**P2.9 DELAYED MORTALITY: SAGUARO CACTI ARE STILL DYING 10 YEARS AFTER WILDFIRE!**

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## 1. INTRODUCTION

Sonoran desert vistas of giant saguaro cacti, *Carnegiea gigantea* [Engelm.] Britt. & Rose, attract millions of visitors to the Tonto National Forest (TNF) each year (Fig. 1). Saguaro, a keystone species, is crucial for the survival of many animal species (Alcock 1990, Turner et. al. 1995).

**Figure 1. Scenic vista looking east toward Four Peaks, on the Mesa District, Tonto National Forest, AZ.**

Unfortunately, over the last three decades fires burned large portions of mature saguaro-shrub habitat, often leaving landscapes devoid of centuries old behemoth cacti (Narog et. al. 1995, 1999, Wilson et. al. 1995a, 1995b, 1996). According to TNF fire records, over 30 percent of the saguaro on the TNF was decimated from more frequent and larger fires that occurred in the 1980s and early to mid 1990s (Fig. 2).

**Fig. 2. The River Fire (1995) affected the scenic saguaro vista west of Four Peaks, Mesa District, Tonto National Forest, AZ.**

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Cave and Patten (1984) clearly stated the need for studies that document the impact of fire on the upper Sonoran Desert communities including the saguaro-shrub. Others have specifically noted the potential for a major loss of saguaro from fire (McLaughlin and Bowers 1982, Rogers 1986, Rogers and Steele 1980, Schmid and Rogers 1988, Thomas 1991, Wright 1988).

Preservation of the protected saguaro and its habitat has become a priority for resource and fire management in the Sonoran Desert of Arizona. This task presents unique challenges and is in sharp contrast to past efforts directed toward the removal of saguaro shrub vegetation to improve rangeland for livestock. Some high use areas have experienced multiple fires that type-convert the saguaro-shrub community to nonnative grasslands and make reconstruction of site specific fire history difficult. Historical evidence from century-old fires is not imprinted on the desert landscape as it has been observed through dendro-ecology studies of fire scars in forest trees.

Variable factors complicate the study of fire effects on the saguaro community: 1) unpredictable biannual precipitation events can sustain or stress (e.g. drought) the diverse and abundant desert vegetation; 2) nonnative grasses and forbs, promoted in part by livestock activities, supply contiguous flashy fuels that affect ignition, fire size and rate of spread; 3) local burgeoning urbanization and recreational use increases ignition potential; and 4) irregular orographic relief, particularly in areas such as The Rolls, Mesa District, TNF, can coalesce with erratic weather conditions (e.g. ,dust devils) to produce extreme fire behavior. Considering these complicating factors, predicting short and long-term post-fire recovery of saguaro-shrub vegetation is difficult.

In an effort to retard future saguaro habitat loss by fire, the resource officers of the TNF recommended that new research be conducted. Scientists at the Pacific Southwest Research Station were approached to develop and design fire related research. During mild fire-weather conditions on May 4, 1993 arson-set ignitions known as the Vista View Fire burned saguaro habitat west of Four Peaks, Mesa District, TNF (Fig.3). In 1994, this fire became the focal point for our comprehensive study to document the effects of fire on the saguaro-shrub community (Narog et. al. 1995). Our post-fire study evaluating fire effects on saguaro and associated vegetation compared unburned and burned habitat

Initial survival, injury and mortality of saguaro and associated vegetation were measured (Wilson et. al. 1995a, 1995b, 1996). Saguaro mortality was reported at 19 percent in the burned areas 1-year post-fire. Long-term mortality was expected to increase based on

the 90 percent fire injury recorded in Wilson et. al. (1996). We also documented the role that associated vegetation plays in this community as a flammable fuel (Wilson et. al.1998).

In this paper, we compare and contrast saguaro from 1 and 10 year post-fire observations. This includes burned areas and an unburned control. We will focus on two striking trends observed in our 10-year post-fire saguaro sample population: 1) individual mortality and 2) variations in main stem height growth and loss. We chose to analyze changes in saguaro height over time to quantify post-fire effects. Future papers will address the 10-year post-fire effects on saguaro-shrub vegetation as fuel.

