

Relocation and Restudy of Historic Saguaro Plots at Saguaro National Park

FINAL REPORT

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Introduction

Saguaro National Monument was established by presidential proclamation in 1933 to preserve and protect extensive and dense stands of saguaro (*Carnegiea gigantea*) at the base of the Rincon Mountains (the “Cactus Forest”) for the enjoyment of future generations of visitors. At the time the monument was established, Park Service personnel and scientists noted that a widespread die-off of older individuals was in progress and initiated a monitoring program. The resulting data form a 61-year baseline for this study.

The saguaro is a long-lived plant species that requires long-term study to distinguish true population demographic trends from short-term population fluctuations (Orum et al. 1998, Pierson and Turner 1998). Wilder and Wilder (1939) conducted saguaro plot studies in Saguaro National Monument that showed negligible saguaro recruitment in the Cactus Forest just after monument establishment as compared to areas approaching and on Tanque Verde Ridge. Although their study provides valuable information for contemporary saguaro researchers, the non-permanent nature of their work does not allow us the opportunity to re-measure the same populations to make direct comparisons.

It was widely believed at the time of early saguaro investigations that the decline of saguaros in the Cactus Forest was the result of an epidemic of a bacterial necrosis disease (Lightle et al. 1942, Gill 1951, Alcorn and May 1962). Later scientists tried to fit saguaro demographics into a broader ecological context. They documented that the widespread death of large individuals was the natural senescence of an aged population, but that depressed rates of recruitment (observed many years earlier by Forrest Shreve [1910]) were a legitimate cause for concern (Niering et al. 1963, Lowe 1966, Steenbergh 1970).

In 1941, permanent 2-ha plots were established in the Cactus Forest of the Rincon Mountain District (RMD) of Saguaro National Monument as part of an extensive U. S. Department of Agriculture inquiry into the bacterial necrosis of the population (Gill and Lightle 1942). Though the 1941 plots were established with a different aim, their permanent establishment provides a baseline of data that has allowed long-term population comparisons. Steenbergh and Lowe (1983) revisited these plots in 1971 and 1975 to assess size (age) structure and changes in saguaro density. They described a severe decline in the density of saguaros in the Cactus Forest over the study period of 1941 to 1975 and provided a new baseline of demographic data with the addition of 6 new plots in the monument, 5 of which were located in the Tucson Mountain District (TMD), established in 1963.

Until recently, the specific locations of these historic plots were unknown to current park management. During the spring of 2001, hand-drawn maps and raw data were discovered as National Park Service files were being sorted for archival. This valuable discovery made relocation and restudy of the plots possible (Attachment 1).

After many years of data demonstrating a decline in saguaro densities at Saguaro National Park, recent work (Dursicoe and Graban 1992, Helbsing and Fischer 1992, Orum et al. 1998, Turner & Funicelli 2000) has quantified a pulse in recruitment of young plants into the population since the mid 1970's. The current project provides a unique opportunity to put the results of Turner and Funicelli (2000) into a longer ecological time frame through the comparison of these data with data from the 11 plots that were established in 1941, 1971, and 1975 by Gill and Lightle (1942) and Steenbergh and Lowe (1983). Table 1 summarizes the distinguishing characteristics between the 2 sets of plots.

Table 1. Distinguishing characteristics between 2 sets of long-term saguaro data at Saguaro National Park.

Plots established by	Duriscoe and Graban (1992)	Gill and Lightle (1942); Steenbergh and Lowe (1983)
Context of establishment	Epidermal browning	Bacterial necrosis
Relocation/ Resurvey	Turner and Funicelli (2000)	Steenbergh and Lowe (1983); this study
Total number of plots	45	11
Plots randomly located	yes	no

We relocated and resurveyed the plots established by Gill and Lightle (1942) and Steenbergh and Lowe (1983), and provide analysis of changes in saguaro demographics at Saguaro National Park.

Study Area

The study area was within the Rincon and Tucson Mountain Districts (RMD and TMD) of Saguaro National Park, Tucson, Arizona. We collected data from 11 plots, 6 at RMD (established 1941 and 1975, Figure 1) and 5 at TMD (established 1971 and 1975, Figure 2). Individual plots were 100 x 200 m (2 ha).

