public outreach, which ultimately has increased public acceptance of prescribed fire and managed wildfire programs. Managers in both study areas take a variety of outreach approaches ranging from interpretive signs, putting information officers at visitor centers or other public venues, maintaining detailed websites to inform the public about individual incidents and the overall fire programs, and conducting educational programs in schools. They also work directly with local media outlets, which is why one can often find well-informed and thoughtful stories on the fire ecology and management of the areas in both local and national publications. It is critical to devote resources to public outreach year round and to frame different messages at different times (before, during and after fires). Maintaining an active fire program is also important;

having fire on the landscape each season (whether prescribed fire or managed wildfire) allows residents in the area to become accustomed to their effects, including smoke. A survey of local ranchers living near the GNF showed that many of these efforts have paid off; over two-thirds of respondents were supportive of the efforts of the GNF to manage wildfires and prescribed fires (Doug Boykin, personal communication).

Risk of Escape

There is always the potential for managed fires to spread beyond designated planning areas and impact sensitive resources or neighboring jurisdictions. This is a particular challenge in the SWA because it is a relatively small landscape surrounded by private, state, and Federal land managed by different agencies. Furthermore, the SWA boundaries are linear and do not follow any natural features that could be used to contain fires (figure 33). Any fire that starts in the SWA and grows to any measurable size is likely to spread beyond the Park's boundaries. Therefore, most large wildfires in SWA have eventually been controlled on some flanks or suppressed completely because they threatened the border with the neighboring Coronado National Forest (CNF) and private lands. This is less of an issue in the GALWC, which is much larger than SWA; however, managers in the GNF must still contend with fire spreading beyond the agency boundaries. Outside of the wilderness areas, there are a number of private land inholdings throughout the forest and managers are challenged with minimizing the impact to these areas. For example the 2006 Skates Fire eventually had to be suppressed to prevent it from threatening a nearby community.

Managers in both areas have dealt with this challenge by collaborating with neighboring jurisdictions, both public and private. For example, SNP and the CNF developed a joint fire management plan, and a joint agency fire management officer oversees that plan. This has facilitated the sharing of resources and coordination of efforts across the agencies. In the GNF, managers worked with New Mexico State Forestry to develop agreements with private landowners in the area, mostly ranchers, to allow the GNF to manage wildfires on some private inholdings. These efforts allow for more effective and efficient management of wildfire as managers can take advantage of natural barriers for containment lines rather than trying to halt the spread of fire at fence lines.

Invasive Species

Spread of invasive species and their impact on fire spread patterns is becoming a significant challenge, particularly in SNP. Minimal fuels in Sonoran Desert habitats at lower elevations in the Park historically provide a barrier to fire spread from the higher elevation forests and woodlands. However, spread of invasive grasses such as buffelgrass (*Pennisetum ciliare* (L.) Link) at lower elevations has resulted in a more continuous fuel bed to support fire spread across these habitats

Figure 33—Eastern boundary of Saguaro National Park. Saguaro National Park shares a boundary with the Coronado National Forest on the north, east and south, which often hampers the ability to manage fires due to the lack of natural barriers and differing levels of risk tolerance and management objectives. This image shows the eastern boundary, in close proximity to frequently burned ponderosa pine forests in the foreground) (photograph taken from Reef Rock looking southeast by Calvin Farris, National Park Service).

Figure 34—Saguaro Cactus among a fuel bed of invasive grasses. Buffelgrass invasion of the lower elevations in Saguaro National Park has increased the connectivity of fuels across the landscape and can be detrimental to desert species that are not adapted to fire (photograph by Bethany Hontz, National Park Service).

(figure 34). The potential for fire to spread in lower elevations could have significant impacts on many important native species in the Park that are not well-adapted to fire, including the namesake saguaro cactus and many other species endemic to the Sonoran Desert. It may also result in more fires in higher elevations if continuous fuels allow fires to spread from lower elevation deserts (where human-caused ignitions are more common) to upper elevations woodlands and forests.

Multiple efforts are underway at SNP to combat the spread of buffelgrass. This includes treating hundreds of acres each year with herbicide or manual pulling, engaging in research and monitoring to inform treatment regimes, and public outreach. Research has shown that management efforts have been effective in slowing spread of the grass (Hunter 2012). In addition, managers at SNP are heavily engaged in a model collaborative effort to raise awareness about the threat of buffelgrass and coordinate volunteer and control efforts across southern Arizona (see www.buffelgrass.org, last accessed 6/10/13).

Reintroducing Fire in Mixed to High Severity Fire Regimes

Managers in both areas have had difficulty reintroducing fires to areas that historically burned with mixed to high severity, namely pinyon-juniper woodlands and mixed conifer forests. When managed wildfire has been attempted in these systems they often either burn out on their own after impacting limited acreage, or burn as large, high intensity crown fires. While this pattern may not be inconsistent with what one would have seen historically, the high intensity fires in particular can be undesirable because of their potential to impact critical resources (such as threatened and endangered species) and may be difficult to control. Thus, many wildfires in mixed conifer forests have been suppressed during dry conditions because of concern for impacts on species like Gila trout and Mexican spotted owl. While these species obviously persisted under the historical mixed to high severity fire regimes, they are more threatened by contemporary high intensity fires given their low population numbers. Plus, recent fires in mixed conifer forests (for example, WWBC) have resulted in high severity patch sizes that are larger than historical estimates, possibly due to greater fuel homogeneity at landscape scales (Ellis Margolis, personal communication). In particular, it appears the high severity patches are burning both in dry and wet mixed conifer whereas historically high severity were relatively small and limited in dry mixed conifer forests (figure 35). If fire is to be used as a tool in these systems, it is inevitable that some of it will be of high intensity and severity and it has been challenging to balance this fact with the protection of critical resources.