## 2. METHODS

The study site is located on The Rolls on the Mesa District of the Tonto National Forest, AZ (Fig. 3). We established eight 1 ha plots to evaluate saguaro-shrub habitat. To increase the saguaro sample size, point quarter transect methods were used to compliment our 1 ha plot line-intersect and quadrat methods. The randomly positioned point quarter transects allowed us to sample saguaro along 350 meters. Eight points were placed 50 m apart along each transect. The nearest saguaro in each of 4 quadrants around each point was described and measured (Wilson et. al. 1996).

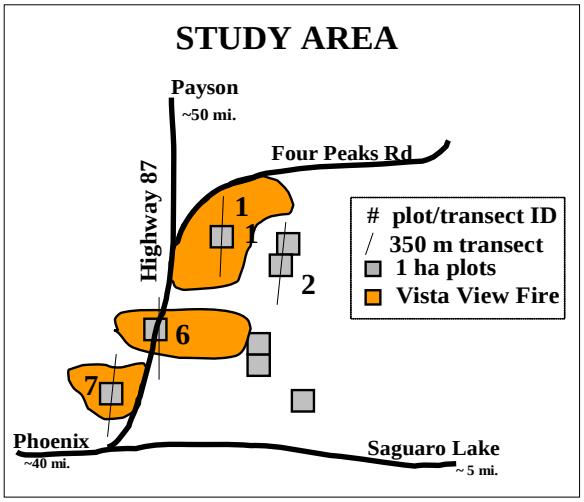


**Figure 3. Study area with N-S running point quarter transects and associated 1 ha plots. Control plot 2 is in an unburned area; Burn plots 1, 6, and 7 were burned in the 1993 Vista View Fire, on The Rolls. Unnumbered plots are additional sample sites not considered here. (R8E: T3-Sec. 2, 4, 5 and T4-Sec. 26, 27, 35 of the Four Peaks Quad) Mesa District, Tonto National Forest, AZ.**

A control area (Fig.3, Control 2)) consisting of two 1 ha plots and a 350 m point quarter transect was placed in unburned vegetation. Three transects were associated with three plots west of the control area that were within the Vista View Fire perimeter (Fig. 3, Burn 1, 6, 7). Unnumbered 1 ha plots were designated for prescribed burn treatments, however, the River Fire burned them in 1995. Ten-year post fire data for these plots will be collected in 2005.

Of the many parameters measured (e.g., DBH, number of arms, height from the base to the highest and lowest arms, scar heights, degrees of injury, etc.) only individual saguaro mortality and main stem height data are analyzed here (Fig. 4).

**Figure 4. Saguaro were described and measured along all four 350 m point quarter transects, Tonto National Forest, AZ.**

We considered a saguaro to be dead if it was down, decomposing, or no longer had apparent active photosynthetic tissues. When a saguaro dies, part or all of it may remain standing, while in other cases a saguaro would fall over from the base--literally being uprooted. For height measurements we used a meter stick or a metric telescoping survey rod (Fig. 4). Various stages of saguaro injury and decomposition were also observed (Fig. 5a, and 5b).

**5a. Determining precisely when a saguaro died was difficult. The rate of de-composition did not ap-pear consistent among dead saguaro observed.**

We measured the main stem height, and recorded if new arms were initiated or if arms were lost. The main stem was used to determine saguaro height even though in some cases arms extended above a broken top (Fig. 5b). Entire and fragmented main stems of

saguaro (both standing and fallen) were measured to evaluate growth (height gain and loss).

**Figure 5b. Some saguaro cacti were topped: possibly weakened by fire injury and removed by wind shears. Note the green fallen top**

## 3. RESULTS

Saguaro in burned plots suffered higher mortality over the span of 10 years than those in the unburned (Table 1, Fig. 6). Although there was some variability among burned plots, we observed an accumulated average saguaro mortality of 32 percent. Our total saguaro sample size was 107 individuals. Of these, 78 percent of were in the burned area. The mortality in the burned area was four times greater than unburned (Table 1).

**Table 1. Ten year post-fire saguaro population burned and unburned number and percent dead in Spring 2003 ( N=107).**

| Plot | Treatment | # Dead | N | % Dead |
|---|---|---|---|---|
| 2 | Control | 2 | 24 | 8.3 |
| 1 | Burn | 5 | 29 | 17.2 |
| 6 | Burn | 14 | 27 | 51.9 |
| 7 | Burn | 7 | 27 | 25.9 |
| Total 1, 6, 7 | Burn | 28 | 83 | 32.0 |

Mortality increased from 1994 to 2003 and was greatest in Burn 6 for 1- and 10-years post-fire (Fig. 6).