Figure 1.

Figure 2.

Methods

During the period of February 2001 through May 2002, we relocated plots from maps drawn by Warren F. Steenbergh and used a Trimble GeoExplorer II Global Positioning System (GPS) unit to permanently record the UTM location of each corner to within 3 m. Each saguaro that was tagged in 1975 was re-located; status (live or dead) and/or height (using a clinometer) and number of arms were recorded. In addition, a detailed search was conducted on each plot to locate saguaros that were either newly recruited on the plot, too small to be detected in 1975, or missed in the 1975 survey. Census efforts followed protocol established by Turner and Funicelli (2000). Our survey methods could not reliably detect saguaros less than 10 cm in height; as a result, it is assumed that the number of saguaros in the smallest size class may be greater than our data show.

The data recorded in conjunction with cactus disease studies in 1941 provided total density of saguaros per plot, but not height data. Therefore, only density comparisons are possible for this portion of the data. In 1971 or 1975 and 2001 or 2002, height measurements were recorded for every plant, which allows for comparison of size structures between those 2 study periods.

All analyses of recruitment and mortality exclude values for plot 71G. Easy access from Golden Gate Road has resulted in vandalism of the plot, including removal of tags from saguaros. The tracking of individuals from this plot proved impossible.

Results

Raw data are presented in Attachment 2. Total saguaro density increased by 62% and 71% at RMD and TMD respectively (Figure 3). The total number of saguaros increased on all plots since 1975 (Table 2, Figures 4, 5). Saguaro density showed a mean increase of 105% ($SE=35$, range 5-338) between 1975 and 2001/2002. After decreasing to 54 in 1975, the mean saguaro density/ha is now at the same level as in 1941, with 86 saguaros/ha; at TMD, the mean density/ha was 90.5 in 1975 and increased to 128 in 2001 (Figure 6). The mean density found on these plots was slightly higher than on those reported in Turner and Funicelli (2000), but the differences were not significant.

Increased density is a result of recruitment as demonstrated by impressive increases in the smallest size class at both TMD and RMD (Table 3, Figures 7,8). The overall population is younger now than in 1941 and 1975, when the oldest size classes dominated the distribution.

Mean mortality of saguaros marked in 1975 was higher at RMD (59%, $SE = 9.43$, $N = 6$) than at TMD (31%, $SE = 9.04$, $N = 4$). There is no obvious demographic reason for the difference, since the two sets of plots had virtually identical size structures in 1975. Turner and Funicelli (2000) found 17% mortality across 10 years, a similar rate (if we assume a continuous rate, this would equal 44% mortality in 26 years).

Table 2. Plot density values, in total saguaros per 2-ha plot.

	1941	1975	2001/2002
RMD			
41A	209	64	94
41B	187	40	174
41C	291	244	265
41D	106	44	162
41F	60	25	51
75M		226	286
TMD			
71G		165	231
75H		322	331
75J		94	193
75K		104	193
75L		220	331