The GNF has attempted to address this challenge by experimenting with ways to reintroduce fire to mixed conifer forests. For example, a project was planned to introduce prescribed fire to a watershed occupied by Gila trout to reduce fuels and increase the resiliency of the population in the face of future wildfires. Unfortunately the project area was burned in the WWBC before the prescribed fire could be implemented. Other recent projects include the 2012 Farm Flats Prescribed Fire, which covered approximately 2,000 acres of mixed conifer forests and was implemented in the fall to reduce fuels and protect a nearby community. Burning in the fall helped to achieve fuel reduction objectives while also keeping fire behavior within manageable levels. If fuels can be reduced in strategic locations to protect critical resources, then opportunities for use of some high

Figure 35—High severity from the 2012 Whitewater-Baldy fire. Although high severity fires are part of the historical fire regime in some mixed conifer forests, recent patches of high severity fire in the Gila National Forest may be larger due to fire exclusion, particularly in the dry/warm mixed conifer type (photograph by Jose Iniguez).

intensity managed wildfire and prescribed fire may increase in other areas.

LESSONS LEARNED

Several factors facilitated the successful initiation of managed wildfire programs in the 1970s and their expansion over the last few decades. First the GAWLC and SWA represent relatively remote forested landscapes, making them ideal places to experiment with managed wildfire; while the SWA is not geographically remote, it is functionally remote due to limited access historically. Other important factors include the presence of vast fire-prone vegetation types, favorable climatic conditions, political environments that facilitated fire restoration, and the occurrence of mid-20th century wildfires that reduced fuel loads in many areas. The environmental and sociopolitical settings of these landscapes differ significantly from many other land management units throughout the West. Thus, we don't necessarily expect the success of these programs to be replicated at similar scales everywhere using the same template. Nonetheless, there is much to be learned from these two programs that might be useful and applicable to other areas. Thus, we culminate this report by highlighting some of the key lessons that can be learned from these fire management programs. This list is by no means comprehensive or organized in order of importance. It simply represents recurring ideas and themes that emerged from the literature, the fire occurrence data, and discussions with managers throughout this project.

- Managed wildfire and prescribed fire can restore southwestern forests
- Managed wildfire, large-scale prescribed fire, and suppression fires create landscape fire mosaics that provide opportunities for fire managers
- Collaboration across disciplines and agencies is imperative
- Preparation and public outreach is critical

Managed Wildfire and Prescribed Fire Can Restore Southwestern Forests

Fire has been an effective restoration tool in the SWA and GAWLC to reduce fuels, restore forest and landscape structure, and reduce the potential for intense wildfire (particularly in the ponderosa pine dominated forests). Overall, both wilderness areas have burned considerably more during the 20th century than most other forested landscapes in the western United States. Within the SWA and GALWC there are extensive areas that have burned three or more times since the inception of the managed wildfire programs, suggesting that current fire frequencies in these areas are closer to historic levels compared to other parts of the Southwest (figures 19 and 20). Although fires are still not as frequent or large as they were historically in most areas, studies have shown that areas where repeated managed wildfires have spread over several decades, forests more closely resemble historical conditions and are more resilient and resistant to wildfires under a variety of conditions. These findings suggest that managed wildfire and prescribed fire should be effective tools in other parts of the Southwest as well. Using fire as a restoration tool at large scales will likely be more difficult to implement in other landscapes that are less remote and more fragmented compared to these study areas. However, the opportunity for more use of managed wildfire and large-scale prescribed fire undoubtedly exists in the Southwest and is evident by the fact that we are beginning to see more use of these practices in a number of areas (for example, Kaibab, Tonto, Santa Fe, and Coconino National Forests).

Managed Wildfire, Large-Scale Prescribed Fire, and Suppression Fires Create Landscape Fire Mosaics That Provide Opportunities for Fire Managers

Acreage of fuels treatments in the western United States is currently dwarfed by wildfires and it is widely accepted that fuels treatments need to be dramatically scaled up to influence wildfire behavior and effects. Managers in both the GNF and SNP have been able to treat large areas with prescribed fire and managed wildfire relative to the size of their respective landscapes. Indeed, our analysis shows that a majority of each study area has been treated with fire at least once since the inception of the managed wildfire programs. This is in stark contrast to other forests in the Southwest where much of the landscapes remain untreated and long unburned, or has burned only through large suppression wildfires. One reason for this trend is that it is often more efficient to implement large-scale prescribed fire and managed wildfire because unlike mechanical treatments, their use is not restricted significantly by access or topography; however, mechanical treatments are not subjected to the same risks of escape or precision and have more predictable effects on stand structure. In addition, the absence of a robust wood products industry makes the use of fire less expensive on a per acre basis than mechanical treatments (Hunter and others 2007).