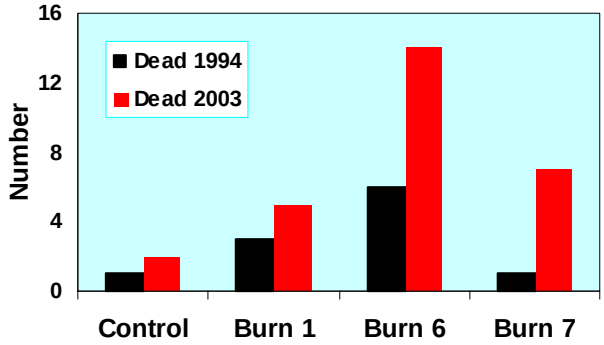


**Figure 6. Saguaro mortality observed 1-year and 10-years after the 1993 Vista View fire, TNF, AZ.**

Post-fire differences in dead saguaro height were discovered to increase among plots between 1-year and 10-years in burned and unburned areas (Fig. 7). Differences in height of dead saguaro in 2003 were compared with the height originally measured for 1994.

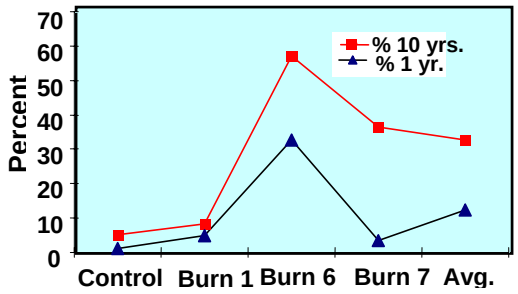


**Figure 7. Stem height lost by dead saguaro as a percentage of total height (live and dead combined) in one unburned and three burned plots (and an average value of the burned) 1-year and 10-years after the 1993 Vista View Fire, TNF, AZ.**

Saguaro growth was estimated by changes in height. Interestingly, there was a net loss in total height over time in the burned plots, while there was no loss for the control (Fig. 8). Burn 1 had the smallest decrease while Burn 6 and Burn 7 had the greatest.

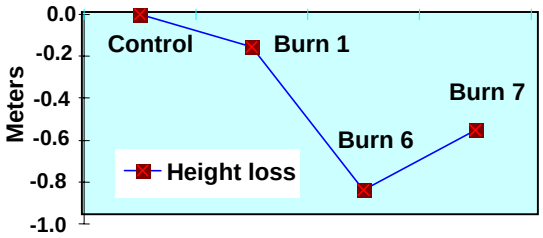

**Figure 8. Burned area saguaro cumulative height loss exceeded growth ten years after the Vista View fire. Unburned area saguaro showed no loss.**

Saguaro growth was observed in the Control and Burn 1 but not in Burn 6 and Burn 7 (Fig. 9.).

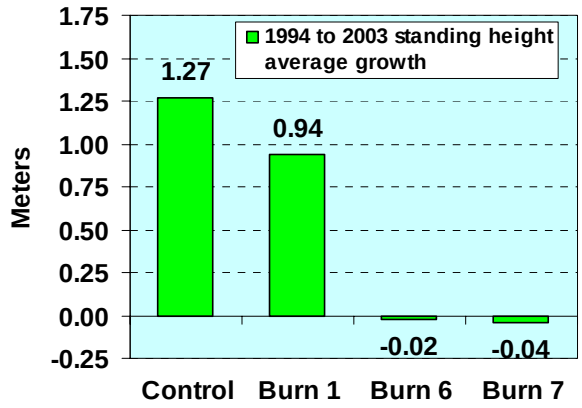


**Figure 9. Average saguaro growth observed 10 years after the 1993 Vista View Fire, Tonto National Forest, AZ.**

Main stems were observed broken at various heights. Most often they broke just above the point of arm formation. Growth trends among all the plots showed that Burn 6 and Burn 7 suffered a greater growth decline due to fallen tops than Burn 1 and the unburned Control (Fig. 10).

