

The Role of Fire in the Arizona Upland Subdivision of the Sonoran Desert

1996 Annual Progress Report to Saguaro National Park

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This report was compiled by Todd Esque, Dustin Haines, Michelle Nijhuis, and Pam Swantek, all of whom participated in the annual survey of saguaro mortality. Saguaro transects in the unburned area were established by Ann McLuckie, Michelle Nijhuis and project volunteers. Annual and perennial vegetation surveys were conducted by Michelle Nijhuis and Dustin Haines, and tortoise monitoring was conducted by Michelle Nijhuis with the assistance of park volunteers. Tortoise population surveys were carried out by Steve Hale, Brent Martin and Betsy Wirt. The GIS fire history database was created by Pam Swantek with the assistance of Michelle Nijhuis and project volunteers.

In June 1994, 7.2% of the 204 saguaros surveyed within the boundary of the May 1994 Mother's Day Burn in Saguaro National Park East had died as a result of the fire. An additional 16.2% mortality was recorded in July 1995. In June 1996, an additional 2.4% mortality was observed. Within the burn area, another 228 saguaros were surveyed for mortality and reproductive condition in 1994 and 1996. These data will be used to estimate mortality rates in the final analysis. In March through May of 1996, 496 saguaros were permanently tagged in an area adjacent to the northern boundary of the burn. These saguaros will be surveyed annually in order to compare saguaro mortality rates in burned and unburned areas. Locations of all tagged saguaros were recorded with a GPS unit, and these data are presently being used to create a GIS coverage in ArcView.

Eleven adult tortoises were fitted with Telonics radiotransmitters in August 1996. All tortoises were greater than 200 mm MCL. Six tortoises (3 male, 3 female) were located within the boundary of the Mother's Day Burn, and five tortoises (2 male, 3 female) were located in the unburned area adjacent to the northern boundary of the burn. After radiotransmitters were attached, tortoises were located with radiotelemetry equipment at two times per month from August through December 1996. These locations were recorded with a GPS unit, and the coordinates are being used to create GIS coverages in ArcView. In November, StowAway temperature dataloggers were attached to two tortoises within the burn. Population surveys were conducted on 2 km² plots in August and September of 1996. Within the Mother's Day Burn, 34 live tortoises and no dead tortoises were observed in 279 hours of search time.

In September 1996, annual vegetation was sampled within the burn and control areas. Biomass and species composition was estimated in the open and under the cover of perennial shrubs using randomly placed 0.5 square meter quadrats, 50 within the burn and 50 in the control. Annual biomass was greater within the burn than on the control (open and under shrubs combined: 625.39 g in the burn, 203.30 g in the control), and biomass was significantly greater in the open than under the cover of perennial shrubs (burn and control combined: 600.24 g in open, 228.45 g under shrubs). In November 1996, perennial vegetation was sampled within the burn and control areas. Sixteen 50-meter long line-intercept transects, eight within the burn and eight within the control, were used to estimate perennial cover. Sixteen belt transects, each 50 meters long and two meters wide, were used to determine perennial species composition and relative species density. There were no significant differences in total cover between the burn and control areas, although individual species did exhibit differences in cover and density between the burn and control areas. As part of this vegetation sampling, a list has been developed of the annual and perennial plant species identified within the boundary of the burn. This list has been updated throughout the year and species will continue to be added as they are encountered.

A bibliography of literature related to the fire ecology of desert ecosystems has also been compiled this year. Over 100 citations of journal articles, technical reports, graduate theses and dissertations concerning fire history, native plant mortality, exotic plant invasions, and effects of fire on

desert wildlife have been entered into a ProCite database. In January 1997, a project technician gave a presentation to park volunteers on the interaction between wildfire and exotic grass invasions.