Over several decades, the numerous managed wildfires and prescribed fires in both areas have created a mosaic of historical burn scars across the landscape that have provided more strategic options during fire suppression events. Many examples of this were highlighted in this report where we discussed the effects of previous fires on the spread of the Miller Fire, WWBC, and Silver Fire in the GNF. For example, managers were able to use a previous prescribed burn to hold the 2012 WWBC to the north, and to devote fewer resources to suppression in the Iron Creek/Lilly Mountain area where the fire was spreading through areas burned previously by multiple managed wildfires (figure 23). Managers in SNP similarly believe that the prescribed fire and managed wildfire program slowed and reduced fire intensity of the 2003 Helen's II Fire where it met previous burns.

Prescribed fire, managed wildfire, and suppression wildfires can facilitate the increased use of fire as a restoration tool. For example, a strong prescribed fire program allows managers to develop fire management skills, reduce fuels on the landscape, and allows the public and resource specialists to become comfortable with fire and its effects. These are all factors that will ultimately facilitate the increased use and success of managed wildfires. The same is true of the influence of managed wildfire on a prescribed fire program. For example, in SNP, the 1994 Rincon Fire reduced fuel loads and provided holding lines for prescribed fires in subsequent years, which is partly why the prescribed burning program was able to expand in the mid- to late-1990s. In addition, large-scale prescribed burning (for example, Indian Peaks project) allowed for managed wildfires to extend beyond the wilderness boundary in the Black Range. Thus in both areas, it is evident that a patchwork of large-scale fires on the landscape can aid all aspects of fire management.

The contribution of suppression fires can also be important for facilitating the use of future prescribed or managed fires, as is illustrated by the early 1950s fires in both wilderness areas (figures 12 and 13). Both fire programs have taken advantage of past burn scars to provide opportunities to implement future fires. By utilizing all types of fire available, a holistic fire landscape puzzle is created where each fire supports additional use of fire on the landscape. While the recent megafires that have occurred throughout the Southwest have had detrimental effects on some ecosystems and communities, they should also be thought of as opportunities and utilized for the safe reintroduction of beneficial fire on the landscape.

Collaboration Across Disciplines and Agencies Is Imperative

Agencies are tasked with managing land for multiple objectives and protecting a variety of resources. At times, management actions that reduce fire risk can conflict with other objectives. For example, a managed wildfire may achieve objectives for reducing fuels and restoring fire as an ecological process, but it might also threaten populations of sensitive aquatic species in ways not experienced in the past (for example, leopard frog). Thus, within an agency, it is imperative to constantly communicate and collaborate across disciplines to assure that managed wildfire and prescribed fire seek to achieve multiple objectives and minimize adverse impacts. It is also essential to work closely with people in neighboring jurisdictions, because fire and smoke do not obey property lines. Managed wildfires can get quite large and a program is not likely to be successful if fires aren't able to spread across multiple jurisdictions.

There are several examples of successful collaboration across disciplines and agencies in both study areas: annual meetings among fire and non-fire personnel in the GNF, the joint fire management plan between SNP and the neighboring Coronado National Forest, and partnerships between Federal and private landowners in the GNF to manage wildfire on both jurisdictions. Managers in both areas have stressed that collaboration tends to facilitate rather than restrict use of managed wildfire across their landscapes.

Preparation and Public Outreach Is Critical

Both fire programs have had active and inactive periods of burning due to external and internal factors. Events external to the organization like the Cerro Grande Fire—escaped prescribed fire that burned part of the town of Los Alamos, New Mexico—or widespread budget cuts can effectively shut or slow down a fire program. Conversely, policy initiatives like the National Fire Plan (2000) can greatly increase capacity in fire management programs by allowing agencies to hire more fire related personnel for implementation, monitoring, and planning managed and prescribed fire. Internally, personnel changes can influence the activity of a program, particularly when new personnel are not familiar or comfortable with the risk that comes with using fire as a restoration tool. It is inevitable that external and internal factors will influence the activity of a fire program, but investing in preparation, both short- and long-term, and public outreach can help managers weather those factors and maintain fire programs through inactive periods.

In the short-term, pre-fire season preparation and collaboration can greatly increase of a manager's ability to use managed wildfire in any given season. One example of this preparation is the annual meetings with fire and non-fire personnel in the GNF where they discuss potential locations to manage wildfire given what is known about sensitive resources, fuel conditions, outlooks, and the recent fire history. Since much of the analysis and discussion is done before a fire starts, decisions regarding fire strategies can be made relatively quickly in the event of an ignition. This type of short-term preparation has allowed the GNF to take advantage of natural ignitions when they occur in the areas where managed wildfire has been deemed a viable option. Similar planning strategies have been adapted by other successful fire programs, such as Grand Canyon National Park and others.

In the long-term, investments in monitoring, planning, and training for personnel can greatly bolster fire programs. Even basic inventory monitoring provides a good understanding of the fuels, fire history, and sensitive resources in an area, which is needed to decide where use of managed wildfire is most appropriate on a landscape. Monitoring information can also be used for public outreach to justify and gain support for increased fire activity. Planning then provides the policy and legal basis for managing wildfire and prescribed fire. Organizations also need ready access to staff qualified to implement managed wildfire. Having all these pieces in place allows managers to take full advantage of favorable climates for managed wildfire or prescribed fire when they do occur. For example, both the GNF and SNP were able to take advantage of resources allocated in the National Fire Plan (2000) because they already had the planning, information on current conditions, and qualified personnel in place to implement managed wildfire and large-scale prescribed fire. This is partly why the prescribed fire and managed wildfire programs were able to accomplish so much in the early 2000s.