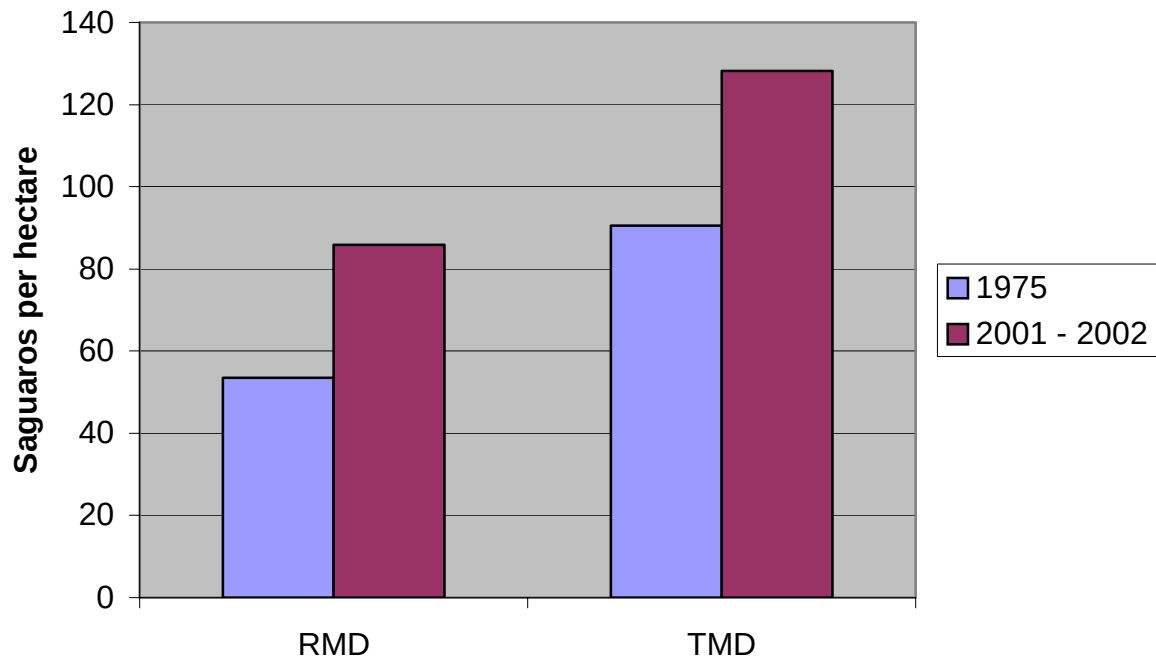


Figure 3. Total density of saguaros per hectare in both districts of Saguaro National Park, 1975 and 2001 – 2002.

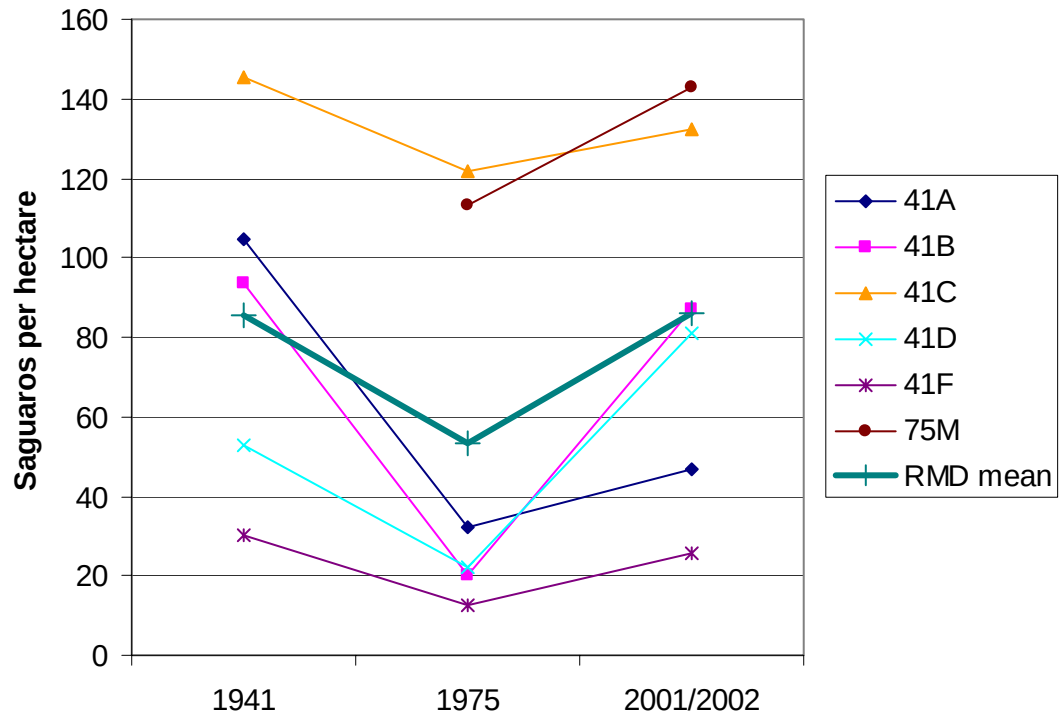


Figure 4. Change in saguaro density per hectare at RMD over the study period. Plots 75M and 41C are rocky habitats; the other plots are flat habitats.