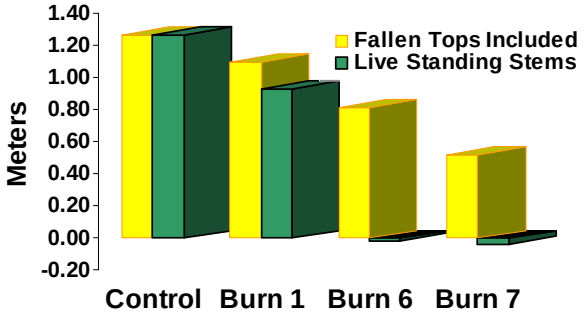


**Figure 10. Surviving live saguaro average height growth accumulated between 1994 and 2003 on burned and unburned plots. Documented growth compares both live standing main stems plus fallen tops when found (yellow) with live standing main stems only (green).**

**4. DISCUSSION**

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We observed a low (8.3%) background level of saguaro mortality in unburned habitat over the span of about a decade. We anticipated higher fire mortality based on our 1-year post-fire observations. Ninety percent of saguaro sustained significant fire injury in the 1993 Vista View Fire (Wilson et. al. 1996). After 10 years saguaro mortality attributable to this fire increased from 19 to 32 percent. More injured saguaro survived than originally expected. One fire-girdled saguaro from Burn 1 that we considered 'dead' during our first evaluation in 1994 was not only still alive in 2003 but grew from 3.1 m to 4.1 m in height. Amazingly, its skeletal ribs were totally exposed for the entire period (Fig. 11).

**Figure 11. A saguaro, girdled to its skeleton, still survives 10 years after the 1993 Vista View Fire Tonto National Forest, AZ.**

One injured saguaro from Burn 6 showed no change in measured height since 1994. It was 1.4 m in height with a DBH of 29.0 and two small arms in 1994, and it was still 1.4 m tall with a DBH of 29.3 and had two small arms in 2003. This saguaro was scared 360 degrees and to it top. The static nature of this individual is indicative of the slow rate of recovery or change seen in this burned desert habitat.

Some of the 68% fire injured saguaro that survived to 2003 had grown in height and produced additional arms. Evident deterioration and partial decay suggest others have become weakened and will eventually die prematurely. Generally, the burned saguaro displayed a lack of vigor as illustrated by reduced growth or broken and stunted individuals. Annual measurements were not collected, so it is possible that 10 year post-fire dead saguaro put on unrecorded growth before dying.

Resource managers on the TNF observed topped and toppled saguaro during 2002 throughout the Forest. Local weather conditions suggest that wind shears were probably responsible for some of the injury observed--particularly for saguaro that lost tops or arms. Because little of this type of mechanical injury was observed in our control plots, we can only hypothesize that the greater damage observed in the burn plots was due to fire-weakened individuals. Similar saguaro windthrow damage was observed by Pierson and Turner (1998). Even when wind shears are considered, our data show marked differences between burned and unburned saguaro survival and growth (Fig. 9). Growth observed on unburned saguaro during the same 10 years post-fire time period suggests that the study area received adequate precipitation following the burn to sustain saguaro at all stages of development.

Fire injured saguaro reproduced after they were injured and before they perished. This delayed mortality appears to still be taking place in conjunction with continued seed production. A major concern for saguaro regeneration relates to the associated vegetative cover that was removed during the fire. Changes in the microhabitat in the burn areas may have ramifications for saguaro progeny that require shelter plants for protection. In an 85-year study of saguaro, Pierson and Turner (1998) reported population declines and recovery through episodic surges of seedling establishment.

Additional analysis of other data collected at 1, 5 and 10 years after the 1993 Vista View and River wildfires will give us further insight into fire effects and rates of saguaro habitat recovery. For future analysis age groups, increments of growth and contribution of arms to growth and reproduction will be addressed.

Presently, based on our developing understanding of disturbance effects on saguaro, the TNF is modifying its grazing and fire policies on this desert rangeland. A greater emphasis is now placed on the protection, maintenance and recovery of this valuable resource. Protective measures include: 1) increases in fire suppression equipment and resources for the immediate attack of all ignitions; 2) public closures of high value areas particularly during high fire danger periods, and 3) the removal or reduction of livestock grazing (per. comm. K. Kerr 2003). Interestingly, recent drought conditions have helped in fire reduction efforts by limiting the growth of contiguous flashy fuels by the ever-present invasive grass and forbs species. Still, too little is known about the long-term consequences of historical range practices and disturbances such as fire on saguaro.

Like the ill-fated gradually dying saguaro, we must wait more than a decade to determine how many progeny were produced and whether or not they were able to survive in a post-fire environment. Another decade or two will be necessary to determine the full impact of the Vista View fire on this saguaro population.

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