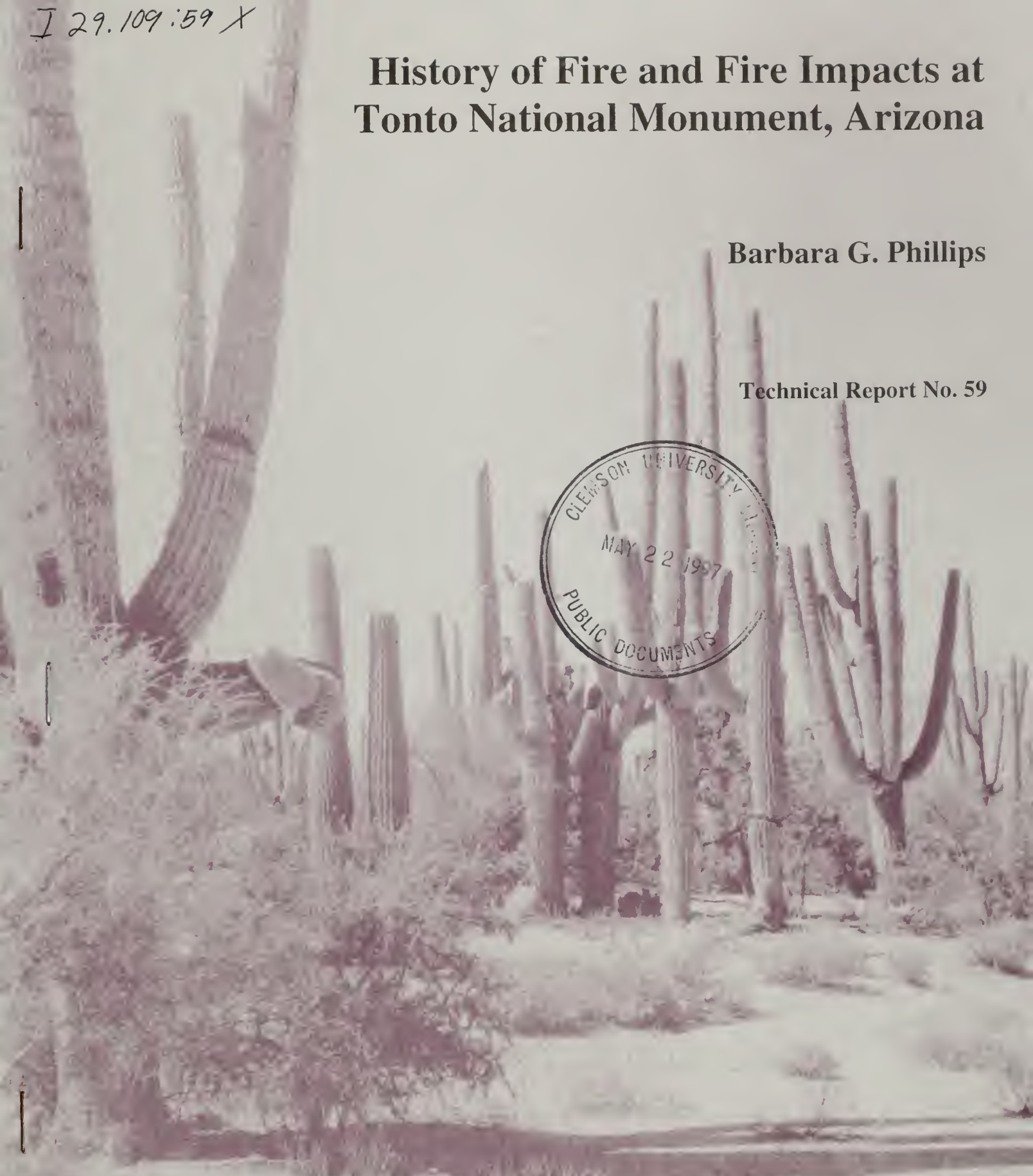
History of Fire and Fire Impacts at Tonto National Monument, Arizona

Barbara G. Phillips

Technical Report No. 59



United States Geological Survey
Cooperative Park Studies Unit
The University of Arizona ♦ Tucson, Arizona

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The University of Arizona, Tucson

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May 1997

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Abstract

A study of the history of fire and fire impacts on desert plants of Tonto National Monument was made in 1990–1991 by the author. Four major fires and several minor ones have occurred on the monument since 1942, all lightning caused. Twenty photo stations set up after the 1964 Schultz Fire were found and replicate photos made at the rebar-marked sites. Photographic documentation of the impacts of several fires made comparison of vegetation changes over time possible.

Five monitoring plots were established in March and April 1990, representing a variety of vegetation associations in burned and unburned areas. An inventory of plants of the monument was completed in 1964 by Burgess (1965) prior to the first major fire. Comparisons of change across the 26-year span were made during this study. The effects of fire—in some areas multiple fires—were determined and reported on.

Introduction

A study of the history of fire and fire impacts on the rich succulent desert of the Arizona Upland Subdivision of Sonoran Desertscrub (Brown and Lowe 1980) at Tonto National Monument (TONT), Arizona (Fig. 1), was conducted by the author in 1990 and 1991. The 4 major goals of this study were to (1) synthesize records on the history of fire in the monument; (2) establish comparison plots in burned and unburned vegetation; (3) rephotograph the photo stations set up after the 1964 Schultz Fire; and (4) survey and assess impacts of fire on cacti, succulents, special status and other notable plants.

In July 1964, 218.5 ha in the western portion of the monument burned. Three major fires (1970, 1976, 1980) subsequent to the Schultz Fire and several minor fires have burned and reburned portions of the 1964 fire area. Some of the line-intercept transects (Strong 1962) that Strong selected in 1961 for vegetation sampling were in areas subsequently burned by the Schultz Fire. A resurvey of these transects by Brian (1991) pointed out that changes in the plant community structure had occurred. Although published by Burgess in 1965, an inventory of the flowering plants and ferns of the monument had been completed at the time of the 1964 fire, providing documentation of species occurrence on the monument prior to most of the fires.

Fire could become a significant selective force in shaping the life-history traits of species (Rogers and Steele 1980) and could strongly influence the community structure of the desert, depending upon fire severity and frequency. The presence of lush succulent Upper Sonoran vegetation in unburned areas at TONT, and the documented evidence of several fires provide a unique opportunity to assess the immediate, mid-term (26 years), and repeated impacts of fire on vegetation not adapted to fire. "No community can be adapted to fires that occur more frequently than the period required for the community to replace the majority of its original species in their former proportions" (Rogers and Steele 1980).

Relating the observations of today to the fire history of the monument provides avenues for interpreting the current vegetation patterns and the historic impact of fire in certain portions of TONT. Noted in this report are post-fire conditions of vegetation, including death, recovery due to different types of responses, degree of recovery, changes in native species composition (Rogers and Steele 1980), and introduction of nonnative plants (Phillips 1992; Jenkins et al. 1995). Immediately after the Schultz Fire, photographic documentation of the impacts of the fire was made at 20 staked sites. Thereafter, photos were taken at regular intervals until September 1972. Photographs were also taken of fire impacts after several more recent fires. Comparing photographs made many years apart provides an effective means for investigating vegetation changes (Hastings and Turner 1965; Gruell 1980; Bowers 1990).

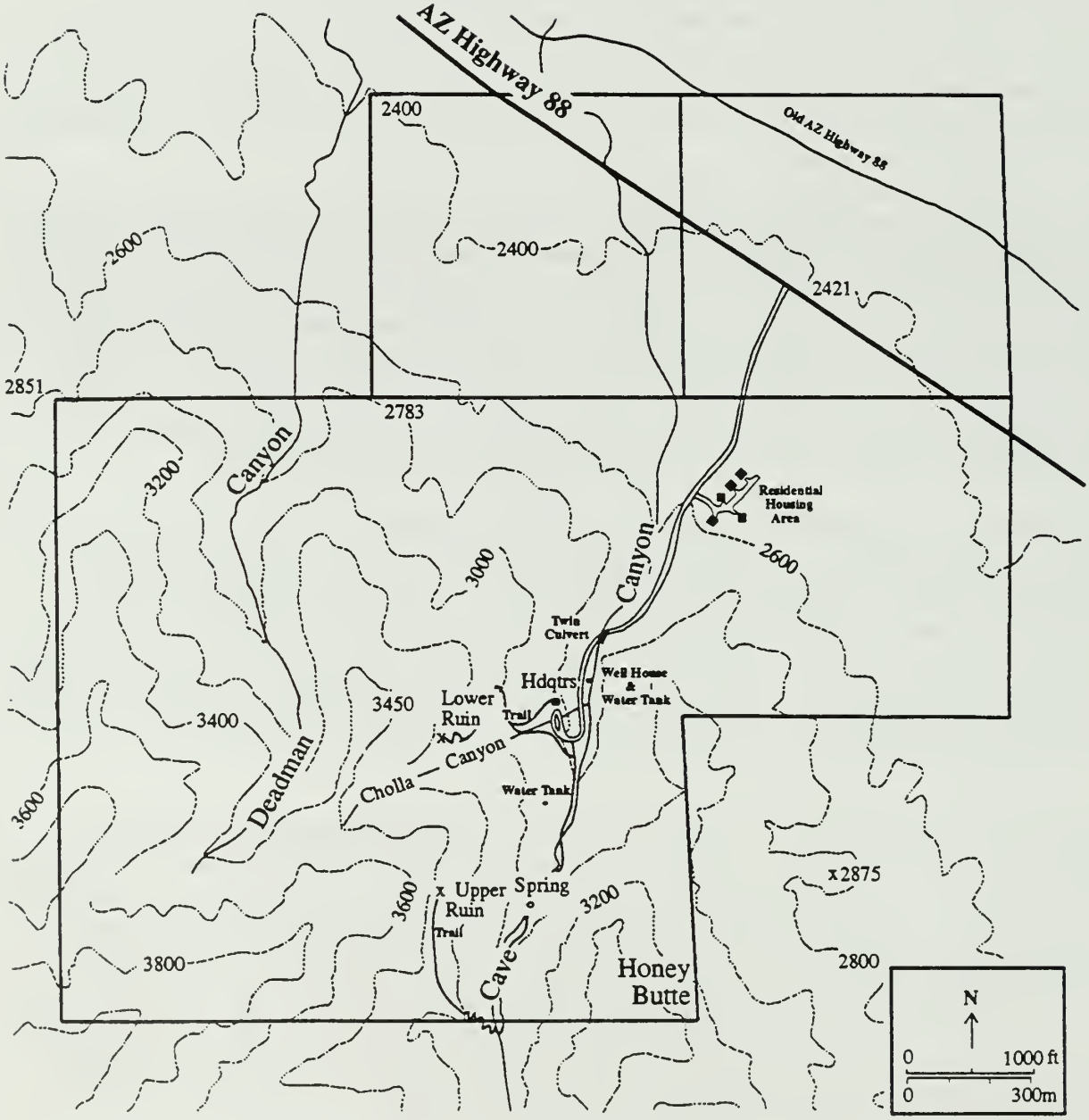


Figure 1. Tonto National Monument, Arizona.

Documentation of Fires

Methods

A documentation of the fire history and the resulting impacts of fire on the vegetation at TONT was made using fire logs located at TONT and Tonto National Forest. Supplementary material such as monument supervisors' reports, memoranda, archival letters, published literature, maps, and photographs was also consulted. Interviews were conducted with some U.S. Forest Service (USFS) personnel who were involved in particular fires or have responsibility for maintaining information regarding fires.

Results

Table 1 lists the fires that have occurred on TONT between 1942 and 1991. A series of maps showing fire boundaries is included (Figs. 2–7). The earliest documention of fires in the Tonto National Forest is on the Fire History Map of the fires of Tonto National Forest (Forest Service 1969), according to T. Bos, Tonto National Forest (pers. comm.). No record of fires on the monument earlier than 1947 was found in the TONT history files. According to F. Morrison, TONT (pers. comm.), no fires have occurred on the monument since 1984. For clarity of presentation, the fire record will be presented in chronological order.

1947

This fire is documented only on the Fire History Map of the fires of Tonto National Forest (Forest Service 1969). This fire was centered around Honey Butte and appears to have entered the monument only in the very extreme southeastern corner of the monument. Most of the burn was located on national forest lands east and south of the monument (Fig. 2).

1964

The Schultz Fire was the largest fire recorded as occurring on the monument. Ignited by lightning on 27 June 1964, the fire was attacked 13 minutes after it started but took 136 hours to control. It burned 2,023.5 ha of national forest land (Forest Service 1964).

On 1 July, the fire moved onto the monument, by nightfall burning 218.5 ha. The fire was contained by 2000 hr. A detailed map (Fig. 3) shows the areas burned and unburned.

Apache and Zuni fire fighters fought this fire. A fire line was constructed from the Cactus Patch Trail down to the bottom of Cholla Canyon. The hillside above Cactus Patch Trail was backfired. According to R. Wagenfahr, Tonto National Forest (pers. comm.), who fought on the 1964 fire, fire hoses were laid from Roosevelt Lake to the buildings. There was some burning around the buildings. Twenty photo stations were installed following this fire (Fig. 8).

Not much written documentation was found for this fire. There are no records of it at TONT or Tonto National Forest. According to T. Bos (pers. comm.), there was a fatality on this fire. A tanker plane went down while fighting the fire. Bos hypothesized that the records were sequestered for litigation and have never been returned. Figures 8–13 show scenes taken after this fire and rephotographed more than 20 years later.

Table 1. Fires occurring on Tonto National Monument, 1942–1991.

Name	Date started	Size (ha)	Location on monument	Figure #
Unknown	1947	40.5	S 1/2 SE 1/4 Sec 34	2
Schultz	27 June 1964	218	Most of Sec 34; SW 1/4 SE 1/4 Sec 27	3
Unknown[1]	1968	unknown	Cave Canyon area	N/A
Cottonwood	3 July 1970	81	S 1/2 SE 1/4 Sec 34; SE1/4 SW 1/4 Sec 34	4
Ruin	14 August 1973	0.4	NE 1/4 SW 1/4 Sec 34	5
Tonto	14 August 1973	0.4	NE 1/4 SW 1/4 Sec 34	5
Trough	14 July 1974	< 0.4	SE 1/4 NE 1/4 Sec 34	5
Monument	18 May 1976	101	S 1/2 SE 1/4 Sec 34; SE 1/4 SW 1/4 Sec 34; SE 1/4 NE 1/4 Sec 34; S 1/2 NW 1/4 Sec 35	6
Deadman	25 July 1976	0.8	NW 1/4 NW 1/4 Sec 34	5
Dead	10 August 1979	0.4	NW 1/4 NW 1/4 Sec 34	5
Monument (#312208)	23 July 1980	40.5	S 1/2 SE 1/4 Sec 34; SE 1/4 SW 1/4 Sec 34	7
Honey	24 July 1983	1.2	NW 1/4 SW 1/4 Sec 34	5
Monument (#312100)	19 July 1984	0.4	SW 1/4 NE 1/4 Sec 34	5

[1]Reported by Valder (1976a, b).

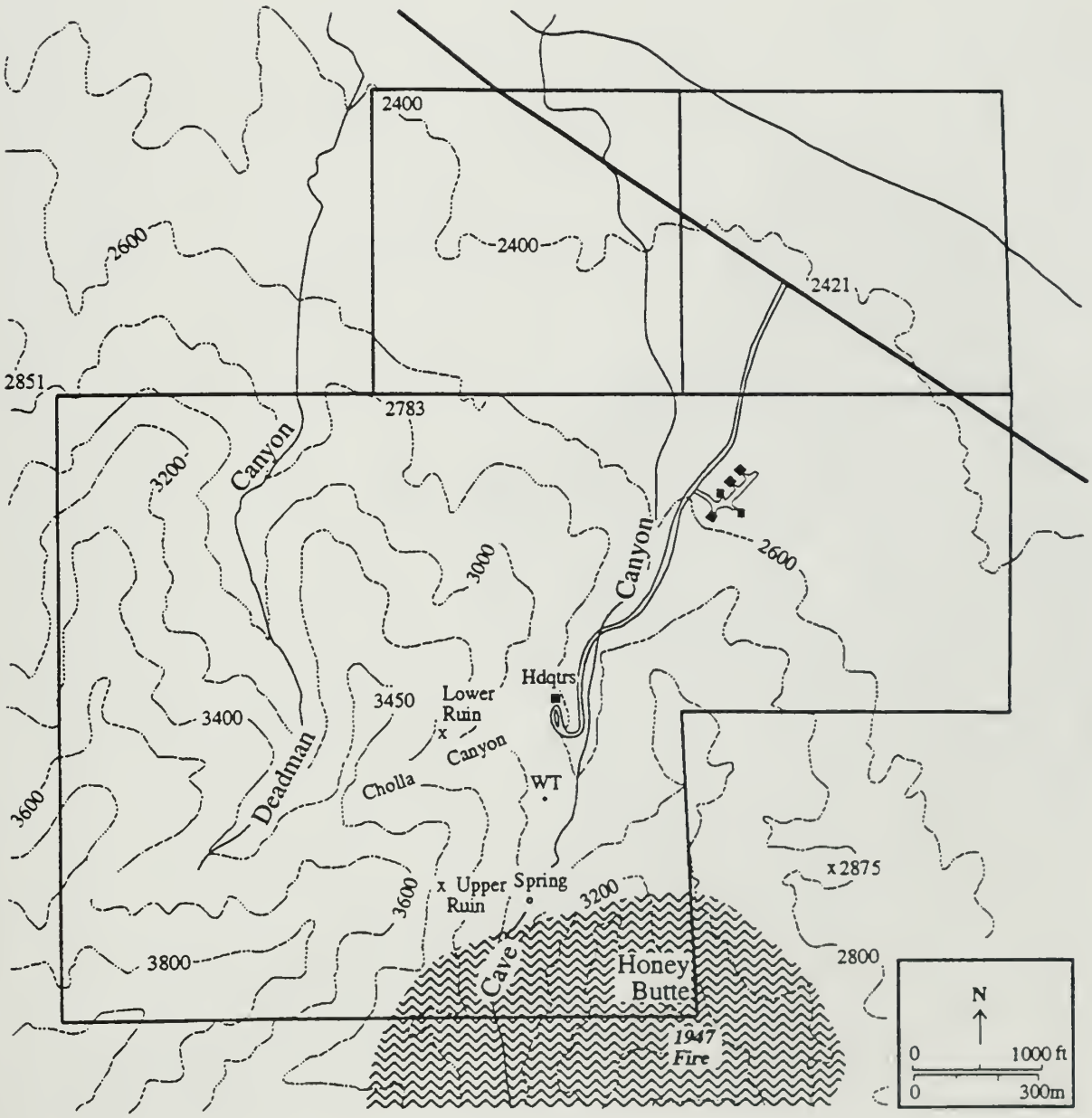


Figure 2. Fire boundaries, Tonto National Monument, 1947.

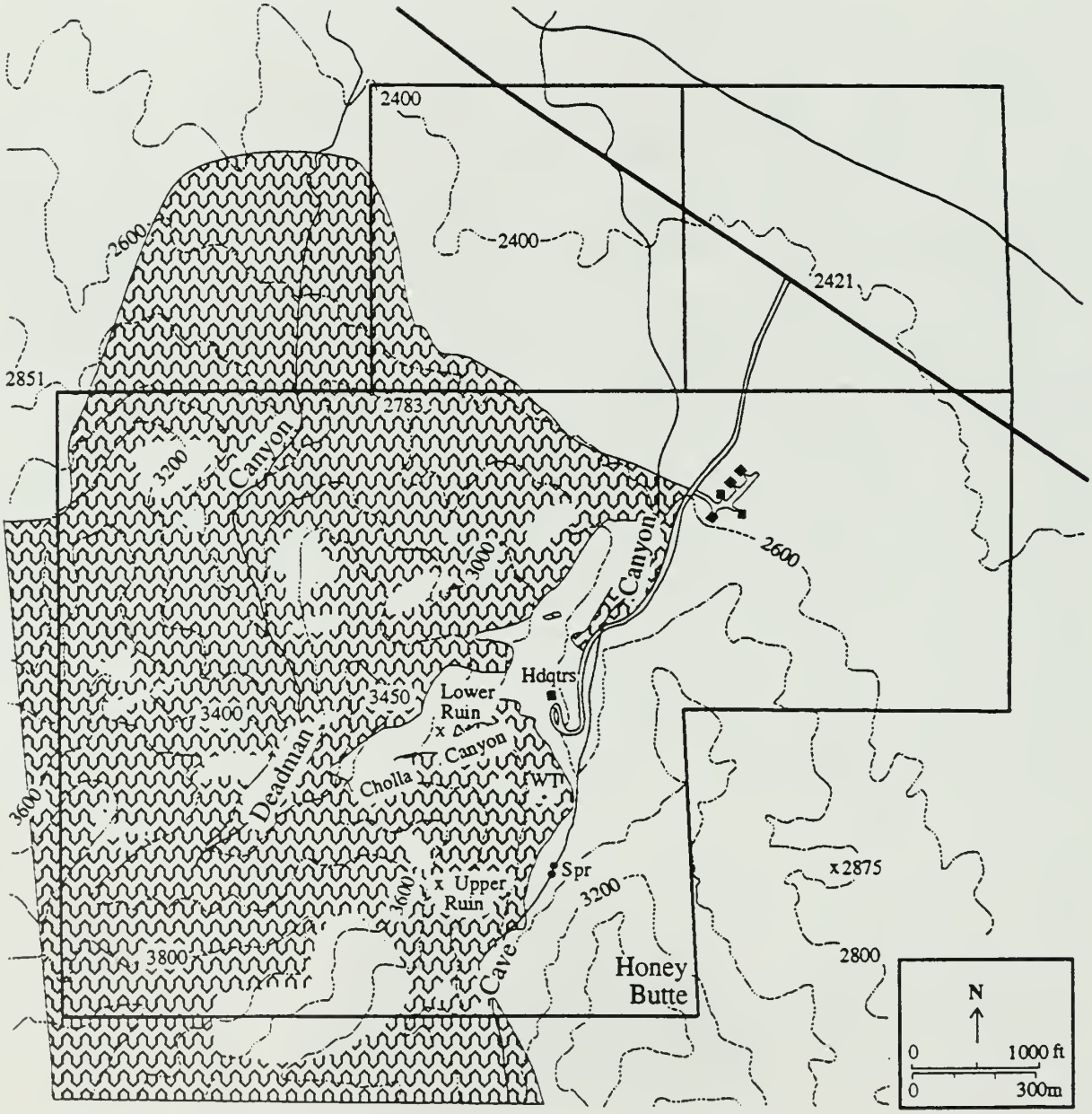


Figure 3. Schultz Fire boundaries, Tonto National Monument, 1964.