Database design and development have been completed for fire-related data contained in USDI 1202 fire report forms for Saguaro National Park from 1937 to 1995. This Microsoft Access database is capable of printing data in 1202 report form and internally linking the data to a GIS system. Point and polygon locations of the fires described in existing 1202 reports have been digitized from the park's fire atlas and attributed via this database. An electronic version of the "code book" used for 1202 data entry has been included in the GIS database as a series of lookup tables. Base coverages of Saguaro National Park have been generated in ARC/INFO, including park boundary, topography, hydrology, park roads, trails, wilderness, landmarks, slope, and aspect. Coverages currently being established include historic vegetation, historic grazing allotments and soil types. All coverages are accessible on personal computers with ArcView 2.1 or higher. Many of these coverages are presently available to personnel at Saguaro National Park, and this database has been presented to park personnel to demonstrate the role of GIS in resource management. This historical fire database has been demonstrated to students at the University of Arizona to address issues regarding the role of fire in the Arizona Upland subdivision of the Sonoran Desert.

Bridget H. Watts

From: Bridget H. Watts [bridget@noao.edu]
Sent: Thursday, January 15, 1998 9:49 PM
To: 'Bridget H. Watts'; 'Cecil Schwalbe'; 'Dustin Haines'; 'Jeff Clark'; 'Ryan Schwarz'; 'Sara Eckert'; 'Todd Esque'; 'Todd Esque-usgs'
Subject: 97 Annual report draft

The Role of Fire in the Arizona Upland Subdivision of the Sonoran Desert

1997 Annual Progress Report to Saguaro National Park
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This report was compiled by Dustin Haines and Bridget Watts. Project participants also include Cecil Schwalbe, Todd Esque, Michelle Nijhuis, Pam Swantek, Jeff Clark, Sara Eckert, Ryan Schwarz, Betsy Wirt and project volunteers. Annual vegetation surveys were conducted by D. Haines, T. Esque and four volunteers (19-23 March) and by D. Haines and J. Clark (15-21 September). The annual saguaro survey was conducted by D. Haines, T. Esque, S. Eckert, R. Schwarz and four volunteers (15-18, 20-23 July). Tortoise monitoring was conducted by M. Nijhuis, D. Haines, T. Esque, J. Clark, P. Swantek, C. Schwalbe, S. Eckert, R. Schwarz and B. Watts. T. Esque gave a presentation at the Sonoran Desert Tortoise Symposium on 26 January. ^{possible} weather station site at Chimínea Canyon was ~~linked to and~~ evaluated on 15 December. Weather monitoring station components for three stations were purchased and assembled by J. Clark, S. Eckert, R. Schwarz and B. Watts. ^{P. Haines}

In June 1994, 6.19% of the 436 saguaros surveyed within the boundary of the May 1994 Mother's Day Burn in Saguaro National Park East had died as a result of the fire. An additional 17.71% mortality was recorded in July 1995, although only about 40% of the original saguaros were surveyed. By July 1997, the total mortality within the burn area was 21.4%, with 430 of the 436 saguaros accounted for. In 1996, 496 saguaros were tagged in a control area north of the burn. The 1996 to 1997 annual mortality in the control area was 0.81%, whereas the corresponding annual mortality in the burn area was 2.03%. ^{XX/xx}

Tortoises fitted with radiotransmitters were located sporadically in January and February, then on a weekly basis from September to December. Of the tortoises radioed at the start of the year, one died and ~~one was lost due to a dead battery in the~~ radiotransmitter. ^{XX/xx} ^{cocker died}

In April 1997, annual vegetation was sampled within the burn and control areas. Biomass was estimated in the open and under the cover of perennial shrubs. Annual biomass was greater within the burn than in the control area (averages of 123.34 kg/hectare in the burn and 69.11 kg/hectare in the control). Biomass was greater under perennial shrubs than in the open (averages of 96.62 kg/hectare under shrubs and 95.84 kg/hectare in the open). ^{unburned} ^{in the canopy}

In September 1997, annual biomass was greater within the burn (averages of 35.66 kg/hectare in the burn and 13.82 kg/hectare in the control), and biomass was greater in the open than under cover (averages of 29.58 kg/hectare in the open and 19.90 kg/hectare under cover). ^{mean} ^{unburned areas} ^{vs}

The report looks great to me. I have a suggestion on the first paragraph where you list who did what. In the sections on Annual Vegetation and Annual Saguaro, it would be a good idea to list Todd first, as he is the reason why those surveys even got done. Also, I had a big part in purchasing the weather station (researching what to buy and writing the purchase orders), but I don't need to be listed first--you guys have spent more time on getting them assembled, etc. than I spent on the purchasing aspects.