Finally, public outreach plays a critical role in alleviating external factors that can influence fire programs in the short- and long-term. Managers from both units mentioned that public outreach has played an important role in acceptance of smoke and other effects that result from the fire programs. For example, in the GNF the 2006 Skates Fire forced the evacuation of a small community, yet evacuees remained mostly supportive of the overall fire program and understood the need for managed and prescribed fire. This was a testament to the year-round investment in public outreach by the GNF. In SNP the active engagement of community volunteers, especially in buffelgrass control efforts, can be attributed to the investments SNP has made in public outreach.

CONCLUSION

All three lines of evidence we explored for this report support the idea that managed wildfire and prescribed fire programs have been largely successful and beneficial in meeting resource management objectives where it has been applied in the GALWC and SWA. Managers from both sites have overcome significant challenges in implementing managed wildfire and large-scale prescribed fire, providing us with lessons that may be applied to other parts of the country. Still, even in these relatively remote landscapes, there are areas where the challenges of implementing managed wildfire and prescribed fire have been too great to overcome. Thus, managed wildfire will likely always need to be utilized in a larger fuels management framework that includes prescribed fire and other treatments. While we recognize that managed wildfire and prescribed fire cannot be applied everywhere, there are likely opportunities to increase their use in many parts of the West. In fact many management units throughout the Southwest, (for example, Kaibab, Santa Fe, and Coconino National Forests) are increasingly adopting the practice.

These two wilderness areas provide examples of how fires can effectively be used to restore landscape-scale forest structure and increase resiliency to wildfire. However, successfully restoring landscapes will require patience (decades) and an understanding that fire will inevitably result in some undesired effects. Current fire managers face a set of increasingly difficult conditions: heavy fuel loads, warming temperature and prolonging drought. It is no longer a question of whether a given tract of forest will burn or not; rather, the decision managers must now make is, *when* and *how* forests will burn, knowing full well that suppressing fires now only postpones the inevitable. Therefore it is in the best interest of the public and future generations to make greater use of fire as a restoration tool to create more resilient and resistant forest ecosystems.

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REFERENCES

Abolt, R.A. 1997. Fire histories of upper elevation forests in the Gila Wilderness, New Mexico via fire scar and stand age structure analysis. M.S. Thesis. University of Arizona.

Allen, C.D. 2002. Lots of lightning and plenty of people: An ecological history of fire in the upland southwest. Pages 143-193 in: T.R. Vale (ed.). Fire, native peoples, and the natural landscape. Island Press, Washington.

Baisan, C.H. 1990. Fire history of the Rincon Mountain Wilderness, Saguaro National Monument. Ph.D. Dissertation. University of Arizona.

Baisan, C.H. and T.W. Swetnam. 1990. Fire history on a desert mountain range: Rincon Mountain Wilderness, Arizona, U.S.A. Canadian Journal of Forest Research 20: 1559-1569.

Bigelow, J., Jr. 1968. On the bloody trail of Geronimo. Westernlore Press, Los Angeles, CA.

Boucher, P.F. and R.D. Moody. 1998. The historical role of fire and ecosystem management of fires: Gila National Forest New Mexico. Pages 374-379 In: T.L. Pruden and L.A. Brennan (eds.). Fire in ecosystem management: Shifting the paradigm from suppression to prescription. Tall Timbers Fire Ecology Conference Proceedings, No. 20. Tall Timbers Research Station, Tallahassee, FL.

Boucher, P.F., W.M. Block, G.V. Benavidez, and L.E. Wiebe. 2000. Implementing the expanded prescribed fire program on the Gila National Forest, New Mexico: Implications for snag management. Pages 104-113 In: W.K. Moser and C.F. Moser (eds.). Fire and forest ecology: Innovative silviculture and vegetation management. Tall Timbers Fire Ecology Conference Proceedings, No. 21. Tall Timbers Research Station, Tallahassee, FL.

Boykin, D. 2013. [Personal communication]. June 27. Socorro, NM: New Mexico Forestry Division, Socorro District.

Breshears, D.D., N.S. Cobb, P.M. Rich, K.P. Price, C.D. Allen, R.G. Balice, W.H. Romme, J.H. Kastens, M.L. Floyd, J. Belnap, J.J. Anderson, O.B. Myers, and C.W. Meyer. 2005. Regional vegetation die-off in response to global-change-type drought. Proceedings of the National Academy of Sciences 102: 15144-15148.

Brown, D.K., A.A. Echelle, D.L. Propst, J.E. Brooks, and W.L. Fisher. 2001. Catastrophic wildfire and number of populations as factors influencing risk of extinction for Gila trout (*Onchorhynchus gilae*). Western North American Naturalist 62: 139-148.

Clemensen, A.B. 1987. Cattle, copper, and cactus: The history of Saguaro National Monument, AZ. Historic Resource Study, Saguaro National Monument. U.S. Department of the Interior, National Park Service, Denver, CO.

Conway, C. J. and C. Kirkpatrick. 2007. Effects of forest fire suppression on buff-breasted flycatchers. Journal of Wildlife Management 71: 445-457.

Cooper, C.F. 1961. Pattern in ponderosa pine forests. Ecology 42: 493-499.