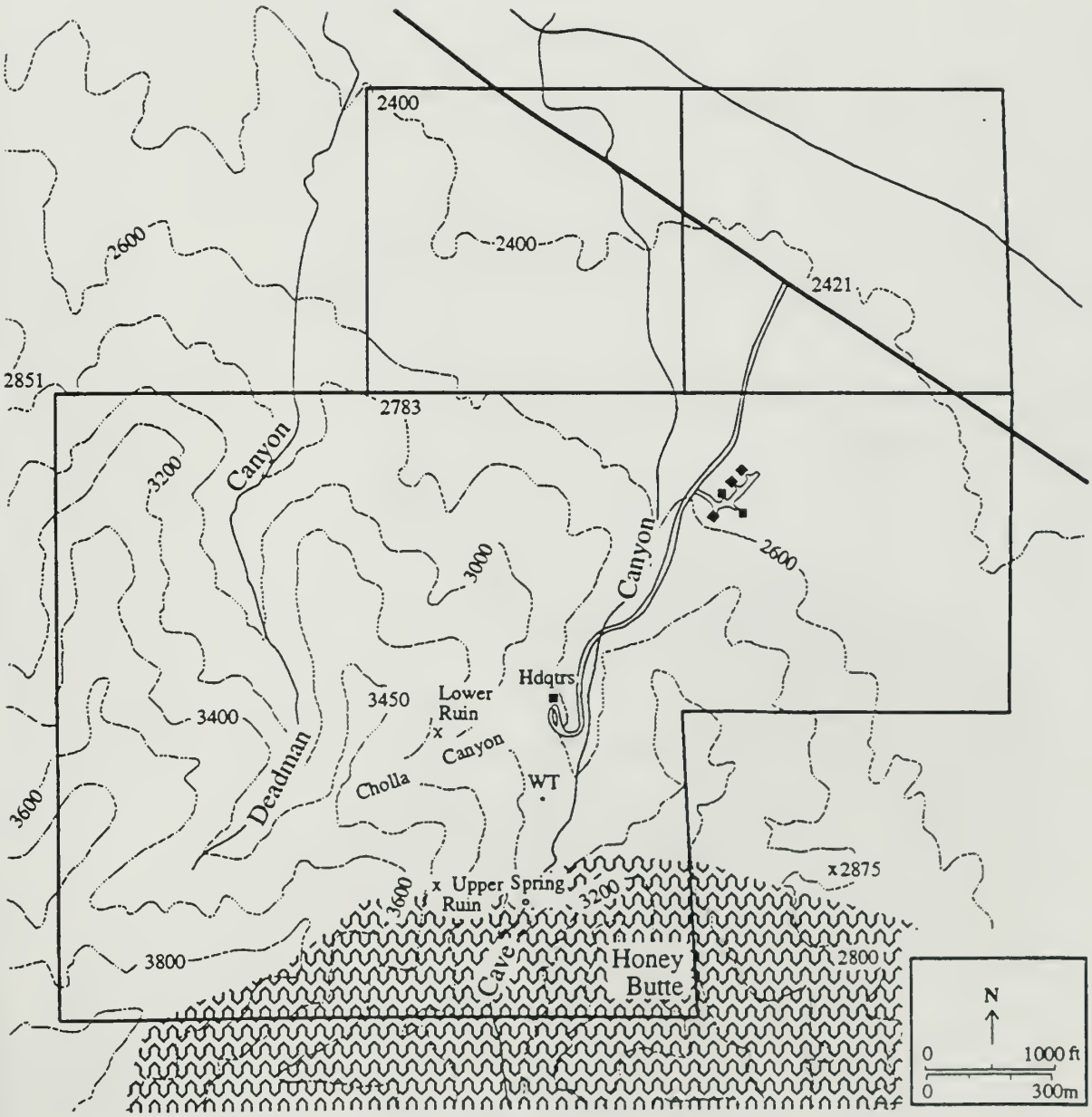


Figure 4. Cottonwood Fire boundaries, Tonto National Monument, 1970.

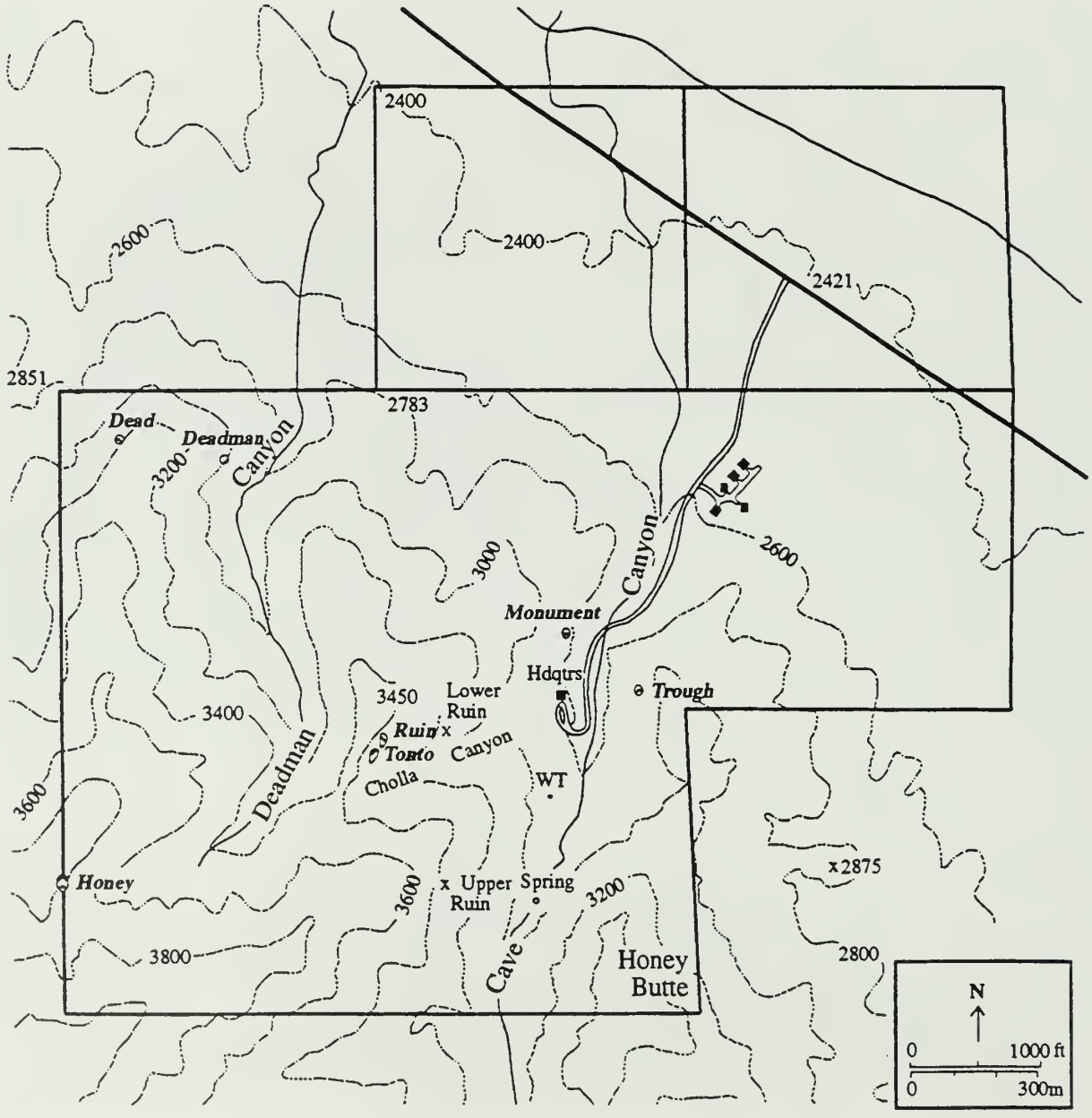


Figure 5. Locations of small fires, Tonto National Monument, 1942–1991.

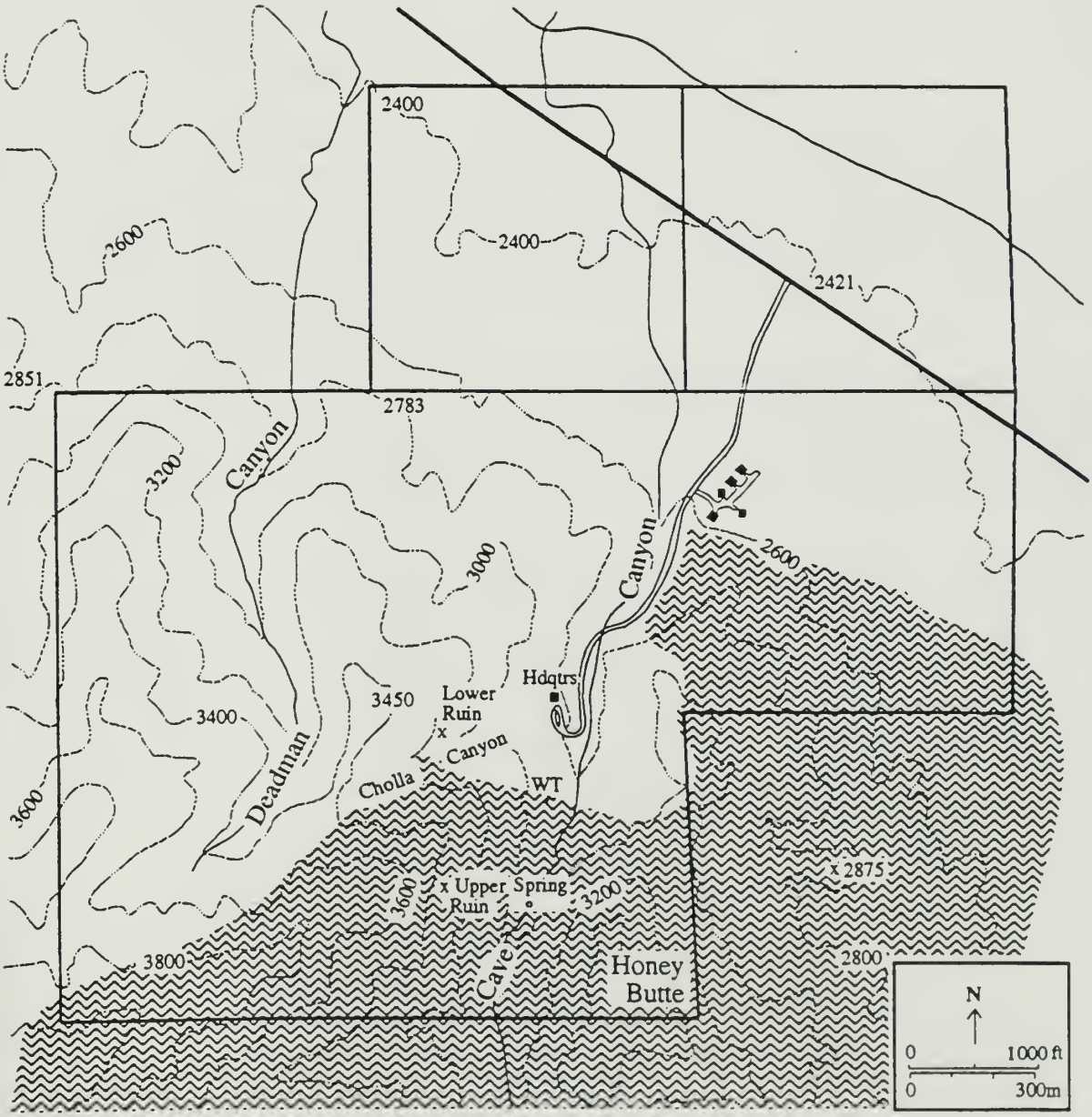


Figure 6. Monument Fire boundaries, Tonto National Monument, 1976.

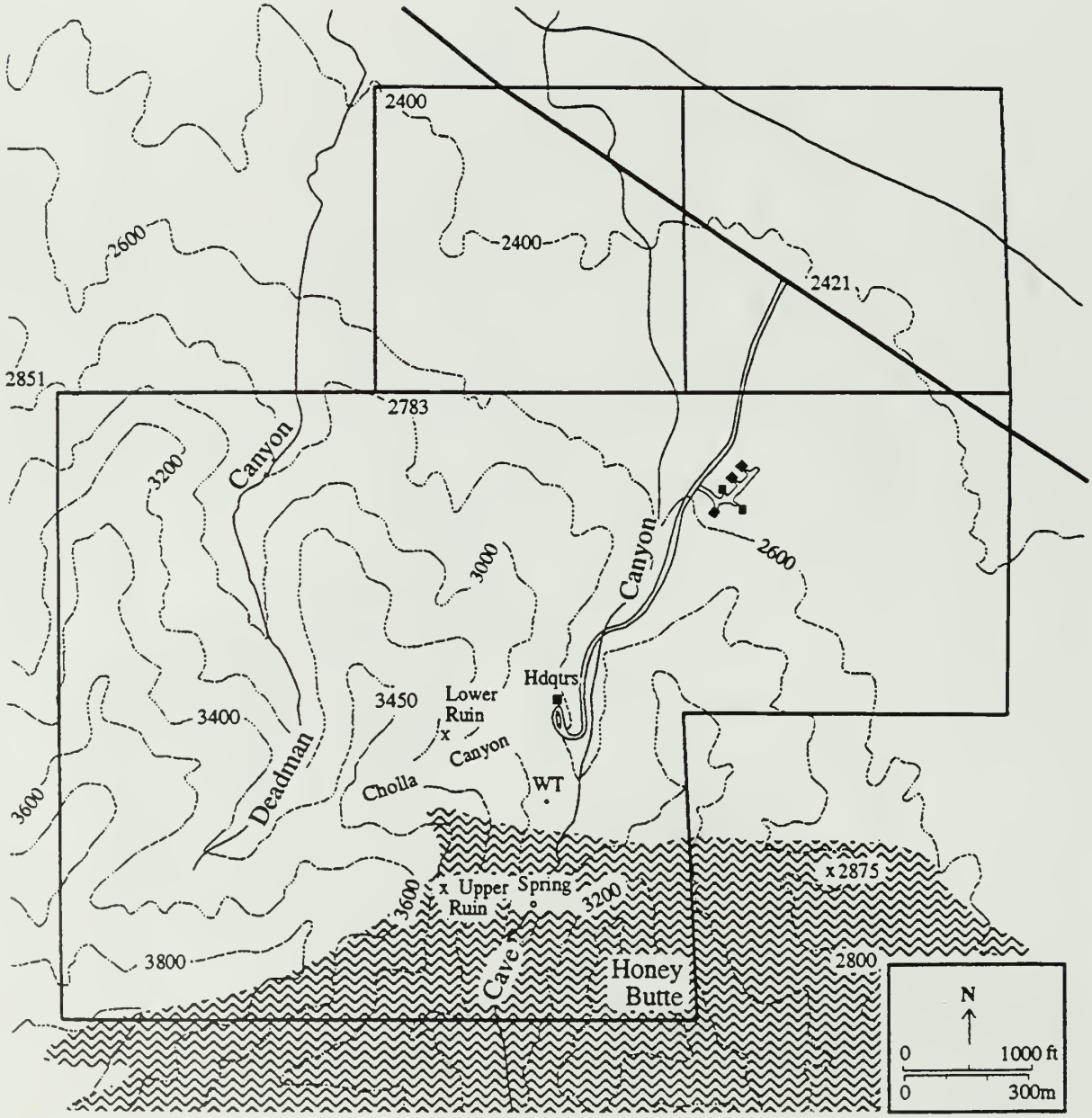


Figure 7. Monument Fire boundaries, Tonto National Monument, 1980.

1968

Tonto National Monument superintendent Valder (Valder 1976a, b) mentioned that there was a fire in Cave Canyon in 1968. I could not find documentation for this fire. Perhaps it was relatively small and did not burn on national forest lands.

1970

The Cottonwood Fire was started by lightning on 3 July 1970 at 1435 hr. It was discovered at 1455 hr and controlled on 7 July at 1600 hr. The fire was declared out on 17 July at 1700 hr. Although it had burned only 0.4 ha when discovered, the fire burned a total of 2,497 ha of forest land and 81 ha of the monument when it was controlled (Fig. 4).

The fire was 2–3.2 ha in size when R. Armstrong (in charge of initial attack force) arrived at 1928 hr. Two men had been fighting the fire, which was burning in deep grass on a steep, northwest-facing slope. Within an hour, the fire had increased to 12 ha due to the high winds and rolling *Dasylirion wheeleri* plants. When Ranger Henderson (second fireboss) took over at 2330 hr, it had increased to 243 ha (Armstrong 1970). The general area had not received any rains for 4 months and was extremely dry and very hot 24 hours a day. The winds were high (greater than 64 km/hr) and varied (Graham 1970).

Superintendent Schaafsma noted that 4 major lightning-caused fires were raging at the same time within Tonto National Forest (Schaafsma 1970). The fires assumed such large sizes and difficulty to control that hot shot crews from Idaho and Montana, as well as Hopi fire fighters from Arizona, were called.

Schaafsma stated, "on July 6 an aerial survey by helicopter gave every reason to believe that Tonto National Monument was doomed; and that all efforts be expended toward saving the visitor center and housing complex . . . By sundown the heat and smoke was very oppressive and a feeling of impending oblivion was experienced by all concerned."

According to the report of R. Graham, third fireboss, the number one priority on the fire at the time he arrived (6 July, 0400 hr) was the protection of TONT (Graham 1970). There were 3 crews on the line for night action; the base camp was set up at Roosevelt Ranger Station.

Graham (1970) noted that the fire was already approaching Upper Ruins. Graham and Schaafma felt the ruins themselves would not be damaged by the fire, since there was little vegetation in the immediate vicinity; and they thought they could keep the fire from reaching Lower Ruins. Schaafsma felt that the facilities at the administrative site, the residential area, trails and the Indian ruins were the resource values requiring the most protection.

"The Forest Service crews put up a valiant fight in an attempt to save as much of the scenic values of the park as possible. A line was bulldozed over the same route used in the 1964 fire . . . One particularly spectacular front was a fire line constructed by the crew from the Bitterroot NF [according to Orr (1970) this was the Payette crew] . . . The line ran from the forested portion of Cave Canyon to the Upper Ruins and was a frontal attack with fire moving in on the control crews" (Schaafsma 1970).

Figure 8. Hillside above parking lot after Schultz Fire, Tonto National Monument, 1964. The center part of this photo is the area where 20 Photo Stations were installed following the fire. A large "fire skip" area shows in the center (see white areas in Fig. 2). Several large fire skip areas occurred in this fire. The areas burned and unburned were mapped after the fire. Photo by T. Swan.

Figure 9. Hillside above parking lot, Tonto National Monument, 1989. The 1989 match photo was taken slightly closer. Six *Carnegiea gigantea* can be seen on the ridgeline, compared to approximately 20 in the 1964 photo. The double *C. gigantea* of Photo Station 8 in 1989 have several arms and can be seen on the left side of the photo. Photo by K. Davis.

Figure 10. Upper Ruin hillside after Schultz Fire, Tonto National Monument, 1964. This photo taken from the Upper Ruin Trail looking north shows a diversity of *Carnegiea gigantea* and other cacti, as well as *Cercidium* sp. and *Simmondsia chinensis*. The burned area above the ruins is very dark. Photo by H. Jones.

Figure 11. Upper Ruin hillside, Tonto National Monument, 1989. This area burned in the 1964 Schultz Fire, the 1970 Cottonwood Fire, the 1976 Monument Fire and the 1980 Monument Fire. The 1989 match photo (probably taken slightly north of the 1964 photo) shows 1 *Carnegiea gigantea* in the foreground and 2 by the Upper Ruin; none appear on the slope and a couple of *C. gigantea* are growing in the drainage. *Simmondsia chinensis* and *Dasylirion wheeleri* dominate the scattered shrubs on the slope. Photo by K. Davis.

Figure 12. Looking southwest from residential road at junction with monument road after Schultz Fire, Tonto National Monument, 1964. This photo taken the day after the fire moved through this area shows blackened north and northeast-facing hillsides. The difference in blackness seen in the photo represents the burned grasses and low shrubs on the north-facing slopes. The cacti, paloverdes, shrubs, and herbs did incur some damage where the fire moved through on the south-facing slopes, although it is not as evident from this distance. The upper parts of the south-facing slopes of each hill (see Fig. 3) did not burn. A firebreak constructed on the left hill effectively stopped the fire as it came around the base of the hill from the north. Photo by T. Swan.

Figure 13. Looking southwest from residential road at junction with monument road, Tonto National Monument, 1989. Plot 3 (control) was installed in the unburned area just outside the photo (on left); Plot 4 was installed in the burn area on the top of the left hill (see Figs. 3 and 18). As discussed in Burned/Unburned Comparison Plots, the occurrence of only 1 fire through this portion of the monument left few long-lasting impacts. Photo by K. Davis.

Another account of this effort: "we decided to burn out from either side of the canyon (Orr 1970). The Payette crew started up the west side. The east side had heavier fuels so the burning went slower. The Hopi crew was coming down from above." "The line was backfired and held successfully. Truly a dramatic battle in oppressive summer heat" (Schaafsma 1970). The administrative offices and residential area were saved.

The Forest Service put "11 crews out on the line July 7 with primary emphasis on the spread of the fire to the south and east and to assure holding of lines in the Tonto monument area. The monument area had pretty well cooled down." Fuels were flashy but usually burned clean, and little mop-up was necessary (Graham 1970).

1973

As recorded by park ranger Bruce D. McKeeman (1973), there were 3 lightning strikes at 1715 hr on 14 August. Two fires resulted on the ridge above Lower Ruin (Fig. 5). The northernmost, called the Ruin Fire, burned 0.4 ha. The second, called the Tonto Fire, also burned 0.4 ha. The fire took 2.5 hr to contain and mop up. Photos were taken of the sites.

1974

A lightning strike started a fire at 1650 hr on 14 July midway up the slope southwest of the junction of the park housing road and the entrance road. Fire lines were constructed around the Trough Fire, and during construction rain began and continued heavily throughout the evening and sporadically throughout the night. The 6 USFS crew members were dismissed at 1755 hr when the line was completed; the 2 National Park Service personnel remained until 1845 hr. The fire was declared out the following morning (Whisenant 1974).

The exact location of this fire is not clear. Figure 5 shows where it is designated on the map at TONT, but this location does not seem to match the description above and the time-frame of events.

1976

On 18 May at 1405 hr, the Monument Fire (Fig. 6) was started by lightning, probably near the top of the ridge between Cholla and Cave canyons, very near the southern boundary of the monument (Valder 1976a). The vegetative cover in the vicinity of Upper Ruins was burned before the fire crew could reach the area.

A relatively strong wind drove the fire in a NNE direction toward the monument visitor center; the first ground attack was conducted along fire lines used in 1970. Slurry was dropped ahead of the ground crew to hold the fire until a scratch line could be put in. When the storm center passed, the wind changed to the east and south, and the fire jumped Cave Canyon and burned Honey Butte. The slurry drops just before dark missed their targets, and the fire jumped the line east of Honey Butte and came back onto the monument in the vicinity of the housing area.

The fire "was held at a permanent fire break protecting the housing area and the fire was virtually controlled about 0100 hr on 19 May. A light drizzle during the night helped to cool the fire and

stop its run to the south and east of the Monument" (Valder 1976a). The fire was declared out at 0900 hr on 23 May. The total extent of the fire was 437 ha, 101 ha on the monument. Figures 14 and 15 show the impacts of this (and previous fires) on several plants; the photograph in Figure 15 was taken in August 1988.