One number in the paragraph on saguaro mortality isn't right--I probably mis-typed it on my e-mail to you. The annual mortality from 1994-1995 is 17.41%, not 17.31% (second sentence in that paragraph).

You may want to include standard deviations with the biomass figures, but I'm not sure. Perhaps Cecil or Todd will have more input on that. Those are the only comments I have. I don't know what to tell you about including more info. on the weather station, or about more info on the fire database.

Annual Report 2000

Objectives:

The primary objective of this study was to acquire a better understanding of the role of fire in the vegetative community of the Arizona Upland Subdivision of the Sonoran Desert. The Mother's Day Fire, on May 8, 1994, burned approximately 1200 acres, 340 acres of which were in saguaro and desert tortoise habitat in the Rincon Mountain District of Saguaro National Park.

Specific objectives were to 1) conduct yearly surveys of annual plant biomass, perennial plant density and composition, and saguaro mortality in burned and unburned areas, 2) determine desert tortoise population size in burned and adjacent unburned areas, 3) use radiotelemetry to compare movement patterns and home range sizes of tortoises in burned and unburned areas, and 4) construct remote, solar-powered weather stations at three sites (burned, unburned, and the highest known tortoise site at Saguaro National Park) to investigate what role site variation in micrometeorology might have on tortoises in these burned, unburned, and high elevation sites.

Findings and status:

During the 1999 field season a number of radio telemeters on the desert tortoises quit transmitting prematurely, so we conducted a massive tortoise search in July of 2000 to look for missing and new tortoises in the burned and unburned habitats. We found 18 tortoises during the two-day search and fitted six of them with radio transmitters. We located all radioed tortoises weekly during the active season.

We surveyed over 900 tagged saguaros in the burned and unburned areas in August of 2000. Mortality rates in the burned and unburned areas since last surveying in 1998 were not significantly different. Mortality rates in both areas were similar, showing higher mortality in the larger size classes. We sampled annual above-ground biomass three times during the 2000 field season: at the peak of spring annual growth, at the peak of summer annual growth, and during mid-summer to measure the available fuel load. We are in the process of identifying unknown annuals and weighing the samples for each quadrat. Using both line transects and established plots, we measured perennial plant cover and density. We are currently completing statistical analysis of the perennial plant data.

Reports Produced:

Esque, T.C., M.J. Nijhuis, D.F. Haines, J.W. Clark, P.J. Swantek, and C.R. Schwalbe. 1999. Short-term effects of fire on desert tortoises of Saguaro National Park. P. 36-37 in L. Benson and B. Gebow, editors. *A Century of Parks in Southern Arizona: Second Conference on Research and Resource Management in Southern Arizona National Park Areas, Extended Abstracts*. USGS Sonoran Desert Field Station, The University of Arizona, Tucson.

Schwalbe, C.R., T.C. Esque, M.J. Nijhuis, D.F. Haines, J.W. Clark, and P.J. Swantek. 1999. Effects of fire on Arizona Upland desert scrub at Saguaro National Park. P. 107-109 in L. Benson and B. Gebow, editors. *A Century of Parks in Southern Arizona: Second Conference on Research and Resource Management in Southern Arizona National Park Areas, Extended Abstracts*. USGS Sonoran Desert Field Station, The University of Arizona, Tucson.