Cordell, L. 1997. Archeology of the Southwest, 2nd edition. Academic Press, San Diego, CA.

Covington, W.W., R.L. Everett, R.W. Steele, L.I. Irwin, T.A. Daer, and A.N.D. Auclair. 1994. Historical and anticipated changes in forest ecosystems of the inland west of the United States. Journal of Sustainable Forestry 2: 13-63.

Dillon, G.K., Z.A. Holden, P. Morgan, M.A. Crimmins, E.K. Heyerdahl, and C.H. Luce. 2012. Both topography and climate affected forest and woodland burn severity in two regions of the western US, 1984 to 2006. Ecosphere 2: 1-33.

Dodge, N. N. 1967. National Park Service Natural History Handbook, Series No. 4 (Saguaro National Monument, Arizona). National Park Service, Washington, DC.

Evans, A.M., R.G. Everett, S.L. Stephens, and J.A. Youtz. 2011. Comprehensive fuels treatment practices guide for mixed conifer forests: California, central and southern Rockies, and the Southwest. Forest Guild, Santa Fe, NM.

Farris, C.A., C.H. Baisan, D.A. Falk, M.L. Van Horne, P.Z. Fulé, and T.W. Swetnam. 2013. A comparison of targeted and systematic fire-scar sampling for estimating historical fire frequency in southwestern ponderosa pine forests. International Journal of Wildland Fire. 22(8):1021-1033.

Farris, C.A., C.H. Baisan, D.A. Falk, S.R. Yool, and T.W. Swetnam. 2010. Spatial and temporal corroboration of a fire-scar-based fire history in a frequently burned ponderosa pine forest. Ecological Applications 20: 1598-1614.

Fire Executive Council. 2009. Guidance for implementation of federal wildland fire management policy. U.S. Department of Agriculture and U.S. Department of the Interior, Washington, DC.

Floyd, M.L., D. Hanna, W.H. Romme, and T.E. Crews. 2006. Predicting and mitigating weed invasions to restore natural post-fire succession in Mesa Verde National Park, Colorado, USA. International Journal of Wildland Fire 15: 247-259.

Fulé, P.Z., A.E. Cocke, T.A. Heinlein, and W.W. Covington. 2004. Effects of an intense prescribed forest fire: is it ecological restoration? Restoration Ecology 12: 220-230.

Fulé, P.Z., J.E. Crouse, J.P. Roccaforte, and E.L. Kalies. 2012. Do thinning and/or burning treatments in western USA ponderosa or Jeffery pine-dominated forests help restore natural fire behavior? Forest Ecology and Management 269: 68-81.

Ganey, J.L., W.M. Block, and P.F. Boucher. 1996. Effects of fire on birds in Madrean forests and woodlands. Pages 146-154 In: P.F. Ffolliott et al. (tech. coords.). Effects of fire on Madrean Province ecosystems. Gen. Tech. Rep. RMRS-GTR-289. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Haire, S.L. and K. McGarigal. 2010. Effects of landscape patterns of fire severity on regenerating ponderosa pine forests (*Pinus ponderosa*) in New Mexico and Arizona, USA. Landscape Ecology 25: 1055-1069.

Holden, Z.A., P. Morgan, and A.T. Hudak. 2010. Burn severity of areas reburned by wildfires in the Gila National Forest, New Mexico, USA. Fire Ecology 6: 77-85.

Holden, Z.A., P. Morgan, M.G. Rollins, and K. Kavanagh. 2007. Effects of multiple wildland fires on ponderosa pine stand structure in two southwestern wilderness areas, USA. Fire Ecology 3: 18-33.

Holden, Z.A., P. Morgan, M.G. Rollins, and R.G. Wright. 2006. Ponderosa pine snag densities following multiple fires in the Gila Wilderness, New Mexico. Forest Ecology and Management 221: 140-146.

Hunter, M.E. 2012 Assessment and guidelines for determining effectiveness and longevity of buffelgrass treatments in southern Arizona. Final Report on file at Saguaro National Park, Tucson, Arizona.

Hunter, M.E., J.M. Iniguez, and L.B. Lentile. 2011. Short- and long-term effects on fuels, forest structure, and wildfire potential from prescribed fire and resource benefit fires in southwestern forests. Fire Ecology 7: 108-121.

Hunter, M.E., W.D. Shepperd, L.B. Lentile, J.E. Lundquist, M.G. Andreu, J.L. Butler, F.W. Smith. 2007. A comprehensive guide to fuels treatment practices for ponderosa pine in the Black Hills, Colorado Front Range, and Southwest. Gen. Tech. Rep. RMRS-GTR-198. U.S. Department of Agriculture, Forest Service Rocky Mountain Research Station, Fort Collins, CO. 93 p.

Iniguez, J.M. 2014. Gila National Forest Compiled Fire History Dataset. Unpublished dataset on file at U.S. Department of Agriculture, Forest Service Rocky Mountain Research Station, Flagstaff, AZ.

Iniguez, J.M., T.W. Swetnam, and C.H. Baisan. 2009. Spatially and temporally variable fire regime on Rincon Peak, Arizona, USA. Fire Ecology 5: 3-21

Jenness, J.S., P. Beier, and J.L. Ganey. 2004. Associations between forest fire and Mexican spotted owls. Forest Science 50: 765-772.