Superintendent Valder (1976a, b) believed that there were indications of too much reliance on the Forest Service for fighting fires. In this particular fire, the USFS crew originally assigned was diverted to another fire, the slurry planes were temporarily diverted, and the USFS portable fire pumps (with could have been used at the Cave Canyon spring) were being repaired. Valder thought the fire could possibly have been held to 81 ha if a pump had been available.

The second fire of 1976 was known as the Deadman Fire (Fig. 5). On 25 July at 1400 hr, lightning started a small fire in the NW1/4 of the NW 1/4 of Section 34 at 1,035 m elevation on 70% slope with east aspect. This fire was out by 1900 hr and about 0.8 ha burned.

1979

In 1979, a lightning-caused fire occurred slightly west of the Deadman fire and was known as the Dead Fire (Fig. 5). This fire occurred on an 80% slope with north-facing aspect at 975 m in Deadman Canyon. There was heavy grass cover. The fire started at 2045 hr on 10 August, and due to darkness, topography, weather conditions and higher priority fires, was not attacked until a helicopter became available on the morning of 11 August (Harlan, in National Park Service 1979). This fire burned 0.4 ha, and it was declared out by 1500 hr on 11 August.

1980

On 23 July at 2000 hr, lightning started a fire in the SE 1/4 of the NW 1/4 of Section 3 in heavy grass on a slope of 90% at 1,036 m with a southwest-facing aspect. This origin was about a kilometer south of the south boundary of the monument. This fire was fought mostly by USFS personnel.

On 24 July at 1014 hr, it was reported that either the original fire had started up again or there was another fire in the same area. This became the second fire to be called "Monument" (#312208) (Fig. 7). (The first "Monument" fire was in 1976, as discussed above. The 1980 Monument Fire is also referred to as the Honey Fire, although the 1983 fire described below officially has that name.) By 1645 hr, the fire entered the monument along most of the south boundary. Figures 16 and 17 show the upper Cave Creek watershed, looking south from Upper Ruins Trail. "At this time, Roy Allen, SOAR [Southern Arizona Group], was notified, and additional help was requested from the Forest Service. All monument personnel were called in to stand by the fire hose to protect the visitor center and housing area" (Anonymous 1980).

Figure 14. Closeup of *Carnegiea gigantea* and *Fouquieria splendens* plants along the Upper Ruin Trail, Tonto National Monument, after the 1976 Monument Fire. The *C. gigantea* plants show damage from previous fires, which at this location include the 1947 Fire as well as the Schultz, Cottonwood, and 1976 Monument fires (see Figs. 2–4 and 6). A burned *Opuntia bigelovii* is evident in the upper left. Photo by P. Young.

Figure 15. Closeup of *Carnegiea gigantea*, Tonto National Monument, 1988. In the match photograph taken in August 1989, the skeletons of the nearer *C. gigantea* and *Fouquieria splendens* lie on the ground. The *Simmondsia chinensis* (dark shrubs) appear to grow in the same locations as in 1976. Some small *Opuntia bigelovii* cacti grow where the larger plant died in 1976. Other species growing on the slope today on the left side of the photo are *Encelia farinosa, Mirabilis bigelovii, Dichelostemma pulchellum, Eriogonum densum, Sphaeralcea* sp., *Galium* sp., and *Selaginella arizonica*. Photo by K. Davis.

Figure 16. Upper Cave Canyon from Upper Ruin Trail, Tonto National Monument, after 1980 Monument Fire (1981). This photograph shows upper Cave Creek drainage, which had burned in all 5 major fires, the last being the 1980 Monument Fire (see Fig. 7). Tonto National Forest is in the distance. The *Carnegiea gigantea* plants are very badly damaged. Most of the grasses present are the nonnative lovegrasses (predominantly *Eragrostis lehmannii*), which were seeded in the 1960s and 1970s after fires in Tonto National Forest. The photograph was taken from a location 60 m south of the fence enclosing Upper Ruin. Photo by M. Rasmussen.

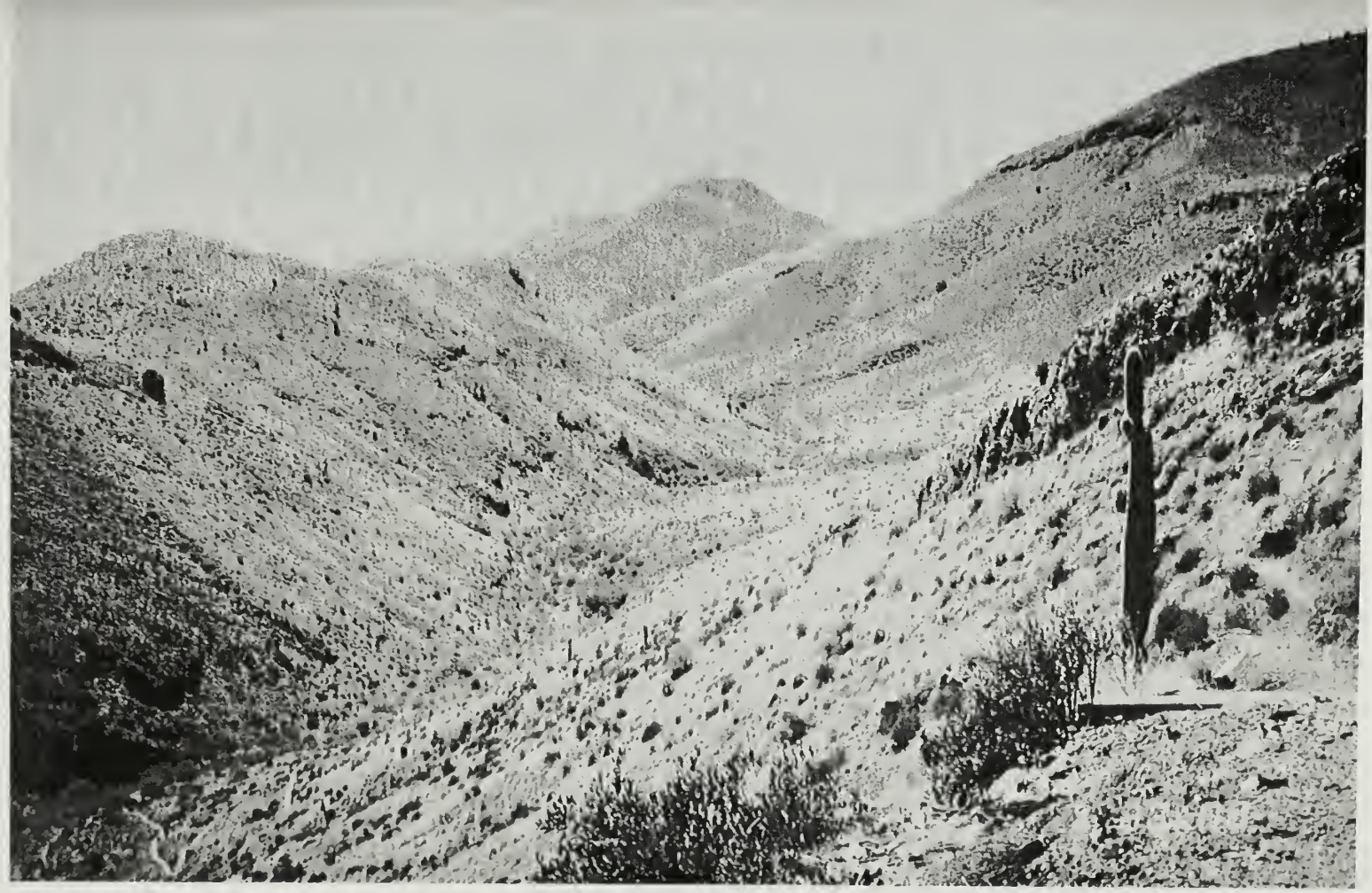


Figure 17. Upper Cave Canyon from Upper Ruin Trail, Tonto National Monument, 1988. Only 1 *Carnegiea gigantea* remains living of the several in the foreground of the previous photo. This plant has 4 arms, but a damaged top. Native *Stipa* sp. grows on the nearer slope above the nonnative lovegrasses. *Prosopis velutina* trees grow in the bottom of the Cave Canyon drainage. Plot 1 of this current study is located (outside the photo) above the rock outcrop that appears in the upper right of this photo. Photo by K. Davis.

The fire was burning very hot and fast in Cave Canyon by 1805 hr. Two slurry drops were made on and behind the visitor center. "It was decided to run a fire line from the bluff to the north of Upper Ruins to the bottom of Cave Canyon and backfire to protect the visitor center. After this was done, the crews went to the east side of Honey Butte, just outside the monument, to stop the fire there before it could burn towards the housing area. At 0600 hr on 25 July, the west side of Honey Butte was backfired. At 1430 hr on 27 July, the last of the hot spots were put out by monument personnel (Anonymous 1980). The fire burned a total of 405 ha, 40 of which were on the monument.

1983

On 24 July at 1557 hr, the Honey Fire started on monument land in the SW 1/4 of the SW 1/4 of section 34 just at the monument boundary. It burned onto national forest land before being controlled. This was a small fire of about 1.2 ha and took about 1.5 hr to control (Fig. 5).

1984

On 19 July at 1338 hr, a person driving on Highway 88 reported a lightning-caused fire on the monument. Called Monument (#312100), this fire started on a 15% north-facing slope at 869 m. The fire was controlled on 19 July at 1530 hr and declared out on 20 July at 1000 hr after burning about 0.4 ha. This fire was located in the SW 1/4 of the NE 1/4 of Section 34 (Fig. 5).

Reconstruction and Revegetation Efforts

After the Schultz Fire, a seed mix including nonnative lovegrasses was used to stabilize the soil (U.S. Forest Service 1991). The area seeded included upper Cave Canyon, immediately south of the monument, and lovegrasses, either inadvertently or on purpose, were introduced onto the monument. According to G. Holder, Tonto National Forest (pers. comm. 1991), the predominate species seeded in the late 1960s and early 1970s was *Eragrostis lehmanniana*. Today *E. curvula* and *E. chloromelas* also grow on the monument near the south boundary (Jenkins et al. 1995; Phillips 1992). According to *Forest Service Nonstructural Range Improvements Handbook* (U.S. Forest Service 1970), these species (native to South Africa) are recommended for seeding in the Tonto National Forest area. In general, *E. lehmanniana* is the species with the most successful record of survival in this area of the Tonto National Forest (G. Holder, pers. comm. 1991), although *E. curvula* grows abundantly on the monument in Cave Canyon (Jenkins et al. 1995).

A bulldozer line was built from the edge of Honey Butte to the bottom of Cave Canyon in July 1970 during the Cottonwood Fire (McKinney 1971), following the same route used in the 1964 fire (Schaafsma 1970). This line was to be the base point of defensive action to save monument developments, but the fire was controlled before reaching the fire line, The fire line remained as an ugly scar slashed through the natural vegetation. Rehabilitation of the bulldozer scar was conducted during July and August 1971. The scar was 457 m long by 4.3 m wide with 26 water bars, averaging 76 cm in height. The objectives in rehabilitation were (1) to reestablish natural contours destroyed in fire break construction; (2) to transplant natural vegetative cover where possible; and (3) to carry in and scatter brush and dead vegetation to help cover the scar, to hold moisture, and provide shade to implement transplanting and natural reseeding (McKinney 1971). Photographs were taken during the process and are included in the report on rehabilitation.

Although native species now dominate the area, the species composition mostly consists of weedy native species such as *Gutierrezia sarothrae* and *Lotus rigidus*.

Waterbars were built on the fireline on 26 July 1980 to assist in preventing erosion during the Monument Fire. Two hundred pounds of *Simmondsia chinensis* nuts were confiscated in 1980 from seed collectors, and in August the seeds were used to seed the areas burned by the fire. The areas seeded were around and above Upper Ruin and in Cave Canyon and up Honey Butte (Tonto National Monument history files). The outcome of this effort is not known. Certainly *Simmondsia chinensis* is common in the area today, but the plants cannot be proven to result from this revegetation attempt. Weather conditions following the seeding would have had an impact on success. Seed germination in *Simmondsia chinensis* requires rainfall, and precipitation amounts greater than 30 mm lead to massive germination. Seedling survival is greatly enhanced by protection and shade of plants or physical barriers (Castellanos and Molina 1990).

Discussion

All the fires documented for TONT since 1942 have been started by lightning. The arid early summer is a crucial time: 4 of the 5 large fires started in late June or July; the 1976 fire started in mid-May. Several large fires (1947, 1964, 1970, and 1980) came onto the monument from the national forest to the south. The 1976 Monument Fire was ignited on the ridge between Cholla and Cave canyons, very near the southern boundary of the monument. These large fires spread very rapidly and were difficult to control. For example, the 1970 Cottonwood Fire was about 2 ha in size at 1928 hr on 3 July and up to 243 ha by 4 July at 0430 hr. The weather conditions during the fires were extreme heat and, in some cases, high winds. The rugged terrain and desert vegetation added to the complexity of fighting the fires. Sometimes other fires were being fought concurrently on national forest lands, leading to manpower and equipment shortages at crucial times.

Most of the late July and August fires burned a small number of hectares (the 1980 Monument Fire being the exception). Rain helped put out some of these fires.

In comparison, a 29-year fire record (1955–1983) for Tonto National Forest as a whole (Schmid and Rogers 1988) showed more human-caused fires than lightning-ignited, although lightning-caused fires burned approximately twice the area. According to their study, fires were numerous from May through August, but the area burned was greater during June than all other months combined.

Methods

A reconnaissance hike was made in late March 1990 to compare the boundaries of the large fires marked on maps with the general topography, and to provide an overview of the types of vegetation in the different areas of the monument. Five plots were established in late March and early April when plants were leafed out, and identifiable. Plots were established on the following dates: Plot 1, 7 March; Plot 2, 8 March; Plot 3, 3 April; Plot 4, 5 April; and Plot 5, 6 April. Plots were revisited 19–20 October 1990 and 30–31 March 1991 to identify unknowns.

The 300 m^2 plots were established on representative slopes and exposures, utilizing information about location and occurrence of fires obtained from the fire history search. Figure 18 shows the location of each plot. A control plot was established in a comparable unburned area. Each plot was intended to sample a plant community that was judged to be typical and representative, and the vegetation within the plot was presumed to be homogeneous. Ecotones were avoided in this sampling procedure. The potential for future relocation of the plot (0,0) stake was a major consideration in placement of the plot. Each corner of each plot was marked with rebar and tied in to topographic features. Photos were taken to document the plant communities and of corners of the plots, and significant associated features to aid in relocation of plots. Each plot is diagramed in Appendix 1.

Standard vegetation sampling techniques (Mueller-Dombois and Ellenberg 1974) were used. In general, a 30 x 10-m rectangle was installed with the long dimension parallel to the slope contours. The metric system was used in recording data. Unknown plants (usually in seedling or vegetative state) were collected outside the plot, and described on the recording sheets. These plants were searched for later to obtain accurate identification.

Trees and shrubs were counted and measured in the full 300-m^2 plot. The 300 m^2 plot was subdivided into 12 equal subplots (5 x 5 m) to permit the recording frequency of occurrence of trees and shrubs (Fig. 19). Perennial herbs and grasses were recorded in 16 (1 x 1 m) subplots located at the 4 corners of the larger plot, and values were converted to the 300-m^2 scale for comparisons. Annual herbs and grasses were recorded in 4-m^2 subplots located at the 4 corners of the larger plot (i.e., the corner m^2 of the 300-m^2 plot ; Fig. 20).

The coverage method was used to measure living shrubs and herbs. The diameter of each plant was recorded in the field. The basal diameter of grasses was measured. Using the radius, the area of a circle was calculated for each plant, then the total coverage for each species was found by summing the areas of the individual plants. Stems of each species were counted at the ground surface for densities. A plant was counted for presence in a plot (frequency) only if rooted in the plot. Absolute frequency, absolute density, and absolute cover were calculated first. Then relative frequency, relative density, and relative cover, and importance values were calculated for each species using standard statistical procedures (Mueller-Dombois and Ellenberg 1974). A formula table for calculations from raw data to importance values is presented as Appendix 2. Appendix 3 contains absolute frequency, density and cover tables for the burned and unburned comparison plots.

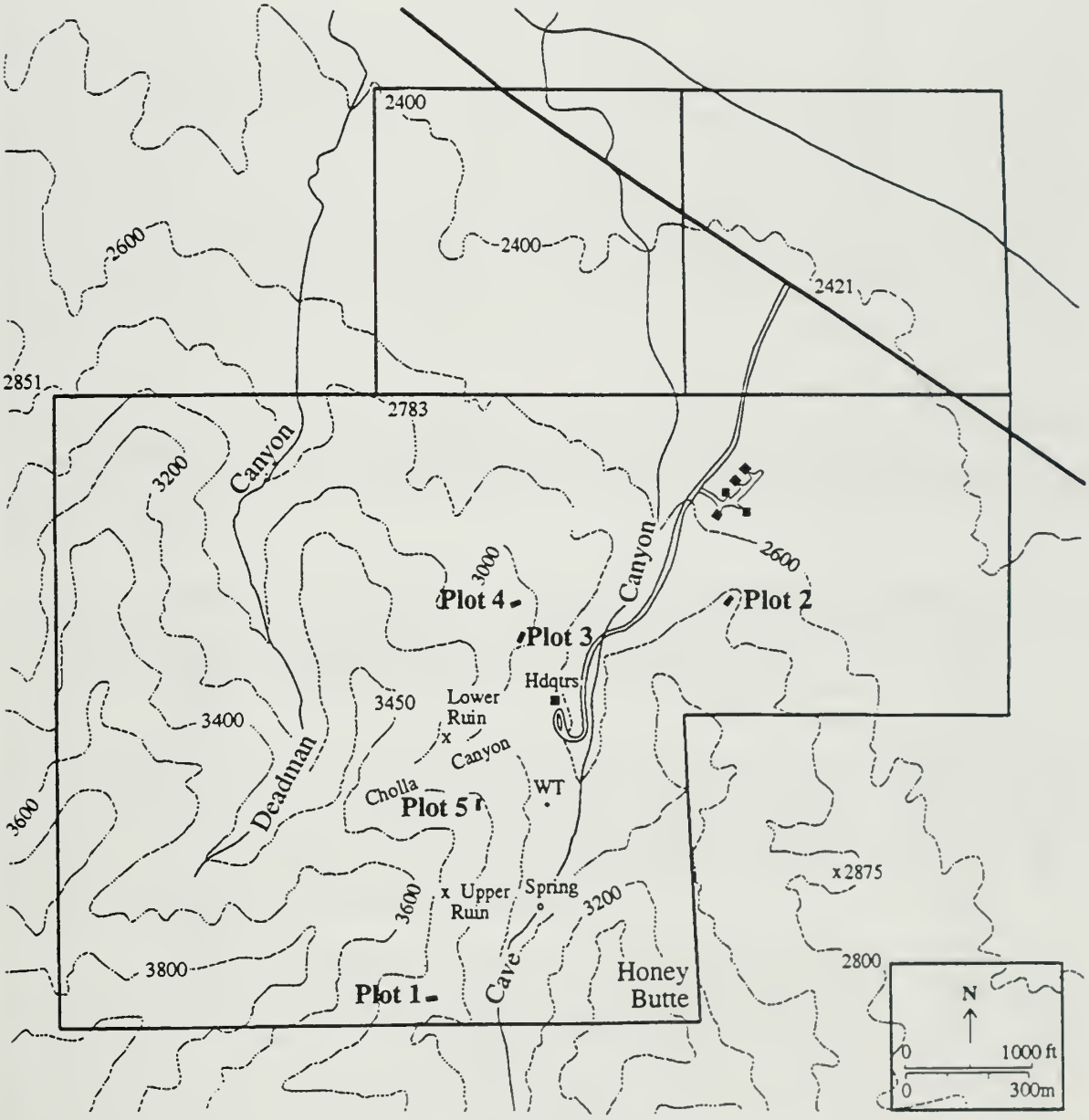


Figure 18. Location of burned and unburned comparison plots, Tonto National Monument.

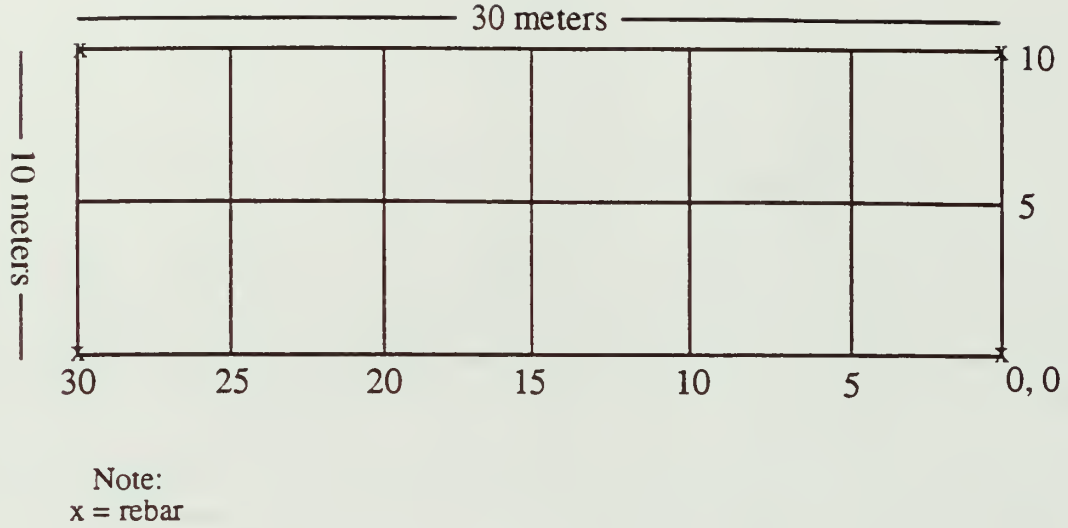


Figure 19. Diagram of plot sampling divisions (trees and shrubs), Tonto National Monument.