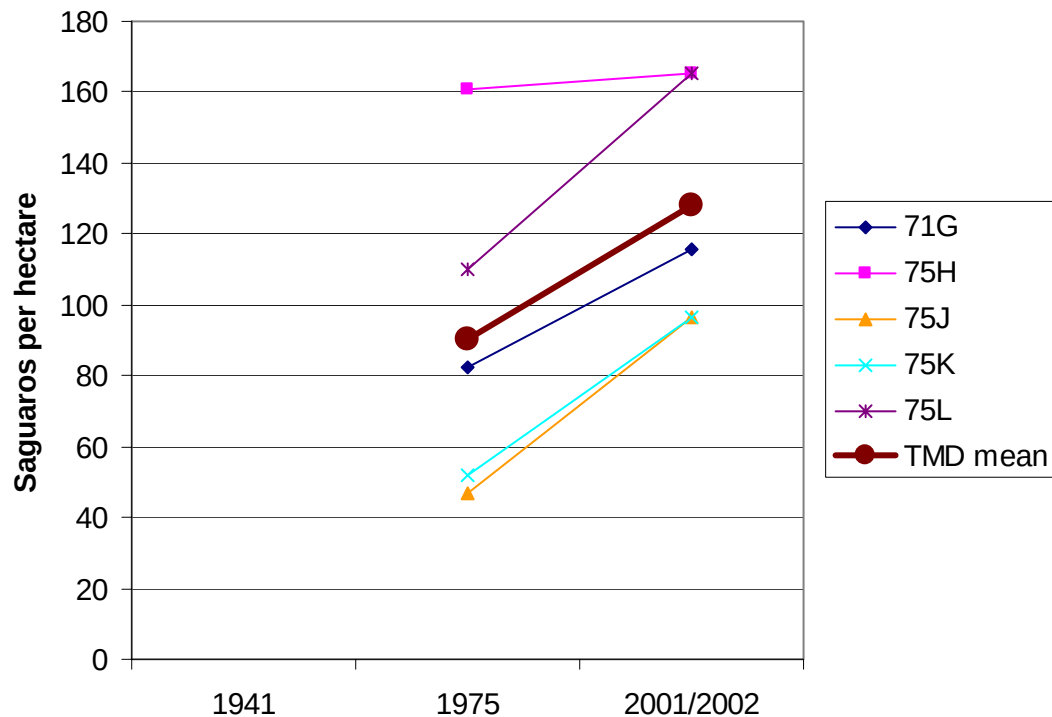


Figure 5. Change in saguaro density per hectare at TMD over the study period. Plots 75H and 75K are rocky habitats; the other plots are flat habitats.