Kirkpatrick, C., C.J. Conway, and P.B. Jones. 2006. Distribution and relative abundance of forest birds in relation to burn severity in southeastern Arizona. Journal of Wildlife Management 70: 1005-1012.

Margolis, E.Q. 2014. Fire regime shift linked to increased forest density in a piñon-juniper savanna landscape. International Journal of Wildland Fire. 23: 234-245.

Margolis, E.Q. 2012. [Personal communication]. October 30. Tucson, AZ: University of Arizona, Laboratory of Tree Ring Research.

Margolis, E.Q., T.W. Swetnam, and C.D. Allen. 2011. Historical stand-replacing fire in upper montane forests of the Madrean Sky Islands and Mogollon Pleateau, southwestern USA. Fire Ecology 7: 88-107.

McLaughlin, S.P. 1995. An overview of the flora of the Sky Islands, Southern Arizona: Diversity, affiliation and insularity. Pages 60-70 In: Debano, L.F. et al. (eds.). Biodiversity and management of the Madrean Archipelago: the Sky Islands of Southwestern United States and Northwestern Mexico. Gen. Tech. Rep. RM-218. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Range and Experiment Station, Fort Collins, CO.

Miller, M.E. 1999. Use of historical aerial photography to study vegetation change in the Negrito Creek Watershed, southwestern New Mexico. The Southwestern Naturalist 44: 121-137.

Niering, W.A. and C.H. Lowe. 1984. Vegetation of the Santa Catalina Mountains: Community types and dynamics. Vegetatio 58: 30-58.

National Fire Plan. 2000. The National Fire Plan. U.S. Department of Agriculture, Forest Service, Forests and Rangelands, Washington, DC. www.forestandrangelans.gov/resources/overview. Last assessed 6/7/2013.

Parker, J.T.C. 2006. Post-wildfire sedimentation in Saguaro National Park, Rincon Mountain District, and effects on lowland leopard frog habitat. U.S. Geological Survey Scientific Investigations Report 2006-5235.

Parks, S.A., C. Miller, C.R. Nelson, and Z.A. Holden. 2014. Previous fires moderate burn severity of subsequent wildland fires in two large western US wilderness areas. Ecosystems 17: 29-42. doi: 10.1007/s10021-013-9704-x.

Peppin, D., P.Z. Fulé, C.H. Sieg, J.L. Beyers, and M.E. Hunter. 2010. Post-wildfire seeding in forests of the western United States: An evidence-based review. Forest Ecology and Management 260: 573-586.

Philpot, C., C. Schechter, A. Bartuska, K. Beartusk, D. Bosworth, S. Coloff, J. Douglass, M. Edrington, R. Gale, M.J. Lavin, L.K. Rosenkrance, R. Streeter, and J. van Wagtendonk. 1995. Federal wildland fire management policy and program review. U.S. Department of the Interior and U.S. Department of Agriculture, Washington, DC.

Platz, J.E. and J.S. Frost. 1984. *Rana yavapaiensis*, a new species of leopard frog (Rana pipens complex). Copeia 1984: 940-948.

Pyne, S.J. 1997. Fire in America: A cultural history of wildland and rural fire. University of Washington Press, Seattle, WA.

Richards, T. 2012. [Personal communication]. October 24. Reserve, NM: U.S. Department of Agriculture, Forest Service, Gila National Forest.

Rollins, M.G., T.W. Swetnam, and P. Morgan. 2001. Evaluating a century of fire patterns in two Rocky Mountain wilderness areas using digital fire atlases. Canadian Journal of Forest Research 31: 2107-2123.

Romme, W.H., C.D. Allen, J.D. Bailey, W.L. Baker, B.T. Bestelmeyer, P.M. Brown, K.S. Eisenhart, M.L. Floyd, D. W. Huffman, B.F. Jacobs, R.F. Miller, E.H. Muldavin, T.W. Swetman, R.J. Tausch, and P.J. Weisberg. 2009. Historical and modern disturbance regimes, stand structures, and landscape dynamics in piñon-juniper vegetation of the western United States. Rangeland Ecology and Management 62: 203-222.

Roth, D. 1990. The wilderness movement and the National Forests. Intaglio Press, College Station, TX.

Stephens, S.L., N. Burrows, A. Buyantuyev, R.W. Gray, R.E. Keane, R. Kubian, S. Liu, F. Seijo, L. Shu, K.G. Tolhurst, and J.W. van Wagtendonk. 2014. Temperate and boreal forest mega-fires: characteristics and challenges. Frontiers in Ecology and the Environment doi: 10.1890/120332.

Swetnam, T.W. and C.H. Baisan. 1996. Historical fire regime patterns in the southwestern United States since AD 1700. Pages 11-32 In: C.D. Allen (ed.). Fire effects in southwestern forests: Proceedings of the La Mesa fire symposium. Gen. Tech. Rep. RM-GTR-286. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Swetnam, T.W. and C.H. Baisan. 2003. Tree-ring reconstructions of fire and climate history in the Sierra Nevada and southwestern United States. Pages 158-195 In: T.T. Veblen, W. Baker, G. Montenegro, T.W. Swetnam, (eds.). Fire and climate change in temperate ecosystems of the western Americas. Ecological Studies Vol. 160. New York: Springer.

U.S. Fish and Wildlife Service. 2012. Final recovery plan for the Mexican Spotted Owl (*Strix occidentalis lucida*), First Revision. U.S. Fish and Wildlife Service. Albuquerque, NM. 413 p.