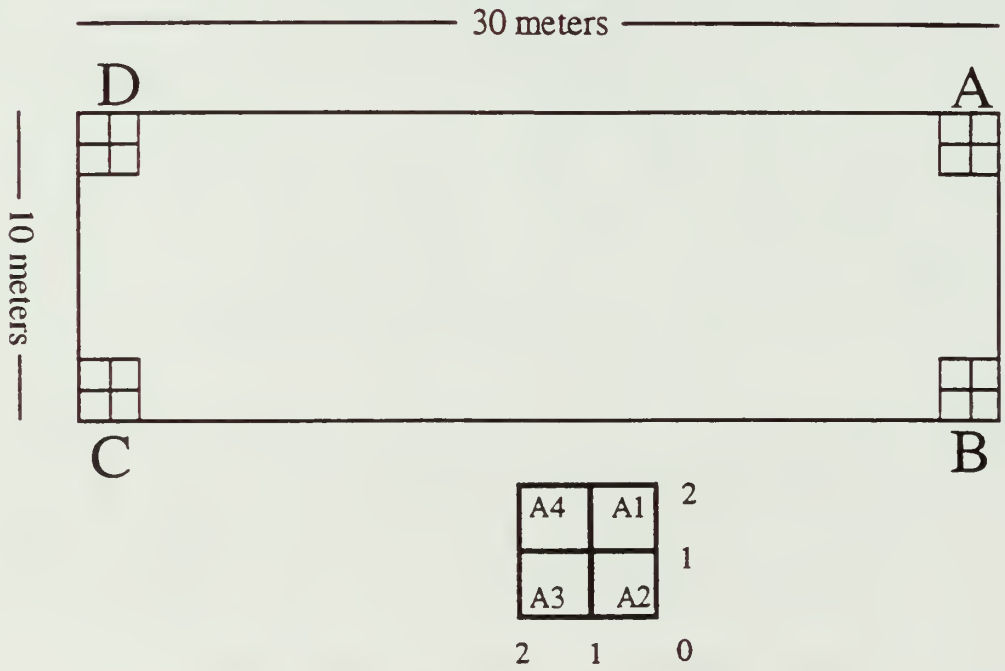


Figure 20. Diagram of plot sampling divisions (herbaceous perennials and annuals), Tonto National Monument.

Results

Plot 1

Plot 1 is located on a south-facing slope at 1,006 m just above and west of the trail to Upper Ruin, near the south boundary fence (Fig. 18). This area burned in all the major fires (1947, 1964, 1970, 1976, and 1980). The plot 0,0 corner is the southeast corner and is marked with rebar. The plot is located at the northwest corner of a rock outcrop (Appendix 1a).

Tables 2 and 3 present the relative cover, relative frequency, relative density, and importance values for the 30 species sampled in this plot. *Dichelostemma pulchellum* (IV 31.70), *Encelia farinosa* (IV 25.86) and *Simmondsia chinensis* (IV 10.78) were the dominant species. The absolute values for these species are shown in Appendix 3a. *Encelia farinosa* had the greatest cover (631,828 cm^2 or 61.56% relative cover), and *Dichelostemma pulchellum* the most plants (6,038). When the trees and shrubs were considered separately from small perennials (Table 4), *Encelia farinosa* assumed an importance value of 59.31. Two large, living *Carnegiea gigantea* were present in the plot, but contributed little cover. Both were about 6 m tall. There were 2 *Cercidium floridum* and 1 *C. microphyllum* in the plot. *Opuntia acanthocarpa* was also present.

Although a native annual herb, *Astragalus nuttallianus* had the largest importance value of the annuals (IV 26.73); 2 nonnatives, *Erodium cicutarium* and *Bromus rubens,* had high importance values of 22.23 and 18.33, respectively (Table 3). *Selaginella arizonica* occurred in approximately 25% of the plots but was not counted, because it was not possible to differentiate individual plants.

In Plot 1, 1 skeleton each was found of *Fouquieria splendens, Carnegiea gigantea*, and *Mammillaria microcarpa*. Three skeletons, or stumps, were found of *Opuntia acanthocarpa*, 3 of *Opuntia bigelovii*, and 7 dead *Encelia farinosa* were noted in the plot.

Plot 2

Plot 2 is located on the top of the ridge above the maintenance shop near the current residence area, at 861 m (Fig. 18). *Carnegiea gigantea* # 1 was the first *C. gigantea* seen when topping the ridge; the northeast corner of the plot contained this *C. gigantea*. The plot 0,0 corner is the southeast corner of the plot and is marked with rebar, as are the other corners (Appendix 2b). This area burned in the 1976 Monument Fire (Fig. 6).

Tables 5 and 6 present the relative cover, relative frequency, relative density, and importance values for the 28 species sampled in this plot. *Dichelostemma pulchellum* (IV 28.87), *Encelia farinosa* (IV 26.95), *Simmondsia chinensis* (IV 15.91), and *Cercidium microphyllum* (IV 7.62) were the dominant species. The absolute values for these species are shown in Appendix 3b. Again, *Encelia farinosa* had the greatest cover (880,371 cm^2 or 50.32% relative cover) and *D. pulchellum* the most plants (2,794). When the trees and shrubs were considered separately from small perennials (Table 7), *Encelia farinosa* assumed an importance value of 53.08. Two living *Carnegiea gigantea* were present in the plot, but again contributed little cover. One was 5 m tall and had 4 arms. The second was 2 m tall and unbranched. *Opuntia bigelovii* was the prominent cactus in the plot.

Table 2. Relative frequency, relative density, relative cover, and importance values for perennials, Plot 1, Tonto National Monument, 7 March 1990 to 30–31 March 1991.

Species	Relative frequency	Relative density	Relative cover	Importance value
Dichelostemma pulchellum	14.86	79.80	0.44	31.70
Encelia farinosa	12.38	3.65	61.56	25.86
Simmondsia chinensis	12.38	0.42	19.53	10.78
Ambrosia psilostachya	6.50	7.19	3.41	5.70
Dyssodia porophylloides	12.38	0.25	0.37	4.33
Aristida spp.	5.57	2.73	1.16	3.15
Sphaeralcea emoryi	7.43	0.11	0.81	2.78
Cercidium floridum	2.00	0.03	5.11	2.54
Bouteloua curtipendula	3.72	2.23	1.19	2.38
Opuntia acanthocarpa	6.19	0.08	0.48	2.25
Mirabilis bigelovii	1.86	0.50	1.76	1.37
Euphorbia melanadenia	2.79	0.74	0.19	1.24
Carnegiea gigantea	1.24	0.01	1.80	1.02
Eriogonum fasciculatum	2.48	0.03	0.30	0.93
Cercidium microphyllum	1.24	0.01	1.32	0.86
Tradescantia occidentalis	1.86	0.50	0.17	0.84
Stipa speciosa	1.86	0.50	0.05	0.80
Mammillaria microcarpa	0.93	0.74	0.21	0.63
Stephanomeria pauciflora	0.93	0.25	0.14	0.44
Sporobolus cryptandrus	0.93	0.25	0.01	0.39

Table 3. Relative frequency, relative density, importance values, and density per square meter for annuals, Plot 1, Tonto National Monument, 7 March 1990 to 30–31 March 1991.

Species	Relative frequency	Relative density	Importance value	Density/ sq m
Astragalus nuttallianus	20.00	33.45	26.73	23.25
Erodium cicutarium	20.00	24.46	22.23	17.00
Bromus rubens	5.00	31.65	18.33	22.00
Eschscholzia mexicana	15.00	6.83	10.92	4.75
Daucus pusillus	15.00	1.44	8.22	1.00
Lupinus arizonicus	10.00	1.08	5.54	0.75
Erodium texanum	10.00	0.72	5.36	0.50
Schismus barbatus	1.22	5.94	3.58	1.17
Sonchus asper	1.22	5.94	3.58	1.17
Plagiobothrys arizonicus	5.00	0.36	2.68	0.25

Table 4. Importance values (perennials considered separately), Plot 1, Tonto National Monument, 7 March 1990 to 30–31 March 1991.

Species	Relative frequency	Relative density	Relative cover	Importance value
Trees and shrubs				
Encelia farinosa	26.32	83.89	67.72	59.31
Simmondsia chinensis	26.32	9.73	21.49	19.18
Sphaeralcea emoryi	15.79	2.43	0.89	6.37
Opuntia acanthocarpa	13.16	1.82	0.53	5.17
Cercidium floridum	5.26	0.61	5.62	3.83
Carnegiea gigantea	5.26	0.61	1.98	2.62
Eriogonum fasciculatum	5.26	0.61	0.33	2.07
Cercidium microphyllum	2.63	0.30	1.46	1.46
Small perennials				
Dichelostemma pulchellum	27.43	83.42	4.85	38.57
Ambrosia psilostachya	12.00	7.51	37.46	18.99
Dyssodia porophylloides	22.86	0.26	4.04	9.05
Aristida spp.	10.29	2.85	12.74	8.63
Mirabilis bigelovii	3.43	0.52	19.34	7.76
Bouteloua curtipendula	6.86	2.33	13.03	7.41
Euphorbia melanadenia	5.14	0.78	2.11	2.68
Tradescantia occidentalis	3.43	0.52	1.91	1.95
Mammillaria microcarpa	1.71	0.78	2.30	1.60
Stipa speciosa	3.43	0.52	0.58	1.51
Stephanomeria pauciflora	1.71	0.26	1.58	1.18
Sporobolus cryptandrus	1.71	0.26	0.06	0.68

Table 5. Relative frequency, relative density, relative cover, and importance values for perennials, Plot 2, Tonto National Monument, 8 March 1990 to 30–31 March 1991.

Species	Relative frequency	Relative density	Relative cover	Importance value
Dichelostemma pulchellum	9.33	77.17	0.12	28.87
Encelia farinosa	21.33	9.20	50.32	26.95
Simmondsia chinensis	21.33	1.49	24.90	15.91
Cercidium microphyllum	7.11	0.08	15.65	7.62
Lycium fremontii	12.44	0.25	4.68	5.79
Opuntia bigelovii	12.44	0.33	1.61	4.79
Anemone tuberosa	5.33	8.29	0.61	4.74
Mirabilis bigelovii	4.00	2.59	1.07	2.55
Carnegiea gigantea	3.56	0.06	0.87	1.49
Gallium stellatum	1.78	0.03	0.15	0.65
Mammillaria microcarpa	1.33	0.52	0.02	0.62

Table 6. Relative frequency, relative density, importance values, and density per square meter for annuals, Plot 2, Tonto National Monument, 8 March 1990 to 30–31 March 1991.

Species	Relative frequency	Relative density	Importance value	Density/ sq m
Bromus rubens	8.57	30.89	19.73	66.25
Pholistoma auritum	8.57	29.60	19.09	63.50
Draba cuneifolia	11.43	19.35	15.39	41.50
Lepidium medium	11.43	3.96	7.70	8.50
Erodium cicutarium	8.57	2.68	5.63	5.75
Astragalus nuttallianus	8.57	1.75	5.16	3.75
Plantago patagonica	5.71	4.55	5.13	9.75
Euphorbia sp.	8.57	1.40	4.99	3.00
Daucus pusillis	5.71	0.35	3.03	0.75
Schismus barbatus	2.86	3.03	2.94	6.50
Unknown #8	2.86	1.40	2.13	3.00
Unknown #4	2.86	0.47	1.66	1.00
Silene antirrhina	2.86	0.12	1.49	0.25
Phacelia sp.	2.86	0.12	1.49	0.25
Lupinus arizonicus	2.86	0.12	1.49	0.25
Lotus humistriatus	2.86	0.12	1.49	0.25
Arabis perennans	2.86	0.12	1.49	0.25

Table 7. Importance values (perennials considered separately), Plot 2, Tonto National Monument, 8 March 1990 to 30–31 March 1991.

Species	Relative frequency	Relative density	Relative cover	Importance value
Trees and shrubs				
Encelia farinosa	22.27	80.63	51.33	53.08
Simmondsia chinensis	27.27	13.08	25.40	21.92
Cercidium microphyllum	9.09	0.73	15.97	8.60
Lycium fremontii	15.91	2.18	4.78	7.62
Opuntia bigelovii	15.91	2.91	1.64	6.82
Carnegiea gigantea	4.55	0.48	0.89	1.97
Small perennials				
Dichelostemma pulchellum	42.86	87.11	6.13	45.36
Mirabilis bigelovii	18.37	2.92	54.35	25.21
Anemone tuberosa	24.49	9.35	30.79	21.54
Gallium stellatum	8.16	0.03	7.67	5.29
Mammillaria microcarpa	6.12	0.58	1.07	2.59

Bromus rubens had an importance value of 19.73 among the annuals, closely followed by native species *Pholistoma auritum* (IV 19.09), *Draba cuneifolia* (IV 15.39), and *Lepidium medium* (IV 7.70) (Table 6). No *Selaginella arizonica* plants were observed.

The slope was littered with down branches, stalks, and stems from plants impacted by the fire. Within the plot both *Carnegiea gigantea* were damaged by the fire. There were 3 dead and 3 damaged *Cercidium microphyllum,* and 2 unidentified dead trees. Two *Simmondsia chinensis* were dead. Thirty-eight dead *Opuntia bigelovii* were recorded, as well as 37 dead *Encelia farinosa* and 1 dead *Mammillaria microcarpa.*

Plot 3

Plot 3 is the control plot and is located at 930 m above the visitor center on the south-facing slope, which has never been burned (Figs. 3 and 18). *Opuntia bigelovii* were abundant in the area. The plot 0,0 corner is the southeast corner and is marked with rebar, as are the other corners. A large rodent nest is located at the northwest corner of the plot (Appendix 1c).

Tables 8 and 9 present the relative cover, relative frequency, relative density, and importance values for the 39 species sampled in this plot. *Mirabilis bigelovii* (IV 17.97), *Simmondsia chinensis* (IV 17.13), *Opuntia bigelovii* (IV 14.44), and *Cercidium microphyllum* (IV 11.19) were the dominant species. The absolute values for these species are shown in Appendix 3c. *Simmondsia chinensis* had the greatest cover (474,350 cm^2 or 26.78% relative cover), and *Mirabilis bigelovii* the most plants (206). When the trees and shrubs were considered separately from small perennials (Table 10), *Opuntia bigelovii* assumed an importance value of 23.19. Three living *Carnegiea gigantea* were present in the plot. A 4-m tall *C. gigantea* had 2 arms. Two *Carnegiea gigantea* were unbranched and 3.5 m and 5 m tall. *Fouquieria splendens, Yucca baccata*, and *Opuntia acanthocarpa* also occurred in this plot.

Twenty species of native annuals were present, although the introduced *Bromus rubens* had the highest importance value (37.97) due to its high density (210.75 plants per sq m) (Table 9). *Selaginella arizonica* occurred in 25% of the plots.

Three *Carnegiea gigantea* skeletons occurred in this control plot. Ten dead *Encelia farinosa*, 12 dead *Opuntia bigelovii* stems, and 2 dead *Eriogonum fasciculatum* were also noted.

Plot 4

Plot 4 is located just east of the control plot on the ridge above the visitor center at 937 m (Fig. 18). This area was burned in the 1964 Schultz Fire (Fig. 3). No living *Carnegiea gigantea* occurred on the ridge north of this plot. The plot 0,0 corner is the southeast corner and is marked with rebar, as are the other corners (Appendix 1d).

Tables 11 and 12 present the relative cover, relative frequency, relative density and importance values for the 43 species sampled in this plot. *Dichelostemma pulchellum* (IV 19.59), *Mirabilis bigelovii* (IV 13.33), *Simmondsia chinensis* (IV 11.27), and *Cercidium microphyllum* (IV 10.25) were the dominant species. The absolute values for these species were shown in Appendix 3d.

Table 8. Relative frequency, relative density, relative cover, and importance values for perennials, Plot 3, Tonto National Monument, 3 April 1990 to 30–31 March 1991.

Species	Relative frequency	Relative density	Relative cover	Importance value
Mirabilis bigelovii	5.00	41.31	7.59	17.97
Simmondsia chinensis	16.00	8.61	26.78	17.13
Opuntia bigelovii	14.67	15.82	12.84	14.44
Cercidium microphyllum	9.33	1.40	22.84	11.19
Encelia farinosa	13.33	7.01	4.17	8.17
Eriogonum fasciculatum	8.00	4.21	8.88	7.03
Fouquieria splendens	4.00	0.60	10.27	4.96
Viguiera parishii	9.33	2.20	2.97	4.83
Dichelostemma pulchellum	2.00	11.27	0.00	4.42
Porophyllum gracile	8.00	2.20	0.39	3.53
Opuntia acanthocarpa	4.00	0.80	2.60	2.47
Carnegiea gigantea	4.00	0.60	0.58	1.73
Stephanomeria tenuifolia	1.00	3.76	0.02	1.59
Yucca baccata	1.33	0.20	0.07	0.53

Table 9. Relative frequency, relative density, importance values, and density per square meter for annuals, Plot 3, Tonto National Monument, 3 April 1990 to 30–31 March 1991.

Species	Relative frequency	Relative density	Importance value	Density/ sq m
Bromus rubens	8.70	67.12	37.91	210.75
Tillaea erecta	4.35	13.38	8.86	42.00
Phacelia cryptantha	8.70	1.19	4.94	3.75
Lepidium medium	8.70	0.96	4.83	3.00
Pholistoma auritum	8.70	0.64	4.67	2.00
Draba cuneifolia	6.52	1.59	4.06	5.00
Filago arizonica	2.17	4.38	3.28	13.75
Parietaria floridana	4.35	1.43	2.89	4.50
Astragalus nuttallianus	4.35	1.35	2.85	4.25
Schismus barbatus	4.35	0.88	2.61	2.75
Thysanocarpus amplectens	4.35	0.56	2.45	1.75
Silene antirrhina	4.35	0.32	2.33	1.00
Amsinckia tessellata	4.35	0.24	2.29	0.75
Descurainia pinnata	2.17	1.35	1.76	4.25
Stellaria nitens	2.17	1.27	1.72	4.00
Erodium cicutarium	2.17	0.96	1.56	3.00
Thelypodium longiocarpum	2.17	0.56	1.37	1.75
Daucus pusillus	2.17	0.48	1.33	1.50
Plantago patagonica	2.17	0.40	1.29	1.25
Pterostegia drymarioides	2.17	0.32	1.25	1.00
Galium aparine	2.17	0.24	1.21	0.75
Lotus humistriatus	2.17	0.16	1.17	0.50
Lupinus arizonicus	2.17	0.08	1.13	0.25
Sonchus asper	2.17	0.08	1.13	0.25
Plagiobothrys arizonicus	2.17	0.08	1.13	0.25

Table 10. Importance values (perennials considered separately), Plot 3, Tonto National Monument, 3 April 1990 to 30–31 March 1991.

Species	Relative frequency	Relative density	Relative cover	Importance value
Trees and shrubs				
Opuntia bigelovii	17.46	38.16	13.96	23.19
Simmondsia chinensis	19.05	20.77	29.11	22.98
Cercidium microphyllum	11.11	3.38	24.83	13.11
Encelia farinosa	15.87	16.91	4.54	12.44
Eriogonum fasciculatum	9.52	10.14	9.65	9.77
Viguiera parishii	11.11	5.31	3.22	6.55
Fouquieria splendens	4.76	1.45	11.16	5.79
Opuntia acanthocarpa	4.76	1.93	2.82	3.17
Carnegiea gigantea	4.76	1.45	0.63	2.28
Yucca baccata	1.59	0.48	0.08	0.72
Small perennials				
Mirabilis bigelovii	31.25	70.57	94.77	65.53
Porophyllum gracile	50.00	3.76	4.91	19.56
Dichelostemma pulchellum	12.50	19.25	0.03	10.59
Stephanomeria tenuifolia	6.25	6.42	0.29	4.32

Table 11. Relative frequency, relative density, relative cover, and importance values for perennials, Plot 4, Tonto National Monument, 5 April 1990 to 30–31 March 1991.

Species	Relative frequency	Relative density	Relative cover	Importance value
Dichelostemma pulchellum	8.03	50.72	0.04	19.59
Mirabilis bigelovii	9.49	19.51	11.00	13.33
Simmondsia chinensis	10.71	1.61	21.49	11.27
Cercidium microphyllum	3.89	0.21	26.66	10.25
Viguiera parishii	11.68	2.03	8.47	7.39
Opuntia acanthocarpa	9.73	1.20	11.10	7.34
Yucca baccata	1.95	15.60	1.72	6.42
Unknown shrub	6.81	0.47	8.47	5.25
Encelia farinosa	6.81	0.78	0.85	2.81
Opuntia engelmannii	2.92	0.21	2.79	1.97
Opuntia bigelovii	1.95	2.93	0.05	1.64
Porophyllum gracile	3.89	0.52	0.223	1.55
Eriogonum fasciculatum	2.92	0.16	0.85	1.31
Galium stellatum	2.92	0.16	0.52	1.20
Sphaeralcea emoryi	2.92	0.21	0.36	1.16
Fouquieria splendens	0.97	0.10	2.18	1.09
Menodora scabra	2.92	0.16	0.07	1.05
Echinocereus fasciculatus	2.92	0.16	0.02	1.03
Lycium fremontii	0.97	0.98	0.97	0.97
Calochortus sp.	0.73	1.95	0.03	0.90
Dasylirion wheeleri	0.97	0.05	1.68	0.90
Carnegiea gigantea	1.95	0.10	0.25	0.77
Brickellia atractyloides	0.97	0.16	0.19	0.44
Mammillaria microcarpa	0.97	0.05	0.00	0.34

Table 12. Relative frequency, relative density, importance values, and density per square meter for annuals, Plot 4, Tonto National Monument, 5 April 1990 to 30–31 March 1991.

Species	Relative frequency	Relative density	Importance value	Density/ sq m
Draba cuneifolia	8.89	23.59	16.24	103.25
Plantago patagonica	4.44	17.53	10.99	76.75
Bromus rubens	8.89	8.85	8.87	38.75
Stellaria nitens	4.44	11.48	7.96	50.25
Erodium cicutarium	8.89	6.40	7.64	28.00
Bromus sp.	2.22	11.76	6.99	51.50
Phacelia cryptantha	6.67	4.23	5.45	18.50
Silene antirrhina	8.89	2.00	5.44	8.75
Astragalus nuttallianus	6.67	2.06	4.36	9.00
Daucus pusillus	6.67	1.31	3.99	5.75
Lepidium medium	6.67	0.86	3.76	3.75
Lupinus arizonicus	4.44	1.83	3.14	8.00
Parietaria floridana	2.22	3.37	2.80	14.75
Pectocarya recurvata	4.44	1.14	2.79	5.00
Amsinckia tessellata	4.44	0.34	2.39	1.50
Lotus humistriatus	4.44	0.17	2.31	0.75
Tillaea erecta	2.22	2.06	2.14	9.00
Fillago arizonica	2.22	0.74	1.48	3.25
Androsace occidentalis	2.22	0.29	1.25	1.25

Cercidium microphyllum had the greatest cover (499,615 cm^2 or 26.66% relative cover). When the trees and shrubs were considered separately from small perennials (Table 13), *Simmondsia chinensis* assumed an importance value of 19.17. One small and 1 large *Carnegiea gigantea* were present in the plot. The large *Carnegiea gigantea* was 6.5 m tall with 5 arms. The small, unbranched *Carnegiea gigantea* was 70 cm tall. *Opuntia acanthocarpa*, *O. engelmannii*, *O. bigelovii*, *Yucca baccata, Dasylirion wheeleri,* and *Fouquieria splendens* also occurred in this plot.

Many species of native annuals were present, and 2 natives, *Draba cuneifolia* and *Plantago patagonica*, had the highest importance values (16.24 and 10.99, respectively) (Table 12). No *Selaginella arizonica* plants were observed in the plot.