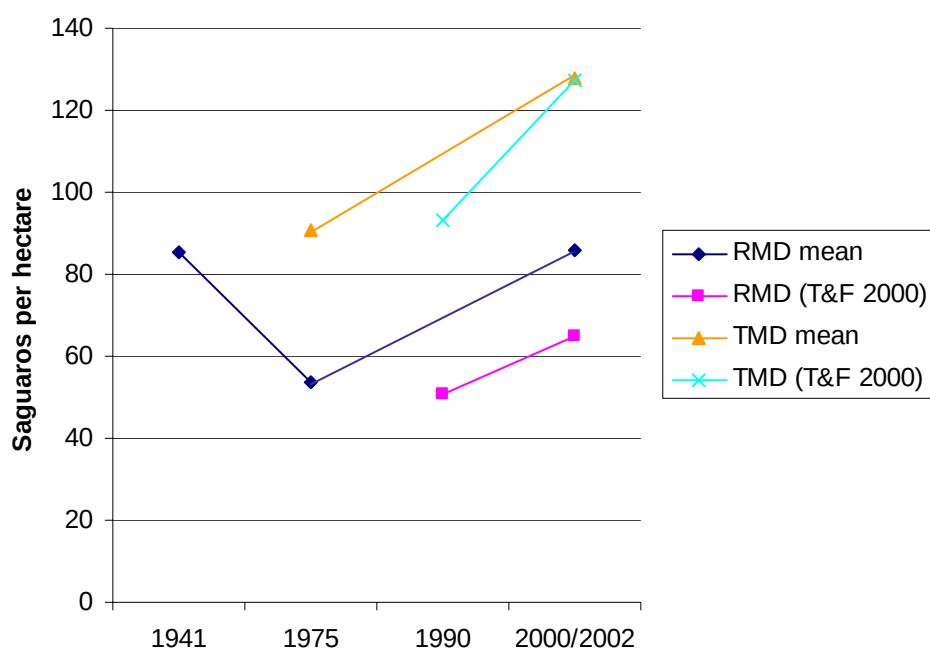


Figure 6. Comparison of mean change in saguaro density per hectare between this study and Turner and Funicelli (2000).

Table 3. Size class distribution of saguaros, 1975 and 2001/2002.

height (m)	RMD 1975	RMD 2002	TMD 1975	TMD 2001
0.00 - 0.99	177	577	214	524
1.00 - 1.99	64	105	115	207
2.00 - 2.99	58	69	127	91
3.00 - 3.99	58	76	88	75
4.00 - 4.99	59	65	54	92
5.00 - 5.99	49	56	53	74
6.00 - 6.99	58	37	78	100
7.00 - 7.99	45	18	62	50
8.00 - 8.99	33	12	71	28
9.00 - 9.99	25	5	23	14
10.00 - 10.99	11	2	9	18
11.00 - 11.99	3	1	3	1
12.00 - 12.99	0	0	0	1
Subtotal	640	1023	897	1275
unclassified (broken off)	2	7	8	7
TOTAL	642	1030	905	1282