Esque, T.C., C.R. Schwalbe, C.R. Tracy, R.C. Averill-Murray, and J.M. Howland. 2000. A river runs through them: conservation status of desert tortoises in the Sonoran and Mojave deserts. P. 25-27 in W.L. Halvorson and B.S. Gebow, editors. *Creative Cooperation in Resource Management: Third Conference on Research and Resource Management in the Southwestern Deserts, Extended Abstracts*. USGS Sonoran Desert Field Station, The University of Arizona, Tucson.

Schwalbe, C.R., T.C. Esque, P.J. Anning, and W.L. Halvorson. 2000. Exotic grasses, long-lived species, and managing desert landscapes: a case history at Saguaro National Park. P. 87 in W. L. Halvorson and B.S. Gebow, editors. *Creative Cooperation in Resource Management: Third*

Conference on Research and Resource Management in the Southwestern Deserts, Extended
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- Esque, T.C., C.R. Schwalbe, C.R. Tracy, R.C. Averill-Murray, and J.M. Howland. 2000. A river runs through them: conservation status of desert tortoises in the Sonoran and Mojave deserts. P. 25-27 in W.L. Halvorson and B.S. Gebow, editors. Creative Cooperation in Resource Management: Third Conference on Research and Resource Management in the Southwestern Deserts, Extended Abstracts. USGS Sonoran Desert Field Station, The University of Arizona, Tucson.
- Schwalbe, C.R., T.C. Esque, P.J. Anning, and W.L. Halvorson. 2000. Exotic grasses, long-lived species, and managing desert landscapes: a case history at Saguaro National Park. P. 87 in W. L. Halvorson and B.S. Gebow, editors. Creative Cooperation in Resource Management: Third Conference on Research and Resource Management in the Southwestern Deserts, Extended Abstracts. USGS Sonoran Desert Field Station, The University of Arizona, Tucson.
- Esque, T.C., M.J. Nijhuis, D.F. Haines, J.W. Clark, P.J. Swantek, and C.R. Schwalbe. 1998. Short-term effects of fire on desert tortoises at Saguaro National Park. 23rd Annual Desert Tortoise Council Symposium, Tucson, AZ.

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Tucson, AZ

Short-term Effects of Fire on Desert Tortoises at Saguaro National Park

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Wildfires are known to kill individual desert tortoises, but effects of fires on tortoise populations are largely unstudied. The Mother's Day Fire (8 May 1994) burned approximately 138 hectares (340 acres) of desert tortoise habitat on the Rincon Management Unit of Saguaro National Park. On standardized surveys conducted in June 1994, we found six live and seven dead tortoises, five of which were apparently killed by the fire. We estimate this fire-caused mortality to be approximately 12% of the adult tortoise population that inhabited the area prior to the burn, a catastrophic loss estimated at six times the expected annualized mortality rate for a sustaining population of this long-lived species. All live desert tortoises appeared to be healthy and continue to be monitored and compared to tortoises in an adjacent unburned site. Fires also may have longer lasting effects on tortoises due to habitat alteration. Approximately one square kilometer plots (0.6 x 0.6 miles) in burned and nearby unburned habitats were intensively surveyed for tortoises during summer 1996. Using radiotelemetry in 1997, we tracked tortoises in burned and unburned areas.

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Exotic Grasses, Long-lived Species, and Managing Desert Landscapes: a Case History at Saguaro National Park

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Desert tortoises and saguaros are long-lived organisms that symbolize the Sonoran Desert of Arizona and northern Sonora. However these charismatic species are threatened by frequent disturbances in desert communities. Our research focuses on the short-term direct and long-term indirect effects of wildfire and exotic grasses in Arizona Upland communities of the Sonoran Desert. Our study area is at Saguaro National Park, and relationships between fire, alien grasses, and native desert inhabitants are relevant throughout the desert. We found that fires of moderate intensity can cause population level declines for desert tortoise and saguaros. We quantified losses of greater than 20% of the adult saguaro population, and 11% of the adult desert tortoise population as a direct result of fire. It appears that all tortoise mortalities occurred on the

surface as a direct result of intense temperatures during the Mother's Day fire of 1994. No carcasses were found in caves or burrows.