The following dead plants were observed in the plot: 1 *Simmondsia chinensis*; 2 *Dasylirion wheeleri*; 2 *Fouquieria splendens*; 1 *Eriogonum fasciculatum*; and 6 *Opuntia acanthocarpa*. The following fire-damaged plants were observed: 2 *Cercidium microphyllum*; 8 *O. acanthocarpa*; 2 *Echinocereus fasciculatus*; 2 *O. engelmannii*; and 2 *Carnegiea gigantea*.

Plot 5

Plot 5 is located below and north of Upper Ruins at 988 m (Fig. 18). The large *Carnegiea gigantea* in the plot was the highest large *C. gigantea* on the hillslope directly above the water tank. This area burned in the 1964 Schultz and 1976 Monument fires, but not in the 1970 Cottonwood Fire, and probably not in the 1980 Monument Fire (Figs. 3, 4, 6, and 7). The plot 0,0 corner is the northwest corner and is marked with rebar. It is located at the southeast corner of a rock outcrop (Appendix 1e).

Tables 14 and 15 present the relative cover, relative frequency, relative density, and importance values for the 28 species sampled in this plot. *Dichelostemma pulchellum* (IV 30.29), *Simmondsia chinensis* (IV 27.36), and *Sphaeralcea emoryi* (IV 12.52) were the dominant species. The absolute values for these species are shown in Appendix 3-5. *Simmondsia chinensis* had by far the greatest cover (327,098 cm^2 or 62.34% relative cover). When the trees and shrubs were considered separately from small perennials (Table 16), *S. chinensis* assumed an importance value of 42.70. Two living *Carnegiea gigantea*, 6.5 m and 28 cm tall, were present in the plot. *Prosopis velutina* was also present.

Two nonnative annual herbs, *Bromus rubens* and *Erodium cicutarium,* had high importance values of 43.91 and 13.27, respectively. The density of *B. rubens* measured 203.25 plants per sq m. No *Selaginella arizonica* plants were found in the plot.

Few woody plants occurred in the plot at the time of this study. No medium-sized cacti were present. Likewise, *Cercidium microphyllum* and *Fouquieria splendens* did not occur in the plot. The large *Carnegiea gigantea* with 7 arms had been badly damaged by fire (its ribs were exposed). Remains of other woody plants killed by fire were not observed. The young *C. gigantea* in the plot showed no fire damage. No nurse tree remains were obvious, but the plant was growing near a rock outcrop that could have provided shade and shelter.

Table 13. Importance values (perennials considered separately), Plot 4, Tonto National Monument, 5 April 1990 to 30–31 March 1991.

Species	Relative frequency	Relative density	Relative cover	Importance value
Trees and shrubs				
Simmondsia chinensis	14.47	18.67	24.38	19.17
Viguiera parishii	15.79	23.49	9.61	16.30
Opuntia acanthocarpa	13.16	13.86	12.59	13.20
Cercidium microphyllum	5.26	2.41	30.23	12.64
Unknown shrub	9.21	5.42	9.61	8.08
Encelia farinosa	9.21	9.04	0.96	6.40
Yucca baccata	2.63	9.64	1.95	4.74
Opuntia engelmannii	3.95	2.41	3.17	3.17
Sphaeralcea emoryi	3.95	2.41	0.41	2.25
Eriogonum fasciculatum	3.95	1.81	0.96	2.24
Menodora scabra	3.95	1.81	0.08	1.95
Echinocereus fasciculatus	3.95	1.81	0.02	1.92
Fouquieria splendens	1.32	1.20	2.48	1.67
Opuntia bigelovii	2.63	1.81	0.06	1.50
Carnegiea gigantea	2.63	1.20	0.28	1.37
Dasylirion wheeleri	1.32	0.60	1.90	1.27
Brickellia atractyloides	1.32	1.81	0.22	1.11
Lycium fremontii	1.32	0.60	1.10	1.01
Small perennials				
Mirabilis bigelovii	36.45	26.76	93.08	52.10
Dichelostemma pulchellum	30.84	69.57	0.32	33.58
Porophyllum gracile	14.95	0.71	1.93	5.87
Galium stellatum	11.21	0.21	4.42	5.28
Calochortus sp.	2.80	2.68	0.23	1.90
Mammillaria microcarpa	3.74	0.07	0.01	1.27

Table 14. Relative frequency, relative density, relative cover, and importance values for perennials, Plot 5, Tonto National Monument, 6 April 1990 to 30–31 March 1991.

Species	Relative frequency	Relative density	Relative cover	Importance value
Dichelostemma pulchellum	20.31	70.47	0.09	30.29
Simmondsia chinensis	16.67	3.08	62.34	27.36
Sphaeralcea emoryi	22.92	9.57	5.09	12.52
Aristida parishii	4.69	6.41	7.83	6.31
Viguiera parishii	10.42	0.80	6.05	5.75
Mirabilis bigelovii	3.13	4.27	3.82	3.74
Prosopis velutina	2.08	0.11	7.24	3.15
Stephanomeria sp.	6.25	0.34	1.26	2.62
Stipa speciosa	2.08	0.23	5.09	2.47
Carnegiea gigantea	4.17	0.23	1.14	1.85
Mammillaria microcarpa	1.56	2.14	0.01	1.24
Calochortus sp.	1.56	2.14	0.00	1.23
Porophyllum gracile	2.08	0.11	0.03	0.74
Cirsium neomexicanum	2.08	0.11	0.01	0.74

Table 15. Relative frequency, relative density, importance values, and density per square meter for annuals, Plot 5, Tonto National Monument, 6 April 1990 to 30–31 March 1991.

Species	Relative frequency	Relative density	Importance value	Density/ sq m
Bromus rubens	11.76	76.05	43.91	203.25
Erodium cicutarium	11.76	14.78	13.27	39.50
Silene antirrhina	11.76	1.96	6.86	5.25
Lupinus arizonicus	11.76	1.50	6.63	4.00
Lepidium medium	8.82	0.56	4.69	1.50
Eschscholzia mexicana	5.88	0.75	3.32	2.00
Descurainia pinnata	5.88	0.65	3.27	1.75
Thelypodium longiocarpum	5.88	0.56	3.22	1.50
Lotus humistriatus	5.88	0.56	3.22	1.50
Thysanocarpus amplectens	5.88	0.28	3.08	0.75
Tillaea erecta	2.94	1.68	2.31	4.50
Plagiobothrys arizonicus	2.94	0.28	1.61	0.75
Amsinckia tessellata	2.94	0.19	1.56	0.50
Cryptantha sp.	2.94	0.09	1.52	0.25
Orthocarpus purpurascens	2.94	0.09	1.52	0.25

Table 16. Importance values (perennials considered separately), Plot 5, Tonto National Monument, 6 April 1990 to 30–31 March 1991.

Species	Relative frequency	Relative density	Relative cover	Importance value
Trees and shrubs				
Simmondsia chinensis	29.63	22.31	76.15	42.70
Sphaeralcea emoryi	40.74	69.42	6.22	38.79
Viguiera parishii	18.52	5.79	7.39	10.56
Prosopis velutina	3.70	0.83	8.85	4.46
Carnegiea gigantea	7.41	1.65	1.39	3.48
Small perennials				
Dichelostemma pulchellum	46.43	81.74	0.49	42.88
Aristida parishii	10.71	7.43	43.16	20.44
Mirabilis bigelovii	7.14	4.95	21.04	11.05
Stipa speciosa	4.76	0.26	28.05	11.03
Stephanomeria sp.	14.29	0.40	6.93	7.20
Mammillaria microcarpa	3.57	2.48	0.04	2.03
Calochortus sp.	3.57	2.48	0.01	2.02
Porophyllum gracile	4.76	0.13	0.19	1.69
Cirsium neomexicanum	4.76	0.13	0.08	1.66

Discussion

Four of the plots selected are in the Palo verde-Mixed Cacti Series of the Arizona Upland of the Sonoran Desertscrub. The fifth plot (Plot 5) is in the Mixed Grass-Scrub Series of the Semidesert Grassland (Brown 1982; Jenkins et al. 1995). These 5 plots were chosen to represent a variety of vegetation associations exposed to the fires that have occurred on the monument since 1947.

According to the fire maps and reports, the area where Plot 1 is located burned in all 5 major fires. Plots 2 and 4 each experienced 1 fire: Plot 4, the 1964 Schultz fire; and Plot 2, the 1976 Monument Fire. Plot 5 burned at least twice (1964 and 1976), perhaps 3 times. Plot 3 (the control) has never burned. It is somewhat difficult to discuss these plots without knowing what species might have been growing at each location prior to the fires. However, remains of fire-killed plants, and live, fire-damaged plants occur in each of the burned plots. The discussion of impacts of fire on individual species will be presented in Effects of Fire on Cacti, Succulents, Special Status, and Other Notable Plants.

In Plot 1, *Carnegiea gigantea*, *Fouquieria splendens, Cercidium floridum* and *C. microphyllum,* medium-sized cacti, and abundant *Encelia farinosa* indicate that a lush Palo verde-Mixed Cactus community did exist there at one time, although it is currently greatly diminished after 5 fires. The map included with Jenkins et al. (1995) shows the area where Plot 1 occurs in the Mixed Grass-Scrub Series, but the vegetation on the south-facing slope is in the Sonoran Desertscrub. The remains of fire-killed plants were fewer than in Plots 2 and 4, probably because successive fires removed the dead and downed plants from previous fires.

Mammillaria microcarpa appeared to be over-stated in its density, perhaps due to the clumpiness of its distribution. However, the other species (such as *Dichelostemma pulchellum*) that had adjustments due to being recorded in the meter-square plots have values that appeared logical for the observed situation in the field.

Although much evidence of fire was observed in Plot 4, the vegetation did not seem greatly different from that in the immediately adjacent, non-burned areas. One fire, therefore, did not greatly impact the desert vegetation as far as changing species composition, although frequency and density of each species were probably initially affected by the fire. A great diversity of trees, shrubs, and perennial herbs existed in both burned and adjacent unburned plots. In fact, more species of shrubs occurred in Plot 4 than in the control (Plot 3). This may partly be due to the northeasterly aspect of Plot 4 and more level terrain (the elevation is almost identical). The annual herb and grass diversity and densities were similar in Plot 4 and the control. *Cercidium microphyllum* in Plot 4 after the fire (although some trees were severely damaged) provided shady microhabitats for many of the annuals. Though still alive 26 years after the fire, the large *Carnegiea gigantea* (with 5 arms) sustained considerable fire damage, and may have a shortened lifespan due to fire impacts. The young *C. gigantea* (only 60 cm tall with a fire-scar at 22 cm) appeared to be healthy.

Plot 2 had much more evidence of fire than Plot 4 in terms of dead and downed woody material and plants showing fire damage. Differential impact to and recovery of species is still apparent

after 14 years. The 3 damaged *Cercidium microphyllum* had not recovered fully from the fire and provided less shade microhabitat than healthy plants would. Although 37 *Encelia farinosa* died, *E. farinosa* was much more abundant in the burned plot than in the control plot. *Opuntia bigelovii* incurred considerable impact from the fire (38 plants were killed). The large *Carnegiea gigantea* had fire scars at the base but seemed quite healthy otherwise.

Plot 5 lacked dead and downed woody plant material, so it was difficult to interpret whether this area had as much woody vegetation prior to the fires as the other 3 burn plots. The lack of trees might partly be due to the extreme steepness of the terrain and rockiness of the substrate. The presence of 2 *Carnegiea gigantea* in the plot might indicate prior presence of nurse trees, although, as mentioned above, the rock outcrop might have provided sufficient protection for the younger *C. gigantea* on the east-facing slope. Whatever the status of the vegetation association prior to the fires, the species composition at the time of this study placed this plot in the Mixed Grass-Scrub Series.

Jenkins et al. (1995) established permanent monitoring plots at TONT called TMPs. They stated that 4 of these monitoring plots, established west of Cave Canyon in the area burned in the 1964 Schultz Fire (TMPs 5, 6, 9, and 10), were in the Mixed Grass-Scrub Series. TMP 6 probably also burned in the 1976 Monument Fire. TMP 9 (close to Plot 1 of this study, but upslope) burned in 1964, 1970, 1976, and 1980, but not in 1947. These plots ranged in elevation from approximately 1,033–1,146 m, or 27–140 m higher than Plot 1, the highest plot of this study. Three of these 4 TMP plots are on north-facing slopes. At these higher elevations above 1,036 m, except perhaps on south-facing slopes, Mixed Grass-Scrub may have been the vegetative composition prior to the 1964 Schultz Fire also.

TMP 3 established by Jenkins et al. (1995) is in an area unburned by the Schultz Fire, located a short distance from the control plot (Plot 3) of this current study. Jenkins et al. noted that very few grasses were present in that plot and most of the cover was provided by *Cercidium microphyllum*, *Encelia farinosa*, *Selaginella arizonica,* and *Simmondsia chinensis*, observations similar to those for Plot 3.

It is interesting to note that the boundary of the *Sphaeralcea emoryi - Stipa speciosa - Eragrostis lehmanniana - Stephanomeria pauciflora - Simmondsia chinensis* Association (143.1551) of the Mixed Grass-Scrub Series on the map by Jenkins et al. followed the boundary of the 1980 Monument Fire west of Cave Canyon (Fig. 7). Likewise, on the eastern side of Cave Canyon, the boundary between the associations of Arizona Upland on the lower slopes, and between the Grassland–Scrub and Interior Chaparral, and Arizona Upland on the upper slopes followed the boundary of the 1980 fire. The area enclosed had previously been burned by several fires, but there has been no large-scale fire in that sector of the monument since 1980. The boundaries of the fire were lines installed and set as backfires.

Rephotography of 1964 Photo Stations

Methods

Twenty photo stations were set up after the 1964 Schultz Fire on 3 August 1964. Various persons rephotographed at these locations, first at monthly intervals, then less frequently (Appendix 4). The dates of the last set of photos prior to this study are 18 and 25 September 1972.

In this current study an attempt was made to relocate all 20 photo stations. Comparison photos were taken replicating the original photos as precisely as possible. In some cases different photographers over the years had changed the view of the photos slightly to accommodate for recording more information visually or to accommodate for growth of plants. Plant species were identified in both the old and current photos; and changes to the vegetation were noted. Such circumstances as death, degree of recovery, recovery due to different types of responses (sprouters vs. seeders, for example), changes in native species composition, and introduction of nonnative species was noted.

Results

Most of the photo stations were relocated. The area where the photo stations were installed is shown in Figure 21. There is some order to the layout. However, it appears that at first the photos were taken at likely spots to illustrate the effects of fire (Photo Stations 1–10), later someone thought that a comparison over time would be useful and established Photo Stations 11–19 (20?).

At most stations rebar marks the point above which the camera is to be stationed on a tripod, and a small, wooden, red number sign on a stake indicates the direction for the photo. Although not in the original photos, this sign is readily apparent in the 18 September 1972 photos used in conjunction with the 1964 photos to find the sites. In some cases the sign was bent, broken or missing. However, all photo stations except 7 and 20 were found. It is possible that photo stations 7 and 20 have been lost due to trail work, although their exact placement is only hypothesized by this author. Both sites were illustrated with closeup photos with no distinguishing background features to aid in relocation of the sites.

Initial attempts at rephotography in 7 March and 4–6 April 1990 were conducted early in the morning and in the late afternoon, before and after the establishment of the vegetation plots. When the initial products of the rephotography were viewed, it became apparent that the middle of the day was a better time for photography on the slope where the photo stations occur. On 30–31 March 1991 most of the photo stations were rephotographed.

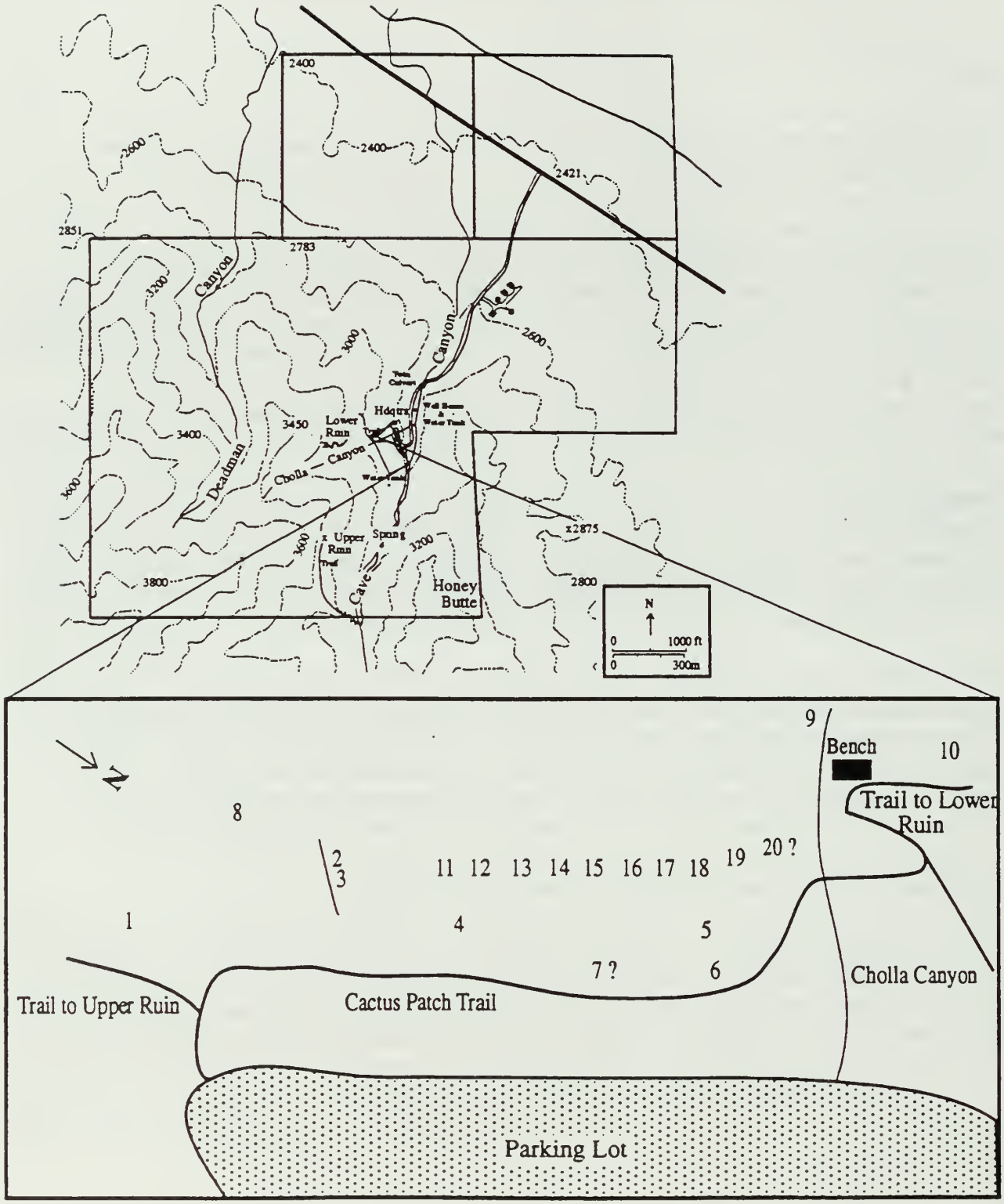


Figure 21. Location of 1964 Photo Stations, Tonto National Monument.

Discussion

The 1964 photos of the east-facing hillside immediately above the visitor center parking lot revealed a diversity of Sonoran Desertscrub species, including *Carnegiea gigantea*, *Ferocactus cylindraceus, Opuntia engelmannii, O. acanthocarpa*, *Cercidium* spp., *Simmondsia chinensis*, *Agave chrysantha*, *Dasylirion wheeleri,* and some *Prosopis velutina. Prosopis velutina, Canotia holocantha,* and *Simmondsia chinensis* grew in Cholla Canyon. The surface of the ground was very rocky, and after the fire there was very little plant litter remaining on the ground. In addition to incurring direct damage from the Schultz Fire, backfires were started in the area to aid in controlling the fire before it reached the visitor center. The lower boundary of the burned area appears to be the Cactus Patch Trail, above the parking lot (see Fig. 3).

In 1961, Charles Strong ran a 1,829-m, south-north vegetation transect (Transect A) that passed slightly above the area where the photo stations were later established. (See Strong 1962 and Brian 1991 for the results, resurvey of, and interpretation of this 1961 survey.) Some of Strong's comments merit mention. He noted that *Cercidium microphyllum* occurred with greater frequency and cover than other species of trees, most prevalently on southeast-facing slopes. *Acacia greggii* and *Prosopis velutina* grew in the washes. Of the shrubs, *Simmondsia chinensis* was the dominant species, and was more homogenous in distribution that the other shrubs. He stated *Krameria* sp. was next in cover, abundance, and homogeneity. *Encelia farinosa* was abundant, but distributed sporadically in groups, as were *Gutierrezia sarothrae* and *Menodora scabra*.

It is evident that many plants died in the 1964 fire. However, the comparison photos taken over a span of many years document that some plants survived and, indeed, now are large and healthy. *Simmondsia chinensis* appears to be the plant best able to do this. Several of the large *Carnegiea gigantea* were killed by the fire, and in the current study it was difficult to locate even their downed skeletons. A few *C. gigantea* probably did not incur much damage and in this study were large, apparently healthy, with many arms. Some of the *Opuntia acanthocarpa*, *O. engelmannii,* and *Dasylirion wheeleri* survived as well, although apparently not all did.

Scattered bunchgrasses may have been present in 1964, especially at the higher elevations and on north-facing slopes. By 1972, there was indication of abundant grasses in some of the photos. Some of these grasses could be the result of seeding efforts when *Eragrostis lehmanniana,* found growing on the slopes along the Upper Ruin trail during this study, was introduced. As noted previously in Documentation of Fires, Tonto National Forest used a seed mix containing nonnative grasses, especially *E. lehmanniana,* in the 1960s and 1970s for seeding after fires. Although the area of the 1964 photo stations did not burn in the 1970 Cottonwood Fire, grass seed could have been deposited either intentionally or inadvertently over the area following the 1970 as well as 1964 fires. The nonnative *Bromus rubens* was an important component of the annual vegetation of this area during the current study. Other, native annuals are abundant in early spring after wet winters.

Effects of Fire on Cacti, Succulents, Special Status, and Other Notable Plants

Cacti, succulents, and species with special status (U.S. Fish and Wildlife Service Candidate, Sensitive, or nonnative species) were noted in the burned areas and plots. A plant list was developed from observations of plant distributions made during inventory of the burned and unburned zones and from sampling plot data. Plants were identified using comparative collections housed at the Museum of Northern Arizona and TONT herbaria. Since there is a recently completed vegetation inventory of TONT by Jenkins et al. (1995), which includes Appendices 3 and 4, with location and habitat for each species in the monument, the discussion here will be limited to fire effects. Nomenclature follows Lehr (1978) and Lehr and Pinkava (1980, 1982), except as noted in Jenkins et al. D. Pinkava, Arizona State University (pers. comm. 1991), provided the nomenclature for the cacti.