U.S. Geological Survey. 1965. Mineral and water resources of New Mexico. Bulletin 87. U.S. Geological Survey State Bureau of Mine and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, NM.

van Mantgem, P.J., J.C.B. Sesmith, M. Keifer, E.E. Knapp, A. Flint, and L. Flint. 2013. Climatic stress increases forest fire severity across the western United States. Ecology Letters 16: 1151-1156.

van Wagtendonk, J. 2007. The history and evolution of wildland fire use. Fire Ecology 3: 3-17.

Weaver, H. 1951. Fire as an ecological factor in southwestern ponderosa pine forests. Journal of Forestry 49: 93-98.

Westerling, A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam. 2006. Warming and earlier spring increases western U.S. forest wildfire activity. Science 313: 940-943.

Willey, D.W. 1998. Influence of fire on Mexican spotted owls in Saguaro National Park. Final Report. Heritage Fund Program, Arizona Game and Fish Dept. Phoenix, AZ. 38 p.

Wood, M.K. and B. Racher. 2010. Recovery of habitat for Gila trout and livestock grazing following wildfire in main Diamond Creek in the Black Range of southwestern New Mexico. Miscellaneous Report No. M30. New Mexico Water Resources Research Institute.

GLOSSARY

Confine: The least aggressive wildfire suppression strategy that can be expected to keep a wildfire within predetermined natural or artificial boundaries under prevailing conditions.

Contain: A moderately aggressive wildfire suppression strategy that can be expected to keep a wildfire within predetermined artificial or natural boundaries under prevailing conditions.

Fire intensity: The rate of energy release from the flaming front of a fire.

Fire regime: A depiction of the role of fire in an ecosystem. It often includes descriptions of fire frequency, intensity, size, severity, and seasonality.

Fire severity: An indicator of the ecological impact of fire on a particular resource. In this report, fire severity is mostly referring to the effects of fire on dominant tree mortality.

Forest composition: All the plant species found in a forested stand or landscape.

Forest structure: The living and non-living physical components, and their spatial arrangement, within a forested ecosystem.

Fuels: Any living or dead vegetation that will burn. It can include coarse wood, litter, duff, grasses, forbs, shrubs, and trees.

Fuels treatment: The manipulation or removal of fuels with the intent to reduce the probability of ignition and/or to lessen potential fire intensity, severity, and resistance to control. Fuels manipulation and removal can be done with prescribed fire, managed wildfire, or with mechanized equipment.

Managed wildfire: A term used in this report to describe naturally ignited fires that are managed with minimal suppression and allowed to spread to meet resource objectives.

Mean fire return interval (MFI): The average number of years between fires for a specified area and time period.

Mechanical treatment: Any fuels treatment that uses mechanized equipment (i.e. chainsaws, masticators, tree harvesters) to remove or redistribute fuels for the purpose of reducing the probability of ignition and/or to lessen potential fire intensity, severity, and resistance to control.

Megafire: A wildfire that burns under fuels and/or climatic conditions that results in extraordinary fire behavior characteristics, size, complexity, and resistance to control.

Natural fire rotation (NFR): The average time required to burn an area equivalent to the size of the entire study area.

Prescribed fire: A fire intentionally ignited by managers to meet specific resource objectives.

Prescribed natural fire: A previously used term (pre 1995) to describe lightning fires that are allowed to burn to benefit resources.

Resilience: The capacity of an ecosystem to recover from a disturbance (e.g. wildfire) and retain essentially the same function, structure, identity, and feedbacks.

Resistance: The capacity of an ecosystem to weather a disturbance (e.g. wildfire) without significant change in function, structure, identity, and feedbacks.

Restoration: The process of assisting the recovery of ecosystems that have been degraded, damaged, or destroyed.

Suppression: The act of extinguishing or confining a wildfire.

Suppression fire: A term used in this report to describe any unwanted fire that is actively suppressed.

Tinajas: Ephemeral pools of water that form in bedrock depressions. These are particularly prevalent and important ecological features in Saguaro National Park.

Wildland fire use: A previously used term (pre 2009) to describe lighting fires that are allowed to burn to benefit resources.

APPENDIX A: MANAGERS INTERVIEWED

Managers that we interviewed for input in this report. Interviews were conducted by telephone, email, or in person.

Craig Allen, US Geological Survey, Research Ecologist

Marcia Andre, Gila National Forest, Supervisor (retired)

Doug Boykin, New Mexico State Forestry, District Forester

Liz Carver, Gila National Forest, Forestry Technician

Pete Delgado, Gila National Forest, Fuels Specialist

Todd Erdody, National Park Service, Lead Fire Effects Monitor

Albert Flores, Gila National Forest, Fuels Specialist

Robert Gallardo, Gila National Forest, Fire Management Officer

Perry Grissom, Saguaro National Park, Fire Ecologist

Gabe Holguin, Gila National Forest, Fire Management Officer

Emily Irwin, USDA Forest Service, Region 3 Program Manager (formerly with Gila National Forest)

Carolyn Koury, Gila National Forest, Hydrologist

Bob Lineback, National Park Service, Regional fire manager (retired) and Incident manager