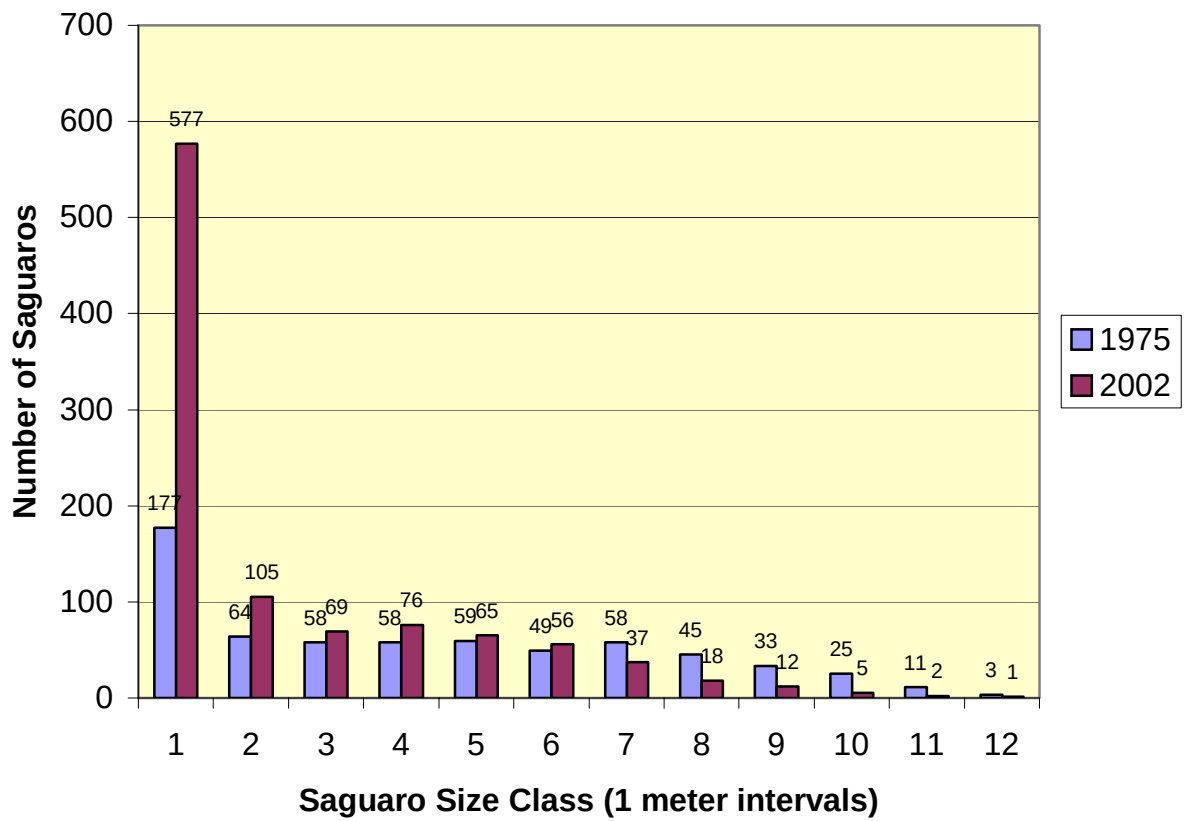


Figure 7. RMD saguaro size distribution, 1975 and 2001.

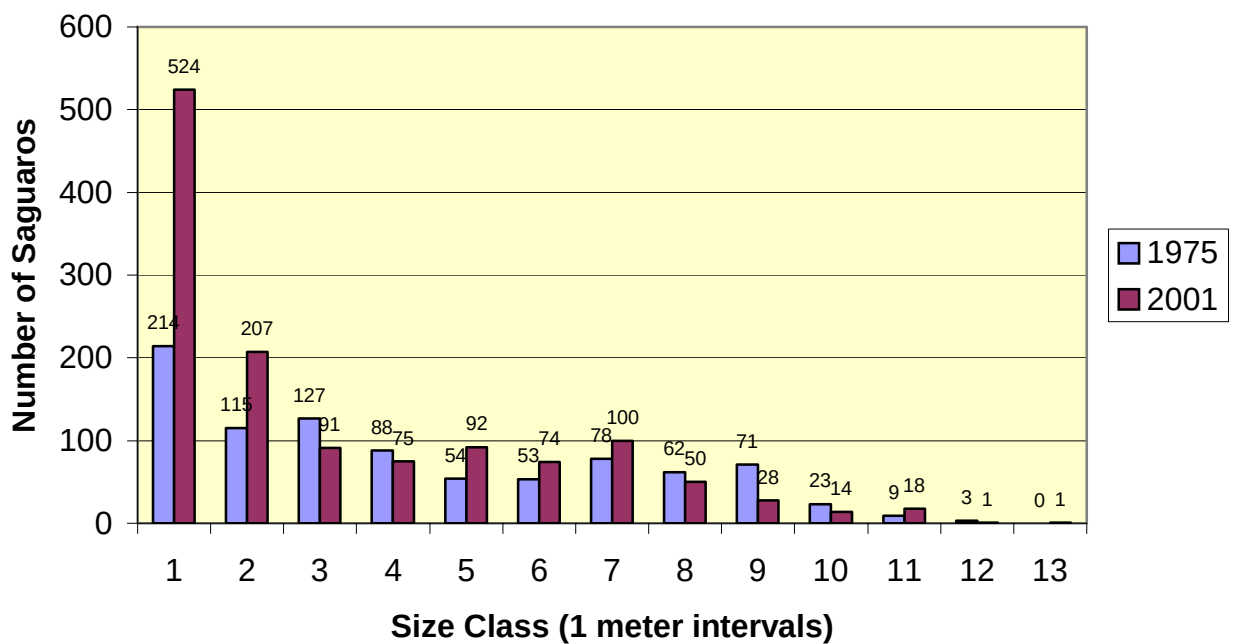


Figure 8. TMD saguaro size distribution, 1975 and 2002.

Recruitment exceeded mortality in all plots. Mean number of recruits/ha was slightly lower at RMD (55, $SE = 9.04$, range 24 – 82.5) than at TMD (64, $SE = 9.40$, range 38.5 – 83). In the Cactus Forest plots (41A, 41B, 41F), the mean percent of saguaros less than 0.60 m in height was 62%.