The effects of fire intensity and frequency on plants at TONT were compared with reports from the literature. Burgess (1965) documented the distribution of species on the monument prior to the 1964 Schultz Fire. Therefore, his notes are provided for background on distribution and abundance of species prior to the fire. Jenkins et al. (1995) represents a recently completed study of the vegetation. Instances in which their assessment differs from this author have been provided for comparison.

Agavaceae

Agave chrysantha was noted by Burgess as moderately common on the monument and *Dasylirion wheeleri* as locally abundant on ridges and north-facing slopes. *Yucca baccata*, noted as locally abundant on ridges and north-facing slopes by Burgess, was recorded in the control plot (Plot 3) during this study. In this study, *D. wheeleri* was recorded only in Plot 4, where there were 2 dead plants and 1 live plant. Badly damaged *D. wheeleri* and *Y. baccata* photographed after the 1964 fire had recovered well by 8 years later and remained healthy 26 years after the fire. The *Agave chrysantha* at Photo Station 17 died.

Wright (1980, from White 1969) reported that *Dasylirion wheeleri* is not tolerant of fire: 97% died in severe fires. All plants survived in light and moderate burns, however. *Yucca baccata* is fire tolerant: generally few plants die and most recover in 2–5 years (Wright 1980). Very hot fires may cause about 25% mortality (Humphrey 1949). *Agave chrysantha* and *Y. baccata* are leaf succulents; *D. wheeleri* has a thick woody caudex.

Cactaceae

Many species of cacti occur on the monument. Mortalities of cacti include interactive effects between fire, insects, drought, and grazing by rodents, rabbits, and domestic animals (Wright 1980). Natural die-offs (not related to fire) of 25–35% occur in cactus species from time to time, complicating interpretation of observations.

The most obvious cactus species on the monument is the tree-sized *Carnegiea gigantea*. Burgess stated this species was scattered throughout the monument, reaching greatest development on the east-facing slope below Lower Ruin. At the time of this study, it was still common in Sonoran Desertscrub, especially on south and southeast-facing slopes. Comparison photos (Figs. 10 and 11) show a decrease in number on the slopes below Upper Ruin.

Many of the large cacti still visible on the slope during this study were badly damaged by the series of fires, and seem to be dying prematurely. However, cacti that were fairly small at the time of a particular fire and that did not suffer severe damage appeared to be healthy during this study. It is possible that some of these occurred in "skip" areas. Rogers (1985) concluded that the mortality of *Carnegiea gigantea* could not be accurately determined several years after fire because of the attrition of small plants. In 1980, Rogers and Steele reported 65% mortality of *C. gigantea* in their study areas north and east of Phoenix.

This comment was made following the 1970 Cottonwood Fire: "The saguaro cactus [*Carnegiea gigantea*] proved to be a menace as bad as any snag in timber country. The saguaro would burn off at the base, burn up through its interior, and roll down the hill spreading fire as it went" (Graham 1970).

Echinocereus fasciculatus var. *boyce-thompsoni* was noted by Burgess as scattered on slopes. Two out of the 3 plants found in Plot 4 were burned by the Schultz Fire. This cactus is fairly small, so it is likely to be consumed by a hot fire and not visible as a dead plant thereafter.

Burgess noted that *Ferocactus cylindraceus* was relatively common in most habitats in the monument. In this study, it was less common in burned Sonoran Desertscrub areas. Graham (1970) said that during the Cottonwood Fire, "The barrel cactus [*F. cylindraceus*] would do the same [as *Carnegiea gigantea*: burn off at the base, burn up through its interior, and roll down the hill spreading fire]." Photo Station 7 had an *F. cylindraceus* that was killed by the Schultz Fire. No barrel cacti were recorded in the plots. A fire-damaged *F. cylindraceus* was found adjacent to Plot 2, and other fire-damaged individuals were seen during hikes.

Wright (1980) stated that *Ferocactus cylindraceus* is not tolerant of fire, and sites require more than 15 years to recover. *Ferocactus cylindraceus* mortality can be 65–82% (Wright 1980; Rogers and Steele 1980). Removal of spines can lead to grazing animals eating the pulpy interior, increasing the percent killed (Reynolds and Bohning 1956).

Burgess noted *Mammillaria microcarpa* as scattered and nowhere abundant, which appeared still to apply during this study. However, its preference for rocky outcrops probably enables it to be less impacted by fire than some other species, because there is usually less fuel-associated with that microhabitat and more tendency for "skips." Rogers and Steele (1980) noted 67–95% mortality of this species in their study areas.

Opuntia acanthocarpa was a common cactus throughout the monument during this study, just as it was before the 1964 fire. Jenkins et al. noted it as occasional in Semidesert Grasslands. Those

areas in the southern part of the monument that were in grasses at the time of this study have been burned once to several times in the past 44 years. *Opuntia acanthocarpa* is very sensitive to fire: 24% of the total plants (dead and alive) observed in the burn plots had been killed by fire. Comparison photos likewise showed some plants that were killed by the 1964 fire. Rogers and Steele (1980) noted 89–97% mortality of this species. The plants can resprout, however (Tratz and Vogl 1977, cited in O'Leary and Minnich 1981).

Opuntia bigelovii is even more sensitive to fire: 73% of the total plants observed in the burn plots had been killed by fire. All 3 plants in Plot 1 were dead. Thirty-eight out of 50 plants were dead in Plot 2. As Burgess noted, this species was common throughout the monument and often formed extensive patches due to joints taking root where they dropped or rolled. Rogers and Steele (1980) noted 88–98% mortality of this species in their study areas.

Opuntia engelmannii grows singly or in patches, reaching, as Burgess noted, local abundance on some slopes. This species is able to rejuvenate well after fire. It appears that the pads may die back to the root-crown of the plant and then grow anew. Burned pads on 2 of the 4 plants in Plot 4 were noted. Wright (1980) stated that this species is moderately tolerant and recovers in about 15 years after a fire, even when reduced in size by 30%. The smaller amount of litter around the bases of these plants compared to chollas makes fire less damaging to *O. engelmannii* (Cable 1972).

The following cacti were not studied in relation to fire on the monument. *Opuntia chlorotica* was widely scattered at lower elevations (Jenkins et al.). Burgess noted *O. fulgida* as scattered on dry rocky slopes and ridges. *O. violacea* var. *macrocentra* grew scattered on dry rocky slopes and ridges and was collected north of Lower Ruins ridge by Burgess in 1962. He recorded *O. leptocaulis* as scattered on flats and in washes and drainageways on the slopes. Rogers and Steele (1980) reported 96–100% mortality for *O. leptocaulis* in their study areas.

Compositae

Encelia farinosa was noted by Burgess as abundant. The differences in absolute numbers in the plots of this current study are quite outstanding: Plot 1 (burned 5 times), 283 plants; Plot 2 (burned 1 time), 370 plants; Plot 4 (burned 1 time), 15 plants; Plot 5 (burned 2 times), 0 plants. Plot 3 (control), 45 plants. The placement of the plots could have quite a lot to do with the number of plants recorded. Strong (1962) in his long line transects stated that *E. farinosa* was abundant, but distributed sporadically in groups. However, Rogers and Steele (1980) noted that *Encelia farinosa* seeds in well after fires, making the greatest relative increase of the perennials in their study areas. Cave and Patten (1984) noted that *E. farinosa* had increased to 762% above preburn status on their controlled burn site within 9 months.

Perityle saxicola is a small perennial herb that is a U.S. Fish and Wildlife Service Category 2 species and USFS Sensitive in Region 3. Burgess noted this species (as *Laphamia saxicola*) was restricted to boulders and cliff faces in the monument and known only from the immediate area (Mazatzal Mountains). Today its distribution is better known, and it was found to be quite common in its particular habitat on the monument (Mazzoni et al. 1982; Jenkins et al. 1995). Its

restriction to boulders and cliff faces having little vegetative cover or litter probably enables it to survive fire quite well.

Gutierrezia sarothrae is not tolerant of fire. Wright (1980) noted 95% mortality of existing plants. It does reestablish with seedlings following wet winters and springs and takes about 5–10 years to reach former abundances.

Crassulaceae

Dudleya saxosa was noted by Burgess (as *Echeveria collomae*) to be locally abundant among rocks on ridges and north-facing slopes, but generally rare in the monument. In this study, it was moderately common on north-facing upper slopes in Sonoran Desertscrub and abundant in places on rocky outcrops in Cave Canyon. Jenkins et al. noted it as common in Semidesert Grasslands and occasional in Interior Chaparral. Although some plants were noted with leaves burned back to the base of the plant, its succulent leaves and habit of growing in very rocky places may make it less vulnerable to effects of fire.

Burgess reported the tiny *Tillaea erecta* as locally abundant in small patches, but apparently rare on the monument. In this study, it was found in Plots 3, 4 and 5, which were sampled in early April. The apparent rareness may in part be due to its small size and ephemeral nature. No relationship to fire effects was noted in this current study.

Fouquieriaceae

Fouquieria splendens was noted by Burgess as common throughout the monument in Upland Desert. Two of the 4 *F. splendens* noted in the burn plots had been killed by the fires. Plate 8 shows the demise of *F. splendens* after the 1976 Monument Fire. There were 3 healthy plants in the control plot. *Fouquieria splendens* is very sensitive to fire. Wright (1980) reported studies where 67% of the plants were killed in severe fires, 40% were killed in moderate fires, and 50% were killed in light fires. Rogers and Steele (1980) reported 97% mortality and 67% consumption of *F. splendens* plants in their study areas.

Gramineae

Bromus rubens, a nonnative grass, may have increased in abundance throughout the monument over the years. Burgess stated that *B. rubens* was an "abundant annual on the flats on northern edge of the monument, reaching immense densities and coverage in good years." However, Jenkins et al. noted it as abundant in nearly every situation on the monument, especially after wet winters. It is especially abundant in burned areas.

Bromus rubens increases with grazing and disturbance. Unlike the majority of the native annuals, which flush in the first year and fade quickly, *B. rubens* persists indefinitely in open patches in the chaparral and creates denser and more uniform cover, which is better able to carry fire (Zedler et al. 1983). Keeley et al. (1981) noted that repeat fires in the chaparral favored nonnative herbs such as *B. rubens* over native ones, particularly the "fire annuals," which were quickly eliminated.

The nonnative bunchgrass *Eragrostis lehmanniana* is common on upper slopes of Sonoran Desertscrub and in Sonoran Riparian Scrub and occasional in Semidesert Grassland on north and west slopes. This species of lovegrass was not recorded by Burgess. As noted above in the rehabilitation discussion, it was likely introduced in the seeding mix following fires in the 1960s and 1970s (G. Holder, pers. comm. 1991). It is the most persistent of the lovegrasses when seeded following fires.

Cable (1972) noted that this species has been used extensively for reseeding in the semidesert Southwest. "It has several desirable characteristics, including drought resistance, ability to tolerate heavy grazing, ease of establishment, and aggressiveness in competing with other vegetation for soil moisture . . . It is so aggressive that within its preferred range it will eventually (within 15–20 years) crowd out and replace most of the native grasses." A relatively hot June fire killed 98% of the lovegrass plants, whereas a relatively cool February fire killed less than 5% of the plants (Cable 1971, cited in Cable 1972). The large bunchgrasses can be severely damaged, but seedlings quickly reestablish burned areas (Wright 1980), especially when mature plants are killed (Cox and Ruyle 1986). Increased germination is due, in part, to direct effects of the heat of the fire on the seed, possibly by increasing germination through seed coat scarification (Ruyle et al. 1988; Sumrall et al. 1990).

Fires in an area occupied by *Eragrostis lehmanniana* can be quite damaging. Cable (1972) noted that twice as many small diameter *Prosopis velutina* were killed on a *E. lehmanniana* area than on a *Bouteloua eriopoda* area.

The nonnative annual *Schismus barbatus* was noted by Burgess as locally abundant on desert slopes. It was found in Plots 1, 2 and 3 in the current study.

Leguminoseae

Burgess noted that *Acacia greggii* was common throughout the monument in Upland Desert. It was not recorded in any plot in the current study. However, literature exists on fire effects on this species. As a tolerant species, it responds to fire with vigorous sprouting, recovering in 10–15 years (Wright 1980). Rogers and Steele (1980) did record 100% mortality following fire in their Saguaro study area.

Prosopis velutina was reported by Burgess as scattered throughout the monument in Upland Desert, but more common along the major washes and on the deeper soils in the north. Only 1 *P. velutina* occurred in the plots, in Plot 5 on the west slope of Cave Canyon.

Young *P. velutina* trees are easily killed by fire, but the species is a vigorous sprouter. The plants sprout from basal stem buds, or crown buds if the fire is not too severe (Cable 1972). Cable (1965) reported 21% kill of plants less than 5 cm in diameter, and 10% mortality of trees larger than 5 cm. The ability to withstand fire relates to the bark thickness on older and larger stems. Large trees of *P. velutina* can be susceptible to fire, especially 2 successive burns on uplands. The recovery period for mesquite trees is 20–30 years, according to Wright (1980). Occasionally

very high kills may be due to high amounts of fuel. Cable (1972) noted that plants are most sensitive to fire during late spring and early summer.

Cercidium floridum and *C. microphyllum* were reported by Burgess as abundant throughout the monument in Upland Desert. These medium-sized trees were still abundant at the time of this report and occurred in Plots 1–4. The plants incurred quite a bit of damage from the fires. There were 3 dead and 3 burned trees in Plot 2 and 2 burned trees (out of 4) in Plot 4. The control plot had 7 live, healthy trees.

Humphrey (1949) reported 90% mortality following wildfire, and Rogers and Steele (1980) noted 78–92% mortality of *C. microphyllum* in man-caused June fires at their study areas. The thin-barked nature of this species makes it susceptible to fire impacts. Cave and Patten (1984) indicated that *C. microphyllum* trees suffered from heat damage (probably to the cambium) during fire, taking several months for the trees or portions of their crowns to die. However, the tree does produce basal and aerial sprouts (McLaughlin and Bowers 1982; Cave and Patten 1984).

Liliaceae

Burgess noted 3 species of *Calochortus* as rare to scattered on rocky slopes and colluvium. This perennial originates from a corm (bulb) and is rather transient in appearance.

Dichelostemma pulchellum, another perennial originating from a corm, was noted by Burgess as moderately abundant throughout the monument. It was very abundant in the plots in this current study. The notation by Jenkins et al. as occasional may simply reflect lack of coordination in timing of sampling with its emergence.

Zedler et al. (1983) noted *D. pulchellum* and *Calochortus* spp. suffered little in chaparral fires because the corms lie deep in soil. The first year after fire these species initiate vigorous sprouts and nearly all flower (Horton and Kraebel 1955; Keeley et al. 1981). "This trait of fire-stimulated flowering appears to be most frequently associated with the monocotyledons, especially the amaryllis, grass, lily and orchid families" (Zwolinski 1990).

Nyctaginaceae

Burgess noted *Mirabilis bigelovii* as relatively common, often growing in the shade of larger trees or shrubs. It was quite abundant in some of the plots, especially the control and Plot 4, which have several *Cercidium* spp. and large shrubs. This species emerges early in the spring and grows well during the cooler months of the year.

Ranunculaceae

Anemone tuberosa was noted by Burgess as moderately common throughout the hillsides and canyons, and uncommon on deeper soils in the northern portion of the monument. Originating from a tuberous root, this species can withstand impacts from fire rather well.

Simmondsiaceae

Simmondsia chinensis is a large shrub, noted by both Burgess and Strong (1962) as the most common shrub on the monument. In this study, it remained the most common shrub. Rogers and Steele (1980) reported 96% mortality for this species at their study sites. Although the density of *S. chinensis* can be substantially reduced following fires, it is an active postfire sprouter (Cave and Patten 1984). As mentioned above, seed germination in *S. chinensis* requires a certain amount of rainfall, but amounts greater than 30 mm can lead to massive germination events. Seedling survival is greatly enhanced by protection and shade of plants or physical barriers (Castellanos and Molina 1990).

Conclusion

This study provides valuable information to resource managers regarding fire history of the monument and fire effects on individual plant species. Five permanent, relocatable vegetation sampling plots were installed in representative burned and unburned areas and sampled to provide quantitative data regarding the plant composition. The data provide information on the current nature and status of species composition in these areas, enabling resource managers to monitor changes in the established plots through time.

As can be seen in Figure 2, most of the western half of TONT burned in the 1964 Schultz Fire. Much of the vegetation of the burned area below 1,036 m remains in Sonoran Desertscrub. However, in that southern portion of the monument that has been burned repeatedly since 1964, I believe the vegetative composition and structure have been so altered by fire that the original vegetative community is no longer present. Comparison photos indicate that the original community was the rich Paloverde-Mixed Cacti Series of the Arizona Upland of the Sonoran Desertscrub as seen elsewhere on the monument today. At the time of this study, that area appeared to have considerable incursion of grasses and perennial herbs and shrubs, changing the composition to the Mixed Grass-Scrub Series.

Rogers and Steele (1980) reported high percentages of mortality for many desert trees and shrubs in 2 man-caused fires north and east of Phoenix. Rogers (1985) suggested his study indicated that *Carnegiea gigantea* could be virtually eliminated by a sequence of fires at intervals of less than 30 years because *C. gigantea* requires 30 years to reach reproductive maturity (Steenbergh and Lowe 1977) and needs shade-producing perennials under which the seedlings get established (Turner et al. 1966). "A pair of fires, separated by an interval of a few years, can result in the local extinction of many desert species, including saguaros [*C. gigantea*]" (Rogers and Steele 1980; Rogers 1985).

The Mixed Grass-Scrub Series is currently the vegetative composition at higher elevations west of Cave Canyon, and at these higher elevations (above 1,036 m, except perhaps on south-facing slopes) this probably was the vegetative composition prior to the 1964 Schultz Fire.

Much of the literature on fire effects to individual species cited above came from studies in grassland situations where cacti and woody trees and shrubs were considered undesirable invaders, or in chaparral where there was concern over maintenance of the watershed condition. Recently, concern has been raised regarding the effects of fire on desert areas, but there is not as much literature at this point in time. Keeley et al. (1981) noted that repeat fires in the chaparral favored nonnative herbs such as *Bromus rubens* and *Erodium cicutarium* (and others) over native ones, particularly the native "fire annuals," and the latter were quickly eliminated from sites under such repeat fire situations. The native fire annuals were apparently unable to compete with the dense stand of nonnatives produced by frequent fires.

Further analysis to define life history traits, including longevity, reproduction, seed sources, phenology (Slatyer 1977; Gill 1978; Catellino et al. 1979, in Rogers and Steele 1980) would assist in predicting the progress of succession.

Literature Cited

Anonymous. 1980. Narrative Monument Fire, 24 July 1980. Unpublished document in Tonto National Monument files.

Armstrong, R. D. 1970 (?). Narrative report of Robert Armstrong (man in charge of initial attack force). Cottonwood Fire.

Bowers, J. 1990. Vegetation change at Organ Pipe Cactus National Monument. P. 83–132 in P. S. Bennett, R. R. Johnson, and M. M. McCarthy, editors. Assessment of Scientific Information and Activities at Organ Pipe Cactus National Monument Biosphere Reserve. Special Report No. 10, National Park Service, Cooperative Park Studies Unit, Tucson, Arizona.

Brian, N. 1991. Resurvey of 1961 line intercept transects at Tonto National Monument, Arizona. Technical Report No. 38, National Park Service, Cooperative Park Studies Unit, Tucson, Arizona.

Brown, D. E. 1982. Biotic communities of the American Southwest-United States and Mexico. Desert Plants 4:1–342.

Brown, D. E., and C. H. Lowe. 1980. Map, biotic communities of the Southwest (scale 1:1,000,000). Rocky Mountain Forest and Range Experiment Station General Technical Report RM-78, U.S. Forest Service, Ft. Collins, Colorado.

Burgess, R. L. 1965. A checklist of the vascular flora of Tonto National Monument, Arizona. Journal of the Arizona Academy of Science 3:213–223.

Cable, D. R. 1965. Damage to mesquite, Lehmann lovegrass, and black grama by a hot June fire. Journal of Range Management 18:326–329.

Cable, D. R. 1971. Lehmann lovegrass on the Santa Rita Experimental Range, 1937–1968. Journal of Range Management 24:17–21.

Cable, D. R. 1972. Fire effects in Southwestern semidesert grass-shrub communities. Proceeedings Annual Tall Timbers Fire Ecology Conference, June 8–9, 1972.

Castellanos, A. E., and F. E. Molina. 1990. Differential survivorship and establishment in *Simmondsia chinensis* (jojoba). Journal of Arid Environments 19:65–76.

Cave, G. H., and D. T. Patten. 1984. Short-term vegetation responses to fire in the Upper Sonoran Desert. Journal of Range Management 37(4):491–496.

Cox, J. R., and G. B. Ruyle. 1986. Influence of climatic and edaphic factors on the distribution of *Eragrostis lehmanniana* Nees in Arizona, USA. Journal of Grassland Society South Africa 3:25–29.

Gill, A. M. 1978. Fire adaptive traits of vascular plants. P. 208–230 in Fire Regimes and Ecosystem Properties. General Technical Report WO-26, U.S. Forest Service, Washington, D.C.

Graham, R. L. 1970. Fireboss narrative, Cottonwood Fire, Tonto National Forest, Arizona, Region 3, July 1970.

Gruell, G. E. 1980. Fire's influence on wildlife habitat on the Bridger-Teton National Forest, Wyoming. Volume I. Photographic record and analysis. Research Paper INT-235, Intermountain Forest and Range Experiment Station and Intermountain Region, U.S. Forest Service, Ogden, Utah.

Hastings, J. D., and R. M. Turner. 1965. The changing mile. The University of Arizona Press, Tucson, Arizona.

Horton, J. S., and C. J. Kraebel. 1955. Development of vegetation after fire in the chamise chaparral of southern California. Ecology 36(2):244–262.

Humphrey, R. R. 1949. Fire as a means of controlling velvet mesquite, burroweed, and cholla on southern Arizona ranges. Journal of Range Management 2:175–182.

Jenkins, P. D., F. W. Reichenbacher, K. Johnson, and A. E. Gondor. 1991. Vegetation inventory, classification, and monitoring for Tonto National Monument, Arizona. Technical Report No. 50, National Biological Service, Cooperative Park Studies Unit, Tucson, Arizona.

Keeley, S. C., J. E. Keeley, S. M. Hutchinson, and A. W. Johnson. 1981. Postfire succession of the herbaceous flora in southern California chaparral. Ecology 62(6):1,608–1,621.

Lehr, J. H. 1978. A catalogue of the flora of Arizona. Desert Botanical Garden, Phoenix, Arizona.

Lehr, J. H., and D. J. Pinkava. 1980. A catalogue of the flora of Arizona supplement I. Journal of the Arizona-Nevada Academy of Science 15:17–32.

Lehr, J. H., and D. J. Pinkava. 1982. A catalogue of the flora of Arizona supplement II. Journal of the Arizona-Nevada Academy of Science 17:19–26.