Ellis Margolis, University of Arizona, Research Associate

Pat Morrison, Gila National Forest, District Ranger

Shilow Norton, Gila National Forest, Fire Management Officer

Gabe Partido, Gila National Forest, Fuels and Vegetation Program Manager

John Pierson, Gila National Forest, District Ranger

Toby Richards, Gila National Forest, Assistant Fire Management Officer

Kathy Schon, USDA Forest Service, Washington Office, Fire Ecologist (formerly with Saguaro National Park)

Martha Schumann, The Nature Conservancy, Southwest New Mexico Field Representative

Chuck Scott, Saguaro National Park, Fire Management Officer (retired)

Art Telles, Gila National Forest, Biologist

APPENDIX B: RESEARCH NEEDS

In conducting the literature review and conversations with managers, it became apparent that there is need for more research on several topics. The most pressing needs for research relevant to fire and fuels management in these study areas are (1) effects of high intensity fire, (2) mortality of drought-stressed trees, (3) effectiveness and effects of post-fire seeding, (4) effectiveness of fuels treatments under current and changing climatic conditions, (5) effects and effectiveness of prescribed and managed fire in poorly understood systems, and (6) limitations of using natural ignitions to achieve objectives.

Effects of High Intensity Fire

Wildfires with large (>500 acre), high severity patches have recently occurred in the GNF in particular and it is unclear how succession will proceed given the size of the patches and current and future climatic conditions. High severity patch size can influence opportunities for pine and conifer recruitment from surviving seed sources (Haire and McGarigal 2010). Drought may also make conditions unfavorable for pine and conifer regeneration. This may mean that sprouting species such as gamble oak and aspen dominate for a while; however, interactions with other disturbance agents (i.e. insects, disease, browsing, and drought) may influence their persistence. In general, there is uncertainty for how succession will proceed in the short- and long-term in areas impacted by large and intense wildfires, and how interacting disturbances such as drought and introduction of invasive species might influence the trajectory of succession. Alternative succession trajectories will undoubtedly have implications for wildlife populations that rely on these forests for habitat. Thus, research is needed on short- and long-term succession and implications for wildlife populations and habitat following large-scale, high intensity fire.

Mortality of Drought-Stressed Trees

Managers in both areas have expressed concern that tree mortality from low intensity fire seems to be higher when trees are drought-stressed. There is some evidence for this phenomenon in forests throughout the West (van Mantgem et al. 2013). However, little is known about the mechanisms responsible for this trend. More research is needed on the interactions between drought and low-intensity fire-induced tree mortality. Such research could inform management decisions on the appropriate timing and application of prescribed fire and managed wildfire under drought conditions.

Effectiveness and Effects of Post-Fire Seeding

Studies throughout the West have suggested that post-fire seeding in high severity areas for the purpose of reducing the potential for soil erosion is often ineffective (Peppin et al. 2010). For a number of reasons, seeded grasses often become sufficiently established to reduce erosion potential. However, managers in these study areas have long speculated that given different climatic conditions in southwestern forests, appropriate application of grass seed can produce effective results. Indeed, post-fire seeding of the WWBC seemed to produce high grass cover in seeded areas (Molly Hunter, personal observation of the WWBC). Thus, managers highlighted the need for research in post-fire seeding effectiveness and effects, particularly in southwestern forests where precipitation from summer "monsoonal" storms may facilitate greater grass establishment.

Effectiveness of Fuels Treatments Under Current and Changing Climatic Conditions

While there was certainly evidence that severity of the recent megafires in the GNF was mitigated by previous managed wildfires and prescribed fires, these fuels treatments were not universally effective in reducing fire behavior and effects, perhaps a result of the severe drought conditions under which these fires burned. Fuels treatments are not designed to be effective in lessening fire behavior under all possible conditions and we might expect their effectiveness to be more limited as the climate becomes warmer and drier. To that end, more research is needed to investigate the degree to which a variety of fuels treatments will be effective under current and future climatic conditions. Such research should consider the multitude of factors that might influence treatment effectiveness (i.e. fuels, weather, terrain, area treated, type and age of treatment).

Effects and Effectiveness of Prescribed and Managed Fire in Poorly Understood Systems

Much of the research conducted on effects and effectiveness of prescribed fire and managed wildfire has focused on ponderosa pine forests. This is not surprising, given that fire management programs have focused more heavily in these systems. Recently however, large fires have impacted pinyon-juniper woodlands and mixed conifer forests with variable severity. These fires have provided opportunities to examine basic fire effects in these systems. Pinyon-juniper woodlands and mixed conifer forests have been the subject of research studies in other parts of the country, but they remain under-studied in the Southwest, particularly in the southern portion of their range.

Limitations of Using Natural Ignitions to Achieve Objectives

Managers in the SWA and GALWC have been able to burn an impressive number of acres with managed wildfire. However, many areas in both units remained unburned decades after the inception of these programs. Examples include higher elevation mixed conifer forests in the GAWLC and Rincon Peak in the SWA. This begs the question: Can landscapes be made more resilient to wildfire using managed wildfire alone? Prescribed fire has not been used in the GAWLC, but managers have recently considered implementing the practice. Prescribed fire has been a very important tool in the SWA in the last few decades, but it is not used currently because funds for National Park Service fuels programs have been directed to areas closer to wildland urban interface. Modeling studies that examine fire ignition and spread patterns would inform managers on what accomplishments could be expected using managed wildfire and prescribed fire.

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