Turner and Funicelli (2000) estimated a total of 1,624,857 ($SE = 320,722$) saguaros at Saguaro National Park. That extrapolation cannot be refined using the data presented here due to the non-random location of the plots throughout the range of saguaros at Saguaro National Park.

Discussion

By relocating and resurveying these plots, this study greatly expands the range and duration of saguaro monitoring in Saguaro National Park. Our results corroborate patterns found in other recent studies (Helbsing and Fischer 1992, Orum et al. 1998, Turner and Funicelli 2000) that the saguaro populations at the park are regenerating due to a high number of recently recruited saguaros.

An important aspect of this resurvey effort has been the accurate relocation of the historic plot corners with GPS. This will ensure that future researchers can find the plots for resurvey in the decades to come. We recommend that this study be included in the Saguaro National Park Resource Management Plan, and that the plots be remeasured every 10 years. In addition, we recommend that the plots established in 1941 at Organ Pipe Cactus National Monument be relocated and restudied to provide insight into demographic trends in the northwestern portion of the saguaro's range.

The size structure of saguaro populations at Saguaro National Park is markedly different now than it was when the monument was established. The populations are younger now, with a greater proportion of saguaros in the youngest size classes. This demographic shift has been especially dramatic in the Cactus Forest. In 1939, the Cactus Forest showed very low levels of recruitment; in 2 plots measured by Wilder and Wilder (1939), only 0.25% and 3.98% of the population was under 0.60 m in height. Our contemporary measurements from different sites in the Cactus Forest indicate much higher recruitment levels, with a mean of 62% of the population under 0.60 m in height.

The 20th-century decline was likely a result of complex interactions between a series of catastrophic freezes (Steenbergh and Lowe 1976), wood-cutting and cactus rustling in the early part of the century (Steenbergh and Lowe 1977, Clemenson 1987), and with livestock impacts (Abouhaidar 1992, Helbsing and Fischer 1992). These saguaro populations have greatly benefited from federal protection in the National Park system, as the negative anthropogenic factors mentioned above have largely been eliminated. In addition, lack of catastrophic freezing combined with a series of consecutive wet seasons in the past 20 years has favored saguaro seedling establishment and recruitment.

The recent surge in recruitment is encouraging news for resource managers at Saguaro National Park—populations seem to have recovered from the negative pressures of the 20th century. Current population structures reveal a healthy population that is regenerating itself. Resource management decisions should, however, be tempered; it will be many decades before researchers will be able to assess the effects that the rapidly changing environment of the 21st century will have on long-lived saguaro populations. Urban sprawl, climate change, shifts in nurse plant associations, and epidermal browning are a few of the potential limiting factors for the next generation of saguaros. It is clear that demographic studies must continue far into the future.