We found little evidence to conclude that the fire of moderate intensity negatively impacted desert tortoises for 4 years following the fire. In contrast, damage to the saguaro population was attenuated with mortality in a burned study population exceeding background mortality of our control population of unburned saguaros for five years after the initial fire. These mortality rates are catastrophic losses for long-lived species. Our ability to manage future Sonoran Desert communities depends largely on how we manage a coterie of exotic annual Mediterranean grasses (*Bromus madritensis*) and perennial African grasses (*Pennisetum* spp).

Effects of Fire on Arizona Upland Desertscrub at Saguaro National Park

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Introduction

Desert wildfires have become increasingly prevalent in Arizona Upland habitats at the wildlands/urban interface (Swanek 1998). These fires can be a threat to native plants, such as the saguaro, that are not adapted to exposure to high temperatures (Steenburgh and Lowe 1977). Also, desert wildland fires have increased in frequency with the encroachment of alien annual and perennial grasses that, when dried, create abundant fine fuels that carry fires in habitats that formerly did not support large fires (Esque et al. 1994). We report preliminary results on a retrospective natural experiment designed to determine how plant community compositions change as a result of wildfire in this desert habitat. Our study site, the Mother's Day Burn within the Rincon Mountain District of Saguaro National Park, is a fire that occurred on 8 May 1994. We report results from the first 5 years of a long-term study.

Methods

This report describes a retrospective study, thus our treatment of burned habitat *versus* unburned habitat does not include a true control in the experimental sense. We selected the portions of the Mother's Day Burn that occurred in Arizona Upland and excluded portions of the burn that occurred in Desert Grassland. We also selected an unburned habitat just north of the burned habitat. The wildfire that caused the disturbance was essentially stopped along an intermittent stream. We sampled annual plants in March (1997 and 1998), and again in September (1996 and 1997) to coincide with the peak production after winter and summer rains.

Aboveground production was characterized on 0.5 m square (20 in square) quadrats. A Global Positioning Unit (GPS unit) was used to locate random sampling sites. We sampled 50 quadrats in burned *versus* unburned areas, and within each treatment 25 quadrats each in open *versus* covered microsites. Open microsites were at least one meter from the drip line of large woody plants. Covered microsites were within the dripline of the nearest woody shrub (*Cercidium microphyllum*, *Acacia greggii*, *Prosopis velutina*, or *Simmondsia chinensis*). The data were analyzed using Analysis of Variance with year, treatment, and microsite as main effects.

We also estimated cover for perennial plants on 16 randomly located, 50-m (164 ft) line-intercept transects. The north-south transects were divided equally between the burned and unburned treatments. Analysis of variance was used to test differences in the means between treatments and years.

Saguaro data were collected along point-quarter transects that were situated at 200 m intervals along the western edge of the burned study plot. The unburned plot was defined by extending the line formed by the starting points for the burned plots. Points on the transects were located at 200 m (650 ft) intervals. Each saguaro was permanently located with a 16-penny spike placed in the ground on the south side of the saguaro and individually numbered with aluminum tags. Every marked saguaro was registered in a GPS data base. Saguaro were only considered dead if they were 100% blackened by fire, or if their stems were broken off at the base.

Results

The flora of the study plots includes 140 species of plants; the number is expected to rise as data from 1998 are added. There were 38 species of winter annuals identified on quadrats in 1997. The top five species on unburned plots included natives *Pectocarya recurvata* (26.9% of total production collected), *Plantago purshii* (25.6%), *Festuca octaflora* (6.1%), *Cryptantha barbigera* (4.7%), and the alien annual grass *Bromus madritensis* (21.5%). On burned quadrats the percentage of production collected for the top five species was *Plantago purshii* (22.4%), *Festuca octaflora* (14.5%), *Stylocline* sp. (14.3%), *Bromus madritensis* (12.7%), and *Aristida adscensionis* (10.4%). Treatment (burned versus unburned) and microhabitat (covered versus open) were not significantly different for winter annual plant production in 1997. However, there was a significantly less overall production in 1997 than in 1998 (plot means: 9.6 g versus 35.9 g).