Mazzoni, J., N. Brian, and B. G. Phillips. 1982. Status report: *Perityle saxicola* (Eastwood) Shinners. Unpublished report submitted to U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

McKeeman, B. 1973. Memorandum to Park Ranger, Tonto. Subject: Fires on 14 August. Unpublished document, 15 August, Tonto National Monument files.

McKinney, Z. V. 1971. Memorandum to General Superintendent, Southern Arizona Group, with copy to Director, Southwest Region, National Park Service, Attn. Park Support Services. Unpublished document, 20 September 1971, Tonto National Monument files.

McLaughlin, S. P., and J. E. Bowers. 1982. Effects of wildfire on a Sonoran Desert plant community. Ecology 63(1) 246–248.

Mueller-Dombois, D., and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York.

National Park Service. Unpublished documents in Tonto National Monument files.

National Park Service. 1974. Individual Forest Fire Report, 18 July.

National Park Service. 1976. Individual Forest Fire Report, Monument Fire, 18 May.

National Park Service. 1976. Individual Forest Fire Report, Deadman Fire. 29 July.

National Park Service. 1979. Individual Forest Fire Report, Dead Fire. 11 August.

National Park Service. 1980. Individual Forest Fire Report, Monument Fire (#312208). 31 July.

National Park Service. 1983. Individual Forest Fire Report, Honey Fire, 24 July.

National Park Service. 1984. Individual Forest Fire Report, Monument Fire, 19 July.

O'Leary, J. F., and R. A. Minnich. 1981. Postfire recovery of creosote bush scrub vegetation in the western Colorado Desert. Madrono 28(2):61–66.

Orr, W. E. 1970. Cottonwood Fire. Narrative report by Line Boss Orr. Unpublished document in Tonto National Monument files.

Phillips, B. G. 1992. Status of non-native plant species, Tonto National Monument, Arizona. Technical Report No. 46, National Park Service, Cooperative Park Studies Unit, Tucson, Arizona. 24 p.

Reynolds, H. G., and J. W. Bohning. 1956. Effects of burning on a desert grass-shrub range in southern Arizona. Ecology 37(4):769–777.

Rogers, G. F. 1985. Mortality of burned *Cereus giganteus.* Ecology 66(2):630–632.

Rogers, G. F. 1986. Comparison of fire occurrence in desert and nondesert vegetation in Tonto National Forest, Arizona. Madrono 33(4):278–283.

Rogers, G., and J. Steele. 1980. Sonoran Desert fire ecology. P. 15–16 in M. A. Stokes and J. H. Dieterich, technical coordinator 1980. Proceedings of the Fire History Workshop, October 20–24, 1980, Tucson, Arizona. General Technical Report RM-81, Rocky Mountain Forest and Range Experiment Station, U.S. Forest Service, Fort Collins, Colorado.

Ruyle, G. B., B. A. Roundy, and J. R. Cox. 1988. Effects of burning on germinability of Lehmann lovegrass. Journal of Range Management 41:404–406.

Schaafsma, H. F. 1970a. Memorandum to Director, 12 July, Southwest Region. Subject: Cottonwood Fire–Tonto. Tonto National Monument, Roosevelt, Arizona.

Schaafsma, H. F. 1970b. Individual Forest Fire Report, August 10, 1970. National Park Service.

Schmid, M. K., and G. F. Rogers. 1988. Trends in fire occurrence in the Arizona Upland Subdivision of the Sonoran Desert, 1955–1983. The Southwestern Naturalist 33(4):437–444.

Steenbergh, W. F., and C. H. Lowe. 1969. Critical factors during the first years of life of the saguaro (*Cereus giganteus*) at Saguaro National Monument, Arizona. Ecology 50(5):825–834.

Strong, C. W. 1962. (No title). Unpublished report on line intercept data from five transects at Tonto National Monument.

Sumrall, L. B., B. A. Roundy, J. R. Cox and V. K. Winkel. 1990. Seedbed ecology of Lehmann lovegrass in relation to fire. P. 186–189 in J. S. Krammes, technical coordinator. Effects of Fire Management of Southwestern Natural Ecosystems, Proceedings of the Symposium, November 15–17, 1988, Tucson, Arizona. General Technical Report RM-191, U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

Turner, R. M., S. M. Alcorn, G. Olin, and J. A. Booth. 1966. The influence of shade, soil, and water on saguaro seedling establishment. Botanical Gazette 127(2–3):95–102.

U.S.Forest Service. 1969. Fire history map [1942–1976], Tonto National Forest (south half). Scale 1/2"=1 mi.

U.S. Forest Service. 1964. Current fire record form 1178R3 and R3-5100-130, Tonto National Forest 1962-1964. Record No. 90. Schultz Fire.

U.S. Forest Service. 1970. Nonstructural range improvements handbook. Chapter 200: Seeding. Forest Service Handbook, R-3. 2209.23. Albuquerque, New Mexico.

U.S. Forest Service. 1990. Prescribed burning plan for Tonto Basin Ranger District, Tonto National Forest (Robert Ortlund, FMO). Unpublished document on file at Tonto National Forest and Tonto National Monument.

Valder, J. B. 1976a. Narrative Monument Fire, 18 May. Unpublished document, Tonto National Monument files.

Valder, J. B. 1976b. Memorandum to General Superintendent, Southern Arizona Group, 23 June. Subject: Fire equipment. Unpublished document, Tonto National Monument files.

Whisenant, K. A. 1974. Memorandum to Park Ranger, Tonto National Monument, 17 July. Subject: Narrative of the "Trough" Fire. Unpublished document, Tonto National Monument files.

Wright, H. A. 1980. The role and use of fire in the semidesert grass-shrub type. General Technical Report INT-85, U.S. Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah.

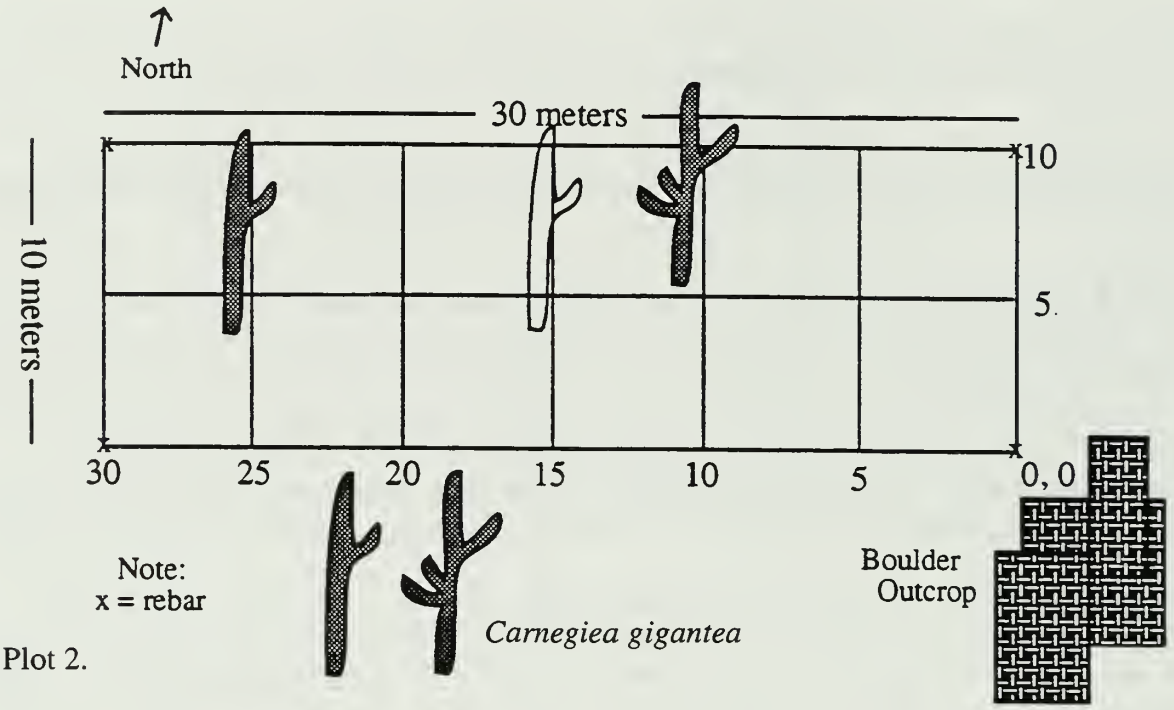
Zedler, P. H., C. R. Gautier, and G. S. McMaster. 1983. Vegetation change in response to extreme events: the effect of a short interval between fires in California chaparral and coastal scrub. Ecology 64(4):809–818.

Zwolinski, M. J. 1990. Fire effects on vegetation and succession. P. 18–24 in: J. S. Krammes , technical coordinator. Effects of Fire Management of Southwestern Natural Ecosystems, Proceedings of the Symposium, November 15–17, 1988, Tucson, Arizona. General Technical Report RM-191, U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

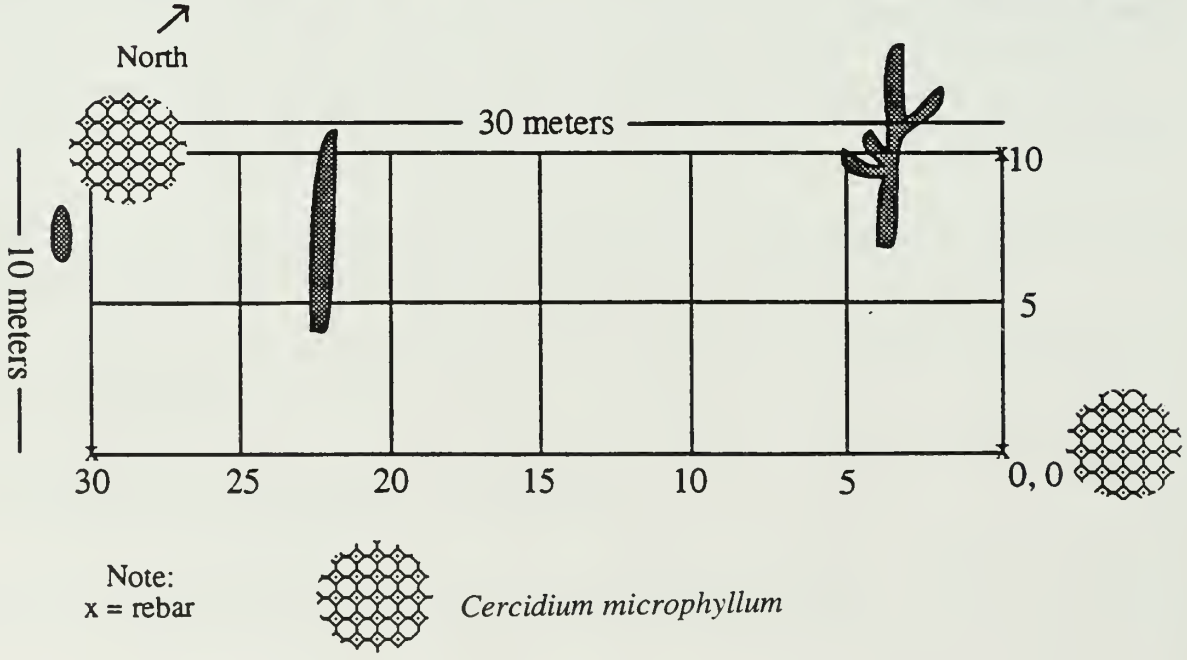
Appendix 1

Schematic Maps of Burned and Unburned Comparison Plots, Tonto National Monument

A. Plot 1.

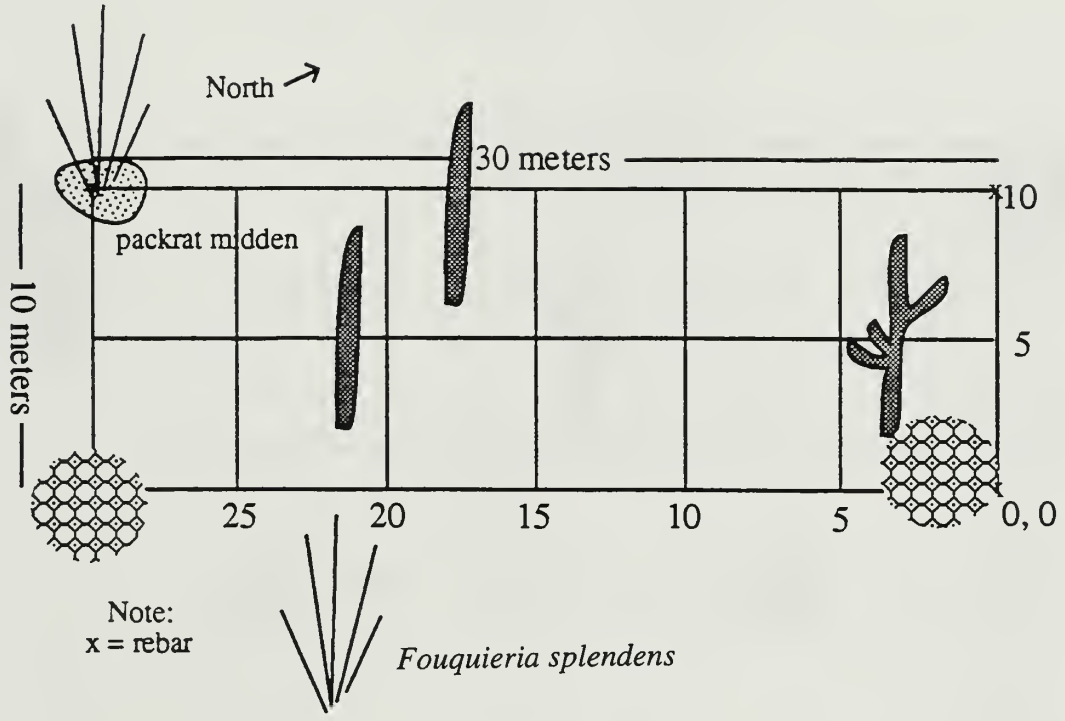


B. Plot 2.

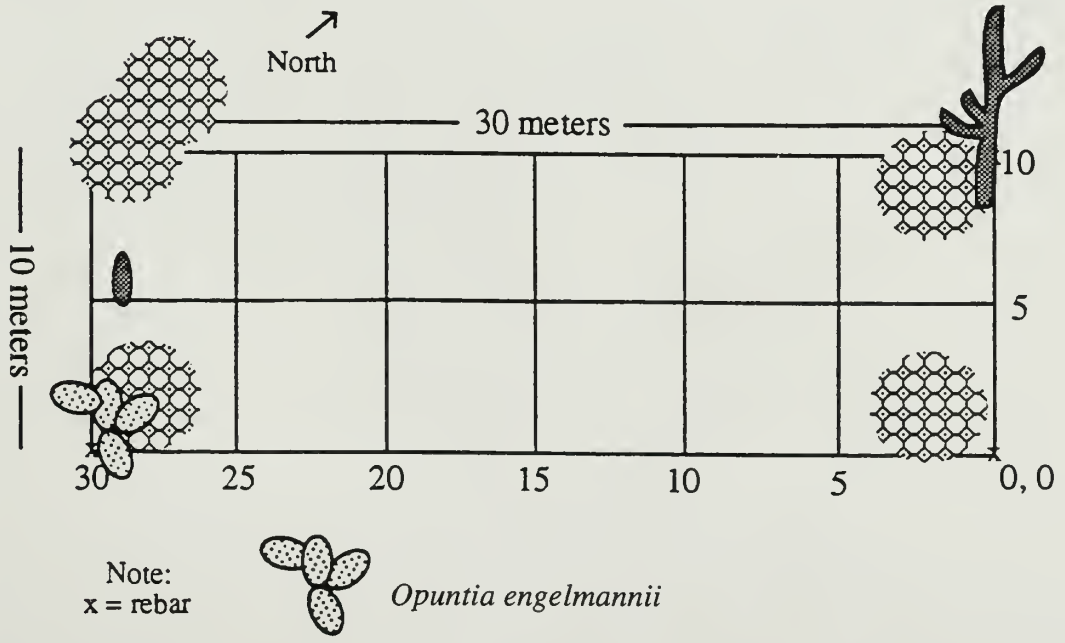


Appendix 1—continued.

C. Plot 3.

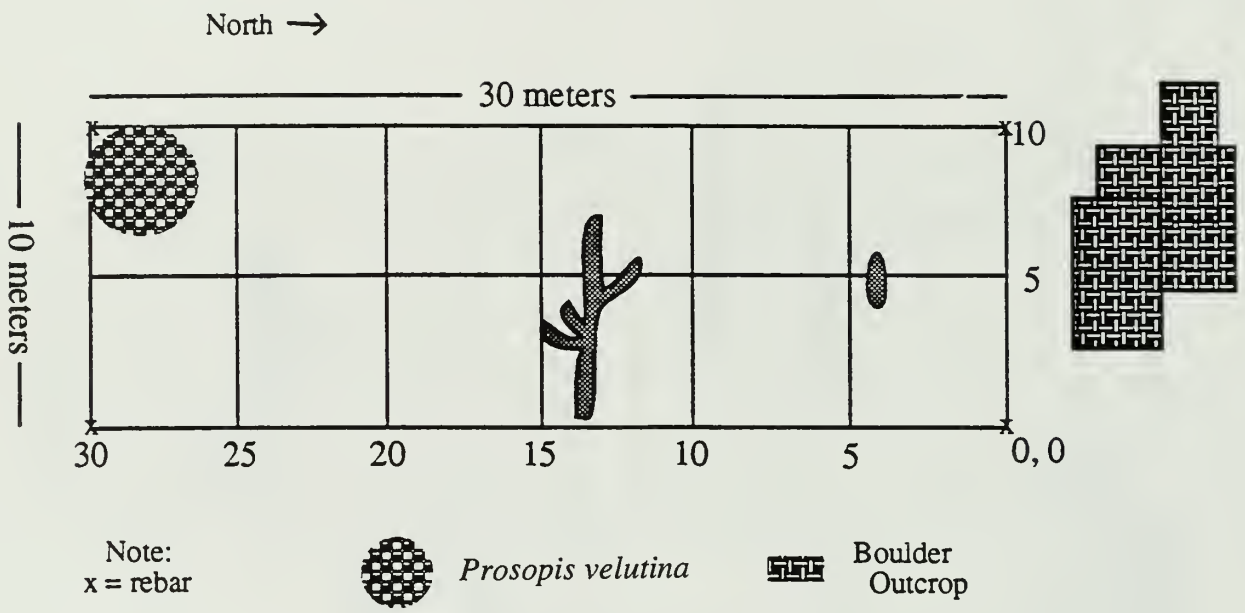


D. Plot 4.



Appendix 1—continued.

E. Plot 5.



Appendix 2

Formula Table for Calculations: Raw Data to Importance Values (Plot 1 ex.),Tonto National Monument, 7 March 1990 to 30–31 March 1991

A.

	A	B	C	D	E
1	Species	No. of plots	Raw frequency	Raw density	Raw cover (sq cm)
2	*Simmondsia chinensis*	12	10	32	200,495.24
3	*Sphaeralcea emoryi*	12	6	8	8,274.71
4	*Encelia farinosa*	12	10	276	631,827.9
5	*Dyssodia porophylloides*	12	10	19	3,770.58
6	*Opuntia acanthocarpa*	12	5	6	4,914.88
7	*Cercidium microphyllum*	12	1	1	13,586.99
8	*Cercidium floridum*	12	2	2	52,404.15
9	*Eriogonum fasciculatum*	12	2	2	3,042.54
10	*Carnegiea gigantea*	12	2	2	18,517.4
11	*Dichelostemma pulchellum*	16	16	322	4,528.13
12	*Aristida* spp.	16	6	11	11,898.43
13	*Sporobolus cryptandrus*	16	1	1	58.9
14	*Stipa speciosa*	16	2	2	544.85
15	*Bouteloua curtipendula*	16	4	9	12,163.5
16	*Mirabilis bigelovii*	16	2	2	18,053.81
17	*Mammillaria microcarpa*	16	1	3	2,149.96
18	*Ambrosia psilostachya*	16	7	29	34,973.73
19	*Euphorbia melanadenia*	16	3	3	1,973.25
20	*Tradescantia occidentalis*	16	2	2	1,781.82
21	*Stephanomeria pauciflora*	16	1	1	1,472.58
22	sum				1,026,433.35
23					
24	Annuals		frequency	density	
25	*Eschscholzia mexicana*	4	3	19	
26	*Erodium texanum*	4	2	2	
27	*Erodium cicutarium*	4	4	68	
28	*Astragalus nuttalianus*	4	4	93	
29	*Daucus pusillus*	4	3	4	
30	*Plagiobothrys arizonicus*	4	1	1	
31	*Bromus rubens*	4	1	88	
32	*Lupinus arizonicus*	4	2	3	
33	*Schismus barbatus*	16	1	1	
34	*Sonchus asper*	16	1	1	
35	sum				

Appendix 2—continued. B.

	A	F	G	H
1	Species	absolute frequency	absolute density	absolute cover
2	*Simmondsia chinensis*	=VALUE(C2/B2)	=D2	200,495.24
3	*Sphaeralcea emoryi*	=VALUE(C3/B3)	=D3	8,274.71
4	*Encelia farinosa*	=VALUE(C4/B4)	=D4	631,827.9
5	*Dyssodia porophylloides*	=VALUE(C5/B5)	=D5	3,770.58
6	*Opuntia acanthocarpa*	=VALUE(C6/B6)	=D6	4,914.88
7	*Cercidium microphyllum*	=VALUE(C7/B7)	=D7	13,586.99
8	*Cercidium floridum*	=VALUE(C8/B8)	=D8	52,404.15
9	*Eriogonum fasciculatum*	=VALUE(C9/B9)	=D9	3,042.54
10	*Carnegiea gigantea*	=VALUE(C10/B10)	2	18,517.4
11	*Dichelostemma pulchellum*	=VALUE(C11/B11)	=(D11/16)*300	4,528.13
12	*Aristida* spp.	=VALUE(C12/B12)	=(D12/16)*300	11,898.43
13	*Sporobolus cryptandrus*	=VALUE(C13/B13)	=(D13/16)*300	58.9
14	*Stipa speciosa*	=VALUE(C14/B14)	=(D14/16)*300	544.85
15	*Bouteloua curtipendula*	=VALUE(C15/B15)	=(D15/16)*300	12,163.5
16	*Mirabilis bigelovii*	=VALUE(C16/B16)	=(D16/16)*300	18,053.81
17	*Mammillaria microcarpa*	=VALUE(C17/B17)	=(D17/16)*300	2,149.96
18	*Ambrosia psilostachya*	=VALUE(C18/B18)	=(D18/16)*300	34,973.73
19	*Euphorbia melanadenia*	=VALUE(C19/B19)	=(D19/16)*300	1,973.25
20	*Tradescantia occidentalis*	=VALUE(C20/B20)	=(D20/16)*300	1,781.82
21	*Stephanomeria pauciflora*	=VALUE(C21/B21)	=(D21/16)*300	1,472.58
22	sum	=SUM(F2:F21)	SUM(G2:G21)	=SUM(H2:H21)
23				
24	Annuals	absolute frequency	density/sqm	
25	*Eschscholzia mexicana*	=C25/B25	=D25	
26	*Erodium texanum*	=C26/B26	=D26	
27	*Erodium cicutarium*	=C27/B27	=D27	
28	*Astragalus nuttallianus*	=C28/B28	=D28	
29	*Daucus pusillus*	=C29/B29	=D29	
30	*Plagiobothrys arizonicus*	=C30/B30	=D30	
31	*Bromus rubens*	=C31/B31	=D31	
32	*Lupinus arizonicus*	=C32/B32	=D32	
33	*Schizmus barbatus*	=C33/B33	=(D33/16)*300	
34	*Sonchus asper*	=C34/B34	=(D34/16)*300	
35	sum	SUM(F25:F34)	=SUM(G25:G34)	

Appendix 2—continued. C.