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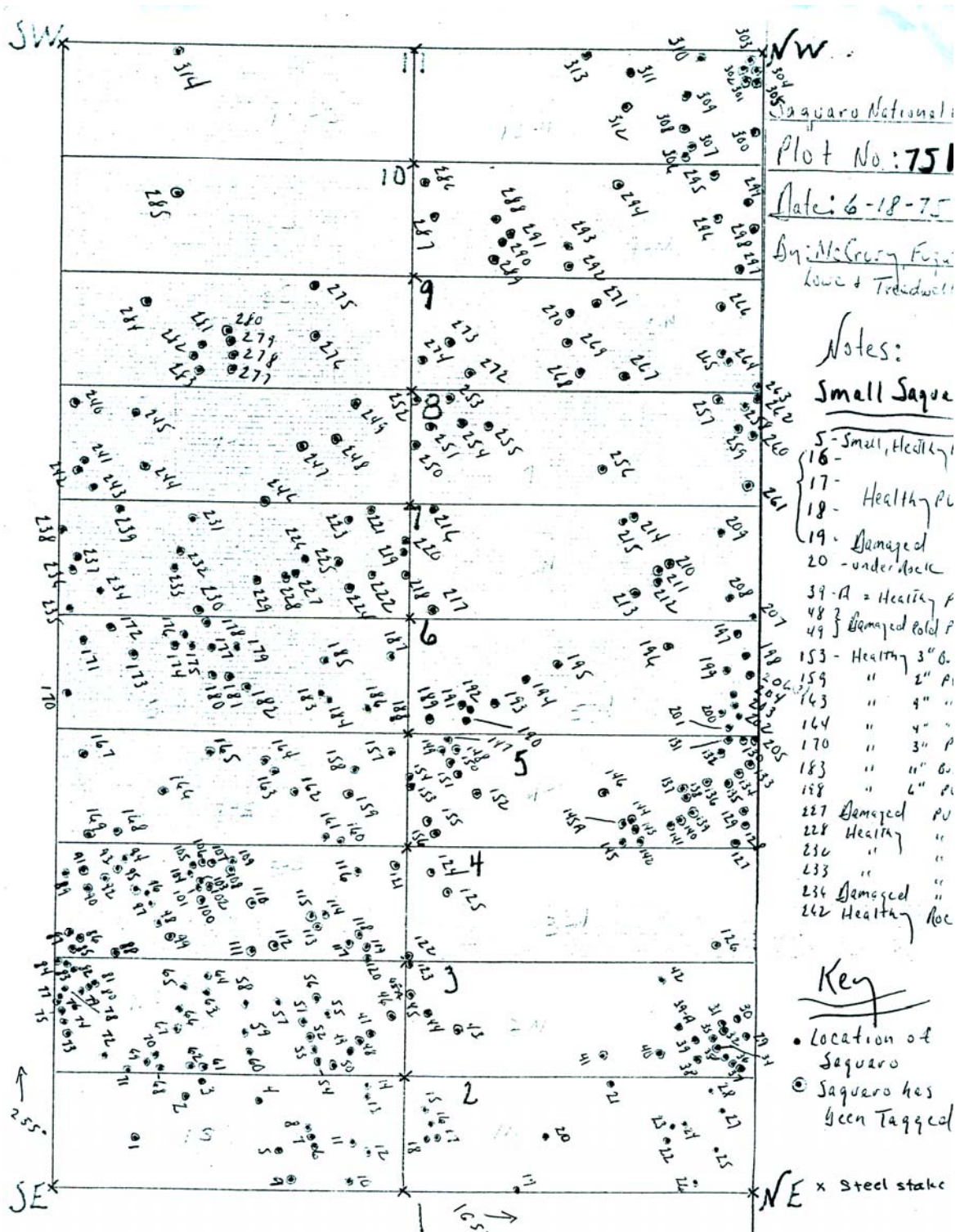
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Appendix 1. UTM Coordinates of Plot Locations (NAD 1983)

Plot #	Corner	Northing	Easting
41A	SW	3564133	525596
41A	SE	3564134	525698
41A	NW	3564335	525597
41A	NE	3564336	525698
41B	SW	3563320	525292
41B	SE	3563324	525494
41B	NW	3563421	525286
41B	NE	3563425	525491
41C	SW	3558495	525903
41C	SE	3558499	526102
41C	NW	3558595	525899
41C	NE	3558604	526101
41D	SW	3561817	525800
41D	SE	3561826	525900
41D	NW	3562019	525793
41D	NE	3562022	525893
41F	SW	3562668	526292
41F	SE	3562676	526497
41F	NW	3562774	526293
41F	NE	3562777	526494
71G	SW	3571227	479902
71G	SE	3571282	479985
71G	NW	3571412	479810
71G	NE	3571455	479898
75H	SW	3569761	482189
75H	SE	3569800	482383
75H	NW	3569854	482172
75H	NE	3569892	482361
75J	SW	3572381	478727
75J	SE	3572375	478827
75J	NW	3572580	478739
75J	NE	3572573	478839
75K	SW	3570199	483461
75K	SE	3570260	483525
75K	NW	3570342	483323
75K	NE	3570407	483397
75L	SW	3568784	481712
75L	SE	3568821	481801
75L	NW	3568970	481638
75L	NE	3569007	481727
75M	SW	3556968	538155
75M	SE	3556974	538356
75M	NW	3557060	538149
75M	NE	3557071	538346

Appendix 2. Example map (plot 75-H) from the files of Warren F. Steenbergh.



Attachment 1. Raw Data