In 1996, eleven species of summer annuals occurred on quadrats, while in 1997 sixteen species of summer annual plants were identified, with no alien annuals collected. The top five unburned annual species by total production were *Bouteloua aristidoides* (33.4%), *Bracharia arizonica* (27.8%), *Aristida adscensionis* (17.7%), *Boerhaavia intermedia* (17.6%), and *Euphorbia hyssopifolia* (1.4%). In 1996 the top five annual species by production on burned plots were *Bouteloua aristidoides* (49.5%), *Bracharia arizonica* (27.0%), *Boerhaavia intermedia* (14.3%), *Euphorbia hyssopifolia* (5.2%) and *Mollugo verticulata* (1.7%).

Summer annual production was significantly different between treatments, microsites, and years—greater in 1996 than in 1997. Per plot means are listed below:

- ♦ 35.8 g for the burned-open plots versus 12.2 g for the unburned-open plots in 1996
- ♦ 14.2 g for burned-covered plots versus 4.1 g for the unburned-covered plots in 1996
- ♦ 4.7 g for the burned-open plots versus 1.2 g for the unburned-open plots in 1997
- ♦ 2.4 g for burned-covered plots versus 1.5 g for the unburned-covered plots in 1997

Fifty-one species of perennial plants were registered on 800 m (2600 ft) of line intercept transects in the burned and unburned plots. *Eragrostis lehmanniana* and *Rhynchelytrum repens* are two alien perennial grasses that were found on transects. *Pennisetum ciliare* is another important alien annual plant that was found growing in both burned and unburned areas over 1 km (0.6 mi) from roadsides. The top five native perennial plants found on transects for burned plots were *Acacia greggii*, *Cercidium microphyllum*, *Calliandra eriophylla*, *Bouteloua repens*, and *Encelia farinosa*. On unburned plots the top five species by amount of cover on transects were *Calliandra eriophylla*, *Bouteloua repens*, *Cercidium microphyllum*, and *Jatropha cardiophylla*. Mean cover was higher on burned transects, but not significantly so.

We permanently marked 436 saguaros in the burned habitat in 1994, and 496 saguaros in the unburned habitat in 1997. After an initial catastrophic die-off within one year of the fire, the mortality rate tapered off; we measured 6.2% saguaro mortality in the burned habitat in 1994, 17.7% in 1995, 2.5% in 1996, and 2.0% in 1997. All of the saguaros determined to be dead in 1994 were less than 1 m (3.2 ft) in height. All saguaro size classes were represented in the 1997 mortality data. We observed 1.4% mortality in the unburned transects in 1997. If this represents a typical year for mortality, then mortality rates due to disturbance are still above background for this population of saguaros, and we have recorded 22.1% mortality across the burned area since the fire. This level is considered a catastrophic loss for a long-lives species such as the saguaro.

Discussion

Though the Mother's Day Fire was of moderate and not high intensity it resulted in significant losses of saguaros. We detected only small differences between treatment plots for winter and summer annual plants, and perennial plant community compositions. We also did not observe an overwhelming abundance of alien perennial or annual plants subsequent to the fire. However, we could still observe changes in the plant community composition that have not yet manifested

themselves. One unexpected result of this work was to learn that the alien perennials *Pennisetum ciliare*, and *Rhynchelytrum repens* have invaded the backcountry in Saguaro National Park over 1 km (0.6 mi) from roadsides where these plants have been known for years. This study has been the catalyst for subsequent proposals to control and eradicate some of these noxious alien plants.

Conclusions from retrospective research must be considered cautiously because we have no *a priori* knowledge of how the paired plots compared. The unburned plot serves as the closest approximation of a control plot that we could establish. Perhaps the greatest value of these plots lie in their use over time. As we understand the vegetation patterns on these plots better, we can detect any changes that occur and use these changes in comparisons of the burned and unburned plots over time.

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