	A	I	J
1	Species	relative frequency	relative density
2	*Simmondsia chinensis*	=(F2/$F$22)*100	=(G2/$G$22)*100
3	*Sphaeralcea emoryi*	=(F3/$F$22)*100	=(G3/$G$22)*100
4	*Encelia farinosa*	=(F4/$F$22)*100	=(G4/$G$22)*100
5	*Dyssodia porophylloides*	=(F5/$F$22)*100	=(G5/$G$22)*100
6	*Opuntia acanthocarpa*	=(F6/$F$22)*100	=(G6/$G$22)*100
7	*Cercidium microphyllum*	=(F7/$F$22)*100	=(G7/$G$22)*100
8	*Cercidium floridum*	=(F8/$F$22)*100	=(G8/$G$22)*100
9	*Eriogonum fasciculatum*	=(F9/$F$22)*100	=(G9/$G$22)*100
10	*Carnegiea gigantea*	=(F10/$F$22)*100	=(G10/$G$22)*100
11	*Dichelostemma pulchellum*	=(F11/$F$22)*100	=(G11/$G$22)*100
12	*Aristida* spp.	=(F12/$F$22)*100	=(G12/$G$22)*100
13	*Sporobolus cryptandrus*	=(F13/$F$22)*100	=(G13/$G$22)*100
14	*Stipa speciosa*	=(F14/$F$22)*100	=(G14/$G$22)*100
15	*Bouteloua curtipendula*	=(F15/$F$22)*100	=(G15/$G$22)*100
16	*Mirabilis bigelovii*	=(F16/$F$22)*100	=(G16/$G$22)*100
17	*Mammillaria microcarpa*	=(F17/$F$22)*100	=(G17/$G$22)*100
18	*Ambrosia psilostachya*	=(F18/$F$22)*100	=(G18/$G$22)*100
19	*Euphorbia melanadenia*	=(F19/$F$22)*100	=(G19/$G$22)*100
20	*Tradescantia occidentalis*	=(F20/$F$22)*100	=(G20/$G$22)*100
21	*Stephanomeria pauciflora*	=(F21/$F$22)*100	=(G21/$G$22)*100
22	sum		
23			
24	Annuals	relative frequency	relative density
25	*Eschscholzia mexicana*	=(F25/$F$35)*100	=(G25/$G$35)*100
26	*Erodium texanum*	=(F26/$F$35)*100	=(G26/$G$35)*100
27	*Erodium cicutarium*	=(F27/$F$35)*100	=(G27/$G$35)*100
28	*Astragalus nuttallianus*	=(F28/$F$35)*100	=(G28/$G$35)*100
29	*Daucus pusillus*	=(F29/$F$35)*100	=(G29/$G$35)*100
30	*Plagiobothrys arizonicus*	=(F30/$F$35)*100	=(G30/$G$35)*100
31	*Bromus rubens*	=(F31/$F$35)*100	=(G31/$G$35)*100
32	*Lupinus arizonicus*	=(F32/$F$35)*100	=(G32/$G$35)*100
33	*Schizmus barbatus*	=(F33/$F$35)*100	=(G33/$G$35)*100
34	*Sonchus asper*	=(F34/$F$35)*100	=(G34/$G$35)*100
35	sum		

Appendix 2—continued. D.

	A	K	L
1	Species	relative cover	IMP VALUE
2	*Simmondsia chinensis*	=(H2/$H$22)*100	=SUM(I2+J2+K2)/3
3	*Sphaeralcea emoryi*	=(H3/$H$22)*100	=SUM(I3+J3+K3)/3
4	*Encelia farinosa*	=(H4/$H$22)*100	=SUM(I4+J4+K4)/3
5	*Dyssodia porophylloides*	=(H5/$H$22)*100	=SUM(I5+J5+K5)/3
6	*Opuntia acanthocarpa*	=(H6/$H$22)*100	=SUM(I6+J6+K6)/3
7	*Cercidium microphyllum*	=(H7/$H$22)*100	=SUM(I7+J7+K7)/3
8	*Cercidium floridum*	=(H8/$H$22)*100	=SUM(I8+J8+K8)/3
9	*Eriogonum fasciculatum*	=(H9/$H$22)*100	=SUM(I9+J9+K9)/3
10	*Carnegiea gigantea*	=(H10/$H$22)*100	=SUM(I10+J10+K10)/3
11	*Dichelostemma pulchellum*	=(H11/$H$22)*100	=SUM(I11+J11+K11)/3
12	*Aristida* spp.	=(H12/$H$22)*100	=SUM(I12+J12+K12)/3
13	*Sporobolus cryptandrus*	=(H13/$H$22)*100	=SUM(I13+J13+K13)/3
14	*Stipa speciosa*	=(H14/$H$22)*100	=SUM(I14+J14+K14)/3
15	*Bouteloua curtipendula*	=(H15/$H$22)*100	=SUM(I15+J15+K15)/3
16	*Mirabilis bigelovii*	=(H16/$H$22)*100	=SUM(I16+J16+K16)/3
17	*Mammillaria microcarpa*	=(H17/$H$22)*100	=SUM(I17+J17+K17)/3
18	*Ambrosia psilostachya*	=(H118/$H$22)*100	=SUM(I18+J18+K18)/3
19	*Euphorbia melanadenia*	=(H19/$H$22)*100	=SUM(I19+J19+K19)/3
20	*Tradescantia occidentalis*	=(H20/$H$22)*100	=SUM(I20+J20+K20)/3
21	*Stephanomeria pauciflora*	=(H21/$H$22)*100	=SUM(I21+J21+K21)/3
22	sum		SUM(L2:L21)
23			
24	Annuals	IMP VALUE	density/sqm
25	*Eschscholzia mexicana*	=SUM(I25+J25)/2	=G25/4
26	*Erodium texanum*	=SUM(I26+J26)/2	=G26/4
27	*Erodium cicutarium*	=SUM(I27+J27)/2	=G27/4
28	*Astragalus nuttallianus*	=SUM(I28+J28)/2	=G28/4
29	*Daucus pusillus*	=SUM(I29+J29)/2	=G29/4
30	*Plagiobothrys arizonicus*	=SUM(I30+J30)/2	=G30/4
31	*Bromus rubens*	=SUM(I31+J31)/2	=G31/4
32	*Lupinus arizonicus*	=SUM(I32+J32)/2	=G32/4
33	*Schizmus barbatus*	=SUM(I33+J33)/2	=G33/16
34	*Sonchus asper*	=SUM(I34+J34)/2	=G34/16
35	sum	SUM(K25:K34)	

Raw and absolute values for perennial and annual plant species, Tonto National Monument, 7 March 1990 to 30–31 March 1991

A. Plot 1.

Species	No. of sample subplots	No. of subplots occurs	No. of plants	Cover per plot (sq cm)	Absolute frequency (%)	Absolute density (No. plants per plot)	Absolute cover (sq cm)
Perennials							
Ambrosia psilostachya	16	7	29	34,973.73	0.44	543.75	34,973.73
Aristida spp.	16	6	11	11,898.43	0.38	206.25	11,898.43
Bouteloua curtipendula	16	4	9	12,163.5	0.25	168.75	12,163.50
Carnegiea gigantea	12	2	2	18,517.4	0.17	2	18,517.40
Cercidium floridum	12	2	2	52,404.15	0.17	2	52,404.15
Cercidium microphyllum	12	1	1	13,586.99	0.08	1	13,586.99
Dichelostemma pulchellum	16	16	322	4,528.13	1.00	6,037.5	4,528.13
Dyssodia porophylloides	12	10	19	3,770.58	0.83	19	3,770.58
Encelia farinosa	12	10	276	631,827.9	0.83	276	631,827.90
Eriogonum fasciculatum	12	2	2	3,042.54	0.17	2	3,042.54
Euphorbia melanadenia	16	3	3	1,973.25	0.19	56.25	1,973.25
Mammillaria microcarpa	16	1	3	2,149.96	0.06	56.25	2,149.96
Mirabilis bigelovii	16	2	2	18,053.81	0.13	37.5	18,053.81
Opuntia acanthocarpa	12	5	6	4,914.88	0.42	6	4,914.88
Simmondsia chinensis	12	10	32	200,495.24	0.83	32	200,495.24
Sphaeralcea emoryi	12	6	8	8,274.71	0.50	8	8,274.71
Sporobolus cryptandrus	16	1	1	58.9	0.06	18.75	58.90
Stephanomeria pauciflora	16	1	1	1,472.58	0.06	18.75	1,472.58
Stipa speciosa	16	2	2	544.85	0.13	37.5	544.85
Tradescantia occidentalis	16	2	2	1,781.82	0.13	37.5	1,781.82
sum					6.81	7,566.75	1,026,433.35
Annuals							
Astragalus nuttalianus	4	4	93		1.00	93	
Bromus rubens	4	1	88		0.25	88	
Daucus pusillus	4	3	4		0.75	4	
Erodium cicutarium	4	4	68		1.00	68	
Erodium texanum	4	2	2		0.50	2	
Eschscholzia mexicana	4	3	19		0.75	19	
Lupinus arizonicus	4	2	3		0.50	3	
Plagiobothrys arizonicus	4	1	1		0.25	1	
Schismus barbatus	16	1	1		0.06	18.75	
Sonchus asper	16	1	1		0.06	18.75	
sum					5.13	315.5	

Appendix 3—continued. B. Plot 2.

Species	No. of sample subplots	No. of subplots occurs	No. of plants	Cover per plot (sq cm)	Absolute frequency (%)	Absolute density (no. plants per plot)	Absolute cover (sq cm)
Perennials							
Anemone tuberosa	16	4	16	10,602.56	0.25	300	10,602.56
Carnegiea gigantea	12	2	2	15,275.54	0.17	2	15,275.54
Cercidium microphyllum	12	4	3	273,899.53	0.33	3	273,899.53
Dichelostemma pulchellum	16	7	149	2,109.38	0.44	2,793.75	2,109.38
Encelia farinosa	12	12	333	880,370.82	1.00	333	880,370.82
Galium stellatum	12	1	1	2,642.00	0.08	1	2,642.00
Lycium fremontii	12	7	9	81,954.67	0.58	9	81,954.67
Mammillaria microcarpa	16	1	1	368.14	0.06	18.75	368.14
Mirabilis bigelovii	16	3	5	18,716.47	0.19	93.75	18,716.47
Opuntia bigelovii	12	7	12	28,089.72	0.58	12	28,089.72
Simmondsia chinensis	12	12	54	435,645.16	1.00	54	435,645.16
sum					4.69	3,620.25	1,749,673.99
Annuals							
Arabis perennans	4	1	1		0.25	1	
Astragalus nuttallianus	4	3	15		0.75	15	
Bromus rubens	4	3	265		0.75	265	
Daucus pusillis	4	2	3		0.5	3	
Draba cuneifolia	4	4	166		1	166	
Erodium cicutarium	4	3	23		0.75	23	
Euphorbia sp.	4	3	12		0.75	12	
Lepidium medium	4	4	34		1	34	
Lotus humistriatus	4	1	1		0.25	1	
Lupinus arizonicus	4	1	1		0.25	1	
Phacelia sp.	4	1	1		0.25	1	
Pholistoma auritum	4	3	254		0.75	254	
Plantago patagonica	4	2	39		0.5	39	
Schismus barbatus	4	1	26		0.25	26	
Silene antirrhina	4	1	1		0.25	1	
UK#4	4	1	4		0.25	4	
UK#8	4	1	12		0.25	12	
sum					8.75	858	

Species	No. of sample subplots *	No. of subplots occurs	No. of plants	Cover per plot (sq cm)	Absolute frequency (%)	Absolute density (no. plants per plot)	Absolute cover (sq cm)
Perennials							
Carnegiea gigantea	12	3	3	10,208.30	0.25	3	10,208.30
Cercidium microphyllum	12	7	7	404,507.39	0.58	7	404,507.39
Dichelostemma pulchellum	16	2	3	42.19	0.13	56.25	42.19
Encelia farinosa	12	10	35	73,912.43	0.83	35	73,912.43
Eriogonum fasciculatum	12	6	21	157,223.44	0.50	21	157,223.44
Fouquieria splendens	12	3	3	181,912.48	0.25	3	181,912.48
Mirabilis bigelovii	16	5	11	134,490.56	0.31	206.25	134,490.56
Opuntia acanthocarpa	12	3	4	46,022.98	0.25	4	46,022.98
Opuntia bigelovii	12	11	79	227,442.24	0.92	79	227,442.24
Porophyllum gracile	12	6	11	6,963.92	0.50	11	6,963.92
Simmondsia chinensis	12	12	43	474,350.01	1.00	43	474,350.01
Stephanomeria tenuifolia	16	1	1	412.50	0.06	18.75	412.50
Viguiera parishii	12	7	11	52,533.73	0.58	11	52,533.73
Yucca baccata	12	1	1	1,256.60	0.08	1	1,256.60
Sum					6.25	499.25	1,771,278.77
Annuals							
Amsinckia tessellata	4	2	3		0.5	3	
Astragalus nuttalianus	4	2	17		0.5	17	
Bromus rubens	4	4	843		1	843	
Daucus pusillus	4	1	6		0.25	6	
Descurainia pinnata	4	1	17		0.25	17	
Draba cuneifolia	4	3	20		0.75	20	
Erodium cicutarium	4	1	12		0.25	12	
Filago arizonica	4	1	55		0.25	55	
Galium aparine	4	1	3		0.25	3	
Lepidium medium	4	4	12		1	12	
Lotus humistriatus	4	1	2		0.25	2	
Lupinus arizonicus	4	1	1		0.25	1	
Parietaria floridana	4	2	18		0.5	18	
Phacelia cryptantha	4	4	15		1	15	
Pholistoma auritum	4	4	8		1	8	
Plagiobothrys arizonicus	4	1	1		0.25	1	
Plantago patagonica	4	1	5		0.25	5	
Pterostegia drymariodes	4	1	4		0.25	4	
Schismus barbatus	4	2	11		0.5	11	
Silene antirrhina	4	2	4		0.5	4	
Sonchus asper	4	1	1		0.25	1	
Stellaria nitens	4	1	16		0.25	16	
Thelypodium longiocarpum	4	1	7		0.25	7	
Thysanocarpus amplectens	4	2	7		0.5	7	
Tillaea erecta	4	2	168		0.5	168	
Sum					11.5	1,256	

Appendix 3—continued. D. Plot 4.

Species	No. of sample subplots	No. of subplots occurs	No. of plants	Cover per plot (sq cm)	Absolute frequency (%)	Absolute density (No. plants per plot)	Absolute cover (sq cm)
Perennials							
Brickellia atractyloides	12	1	3	3,593.88	0.08	3	3,593.88
Calochortus sp.	16	1	2	520.31	0.06	37.5	520.31
Carnegiea gigantea	12	2	2	4,672.20	0.17	2	4,672.20
Cercidium microphyllum	12	4	4	499,614.74	0.33	4	499,614.74
Dasylirion wheeleri	12	1	1	31,415.00	0.08	1	31,415.00
Dichelostemma pulchellum	16	11	52	703.13	0.69	975	703.13
Echinocereus fasciculatus	12	3	3	326.72	0.25	3	326.72
Encelia farinosa	12	7	15	15,900.70	0.58	15	15,900.70
Eriogonum fasciculatum	12	3	3	15,900.70	0.25	3	15,900.70
Fouquieria splendens	12	1	2	40,918.04	0.08	2	40,918.04
Galium stellatum	12	3	3	9,792.84	0.25	3	9,792.84
Lycium fremontii	12	1	1	18,145.30	0.08	1	18,145.30
Mammillaria microcarpa	12	1	1	19.63	0.08	1	19.63
Mirabilis bigelovii	16	13	20	206,205.11	0.81	375	206,205.11
Opuntia acanthocarpa	12	10	23	208,005.00	0.83	23	208,005.00
Opuntia bigelovii	12	2	3	921.14	0.17	3	921.14
Opuntia engelmannii	12	3	4	52,305.98	0.25	4	52,305.98
Porophyllum gracile	12	4	10	4,283.44	0.33	10	4,283.44
Simmondsia chinensis	12	11	31	402,814.91	0.92	31	402,814.91
Sphaeralcea emoryi	12	3	4	6,741.66	0.25	4	6,741.66
Menodora scabra	12	3	3	1,335.92	0.25	3	1,335.92
Unknown shrub	12	7	9	158,824.03	0.58	9	158,824.03
Viguiera parishii	12	12	39	158,824.03	1.00	39	158,824.03
Yucca baccata	12	2	16	32,271.18	0.17	16	32,271.18
sum					8.56	1,567.5	1,874,055.59
Annuals							
Amsinckia tessellata	4	2	6		0.50	6	
Androsace occidentalis	4	1	5		0.25	5	
Astragalus nuttalianus	4	3	36		0.75	36	
Bromus rubens	4	4	155		1.00	155	
Bromus sp.	4	1	206		0.25	206	
Daucus pusillus	4	3	23		0.75	23	
Draba cuneifolia	4	4	413		1.00	413	
Erodium cicutarium	4	4	112		1.00	112	
Filago arizonica	4	1	13		0.25	13	
Lepidium medium	4	3	15		0.75	15	
Lotus humistriatus	4	2	3		0.50	3	
Lupinus arizonicus	4	2	32		0.50	32	
Parietaria floridana	4	1	59		0.25	59	
Pectocarya recurvata	4	2	20		0.50	20	
Phacelia cryptantha	4	3	74		0.75	74	
Plantago patagonica	4	2	307		0.50	307	
Silene antirrhina	4	4	35		1.00	35	
Stellaria nitens	4	2	201		0.50	201	
Tillaea erecta	4	1	36		0.25	36	
sum					11.25	1,751	

Appendix 3—continued. E. Plot 5.

Species	No. of sample subplots	No. of subplots occurs	No. of plants	Cover per plot (sq cm)	Absolute frequency (%)	Absolute density (No. plants per plot)	Absolute cover (sq cm)
Perennials							
Aristida parishii	16	3	3	41,084.93	0.19	56.25	41,084.93
Calochortus sp.	16	1	1	14.06	0.06	18.75	14.06
Carnegiea gigantea	12	2	2	5,985.34	0.17	2	5,985.34
Cirsium neomexicanum	12	1	1	78.54	0.08	1	78.54
Dichelostemma pulchellum	16	13	33	464.06	0.81	618.75	464.06
Mammillaria microcarpa	16	1	1	38.48	0.06	18.75	38.48
Mirabilis bigelovii	16	2	2	20,027.06	0.13	37.5	20,027.06
Porophyllum gracile	12	1	1	176.71	0.08	1	176.71
Prosopis velutina	12	1	1	38,012.15	0.08	1	38,012.15
Simmondsia chinensis	12	8	27	327,097.69	0.67	27	327,097.69
Sphaeralcea emoryi	12	11	84	26,702.75	0.92	84	26,702.75
Stephanomeria sp.	12	3	3	6,597.94	0.25	3	6,597.94
Stipa speciosa	12	1	2	26,702.75	0.08	2	26,702.75
Viguiera parishii	12	5	7	31,733.08	0.42	7	31,733.08
Sum					4.00	878	524,715.54
Annuals							
Amsinckia tessellata	4	1	2		0.25	2	
Bromus rubens	4	4	813		1.00	813	
Cryptantha sp.	4	1	1		0.25	1	
Descurainia pinnata	4	2	7		0.50	7	
Erodium cicutarium	4	4	158		1.00	158	
Eschscholzia mexicana	4	2	8		0.50	8	
Lepidium medium	4	3	6		0.75	6	
Lotus humistriatus	4	2	6		0.50	6	
Lupinus arizonicus	4	4	16		1.00	16	
Orthocarpus purpurascens	4	1	1		0.25	1	
Plagiobothrys arizonica	4	1	3		0.25	3	
Silene antirrhina	4	4	21		1.00	21	
Thelypodium longiocarpum	4	2	6		0.50	6	
Thysanocarpus amplectens	4	2	3		0.50	3	
Tillaea erecta	4	1	18		0.25	18	
Sum					8.50	1,069	

Appendix 4

Photo stations, Tonto National Monument

Set	Date	Photographers	Comments
1	31 August 1964	R. Burgess, Hank Jones	
2	24 September 1964	Jess Rowland	
3	8 October 1964	Jess Rowland	
4	8 November 1964	Jess Rowland	
5	4 January 1965	Jess Rowland, Hank Jones	
6	25 February 1965	Hank Jones, Dave Jordan	
7	31 March 1965	Hank Jones	
8	28 February 1965	Hank Jones	
9	2 November 1965	Hank Jones, Jess Rowland	
10	6 December 1965	Hank Jones	
11	2 February 1966	Hank Jones	
12	13 April 1966	J. M. Broadbent, Hank Jones	
13	6 July 1966	J. M. Broadbent	incomplete
14	19 August 1966	J. M. Broadbent	
15	5 October 1966	J. M. Broadbent	
16	29 November 1966	J. M. Broadbent	
17	1 February 1967	J. M. Broadbent, R. Ice	
18	14 March 1967	Jess Rowland, R. Ice	
19	9 May 1967	R. Ice	sky overcast
20	8 July 1967	R. Ice	
21	9 August 1967	R. Ice	
22	13 September 1967	R. Ice	
23	28 October 1967	R. Ice	
24	30 December 1967	R. Ice	
25	27 February 1968	R. Ice	
26	14 April 1968	R. Ice	stake 10 not found due to dense growth
27	18 May 1968	R. Ice	
28	19 June 1968	R. Ice	
29	20 July 1968	R. Ice	
30	22 August 1968	R. Ice	
31	25 September 1968	R. Ice	
32	22 October 1968	R. Ice	
33	24 November 1968	R. Ice	
34	5 May 1969	Snodgrass (harassed by Ice)	
35	22 April 1969	R. Ice	
36	30 August 1969	R. Ice, Morgan	
37	18, 25 September 1972	McKeeman	no photos taken between 1969 and 1972
38 stakes	7 March 1990; 4–6 April 1990; 30–31 March 1991	B. Phillips	unable to find 7 and 20

The cover photograph was taken October 4, 1935, in Saguaro National Monument by the first National Park Service photographer, George Alexander Grant (1891-1964).

As the nation's principal conservation agency, the U.S. Department of the Interior has responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting fish, wildlife and plants, preserving the environmental and cultural values of national parks and historic places, and providing for enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.