

# Acuña Cactus

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## Objectives

Acuña cactus sampling was designed to detect population trends and dynamics by monitoring growth, mortality, recruitment, and reproductive status.

## Introduction

Acuña cactus (*Echinomastus erectocentrus* var. *acunensis*) is known from only 5 populations in southern Arizona and one in northern Sonora, Mexico. These populations are in hills and flats of the desert at 400m to 1200m elevation in south-central and southwestern Arizona (Pima, Pinal and Maricopa Counties) and in Sonora, Mexico. The five documented populations are in Organ Pipe Cactus National Monument (OPCNM), Coffee Pot Mountain (BLM), Ajo (private land), Florence (state and private land) and Sonoyta, Mexico. Potential habitats exist in the Sand Tank Mountains of the Barry M. Goldwater Air Force Range and Tohono O'odham tribal lands.

Acuña cactus is listed as a Candidate species by the U.S. Fish and Wildlife Service due to its small, isolated populations, and impacts from past mining operations, illegal collecting and drought. The population at OPCNM is one of 2 that may be considered relatively free from habitat degradation due to land management practices (the other is located in the recently established Sonoran Desert National Monument), however, climate change, predation pressures and border related impacts have the potential to impact the species.

Occurrence of the species is associated with granite or granodiorite materials, with coarse to fine texture; with a patchy distribution on open, rounded small hills, benches and flats at elevations 400 to 1200m elevation, restricted to well drained knolls (Phillips et. al 1982). Dominant associated species include

*Larrea divaricata*, *Fouquieria splendens*, *Ambrosia deltoidea*, *Encelia farinosa*, *Olneya tesota*, *Opuntia acanthocarpa*, *Cercidium microphyllum* and *Ephedra* spp.

Dr. William Buskirk and students from the Southwest Studies Field Program at Earlham College, Indiana, surveyed and mapped acuña cactus distribution at OPCNM from 1977 – 1986 (Buskirk 1981, Phillips III and Buskirk 1982). Buskirk also set up 4 study plots to monitor growth patterns and population dynamics. Two additional plots were added by Ruffner Associates in 1988 as part of the Special Status Plants inventory and monitoring program. The six plots have been monitored by OPCNM staff annually since 1989 for growth and mortality. Two major declines in population on acuña plots have been documented: 1980 – 81 and in the mid-1990s. Although the current sample size and methods may be insufficient to determine the long-term viability of the OPCNM population, monitoring to date has provided managers with important data on acuña longevity, growth, reproduction and natural history.

## Methods

In 1977, Buskirk established two 0.1 ha (20 x 50m) plots (Plot 0 and Plot 1) in the heart of the acuña population, one adjacent to the North Puerto Blanco drive and one 170 meters away from the drive. Both plots were selected for their high densities of acuña cactus. The plots were searched systematically by a team of students, and most plants over 2 cm high were located and measured. In 1980, a mapping system was instituted to track individual plants without permanent marking.

In 1983, two more (20 x 50 m) plots (Plot 2 and Plot 3) were added. Cacti were measured to the nearest 0.5 cm from the ground (the base of

the spined body of the cactus) to the tip of the highest spine. Measurements were taken along the longitudinal axis of the plant – not the perpendicular distance from spine tip to ground, which is less than the length of the long axis for leaning cacti. Measuring methods changed in 1988, so size class information may not be comparable with the earlier data.

The current monitoring methods were developed in 1988 by Ruffner Associates (Ruffner Associates 1995). Two additional plots (Plot 4 and Plot 5) were added at the extreme eastern and western limits of the acuña distribution near the North Puerto Blanco Drive. At all 6 plots, acuña plants were mapped and permanent identification tags were wired to small rocks next to the plants. Plants were assigned X and Y coordinate values relative to the 0 x 0-m corner point (“origin”) of the plot (southwest corner).

From 1988 to 2005, primary sampling was conducted in March. All mapped plants were located and measured to the nearest mm. Height was measured as a perpendicular distance from the base of the plant (from a standardized measuring point) to the top of the fleshy part of the plant (not the top of the spines). Two perpendicular width measurements were taken at the widest point of the plant using calipers. The average of these two width measurements was used. If plants were not found, evidence of mortality (carcass or spine clusters) was recorded. Flowers and buds were counted during the primary visit, and during two subsequent visits to determine peak flowers per plant. In 2004 and 2005, the six plots were revisited to count fruits.

From 1988 to 1994 during the primary March visit, an intensive and systematic search was made of each plot to locate new, small plants-including: seedlings (plants that probably had germinated since the last monitoring activity) and young pre-reproductive plants that may have been present during the previous census but had not been detected. For the seedling search effort, plots were divided into 2 x 20-m subplots

using non-stretchable measuring tapes, and staff intensively searched for seedlings in the 2 m lanes, often on hands and knees. All new plants were measured, tagged (tag attached to rock near plant), and given an X and Y coordinate. Associated nurse plants or rock or bare substrate were recorded.

Concerns were raised in 1995 that the intensive seedling search may be impacting very small seedlings and plants due to trampling. In order to reduce these possible impacts, the seedling search was conducted on only half of each plot (10 x 50 m, including origin), with staff searching while standing up, at a rate calculated to detect very small plants, but not necessarily seedlings. In 2003 and 2005, the intensive seedling search was not conducted due to staff constraints.

## Results

### *Numbers of individuals*

Acuña cacti numbers in the three size classes ranging from 31-120 mm in height declined from 1988 to 2005 (Table 2-1, Figure 2-1). Numbers of individuals in the three size classes from 121-180+mm height classes have shown fluctuations, but no significant changes in numbers. Due to changes in how seedlings were sampled, we are not able to draw conclusions about the 1-30 mm size class. When data are compared from 1977-1981 from Buskirk’s original two plots, to data collected from 1988-2005, it appears there has been a decline in the number of individuals on these two plots over time (Figure 2-3). The long-term trends (1977-1981, 1988-2005) for these original plots (0 and 1), indicate a major decline in the late 1970s and early 1980s, followed by partial recovery in the late 1980s and early 1990s, followed by another decline in the mid 1990s.

### *Annual mortality*

Annual mortality is generally greatest for the smallest (1-10 mm height) individuals. Annual mortality was highly variable between years for all size classes. Annual mortality rates (since previous census) appear to spike over 20% in 1993, 1996-2000, and 2003-2004, for

individuals 11-40 or 41+ mm height (Table 2-4, Figure 2-4). Only in 2005 was the rate zero. The annual mortality rate for individuals 1-10 mm height tops out at 49.5% in 1996. For the period 1996-2000, mortality among 41+ mm height individuals appears to be delayed by one year compared to the smaller, 11-40 mm height individuals.

### **Reproduction**

Acuña cacti are estimated to reach reproductive status at 25 mm in height. Data indicates there has been a decline from 143 to 75 individuals (47.6%) of the population that is 25 mm in height or taller (Table 2-2, Figure 2-2). Total flower production on all plots combined, ranged from 63 in 2002 to 902 in 1992 (Table 2-5, Figure 2-5). Peaks in flower production occur in 1989, 1992-1993, 1995, 1998, and 2001. Total flower production has increased steadily on all 6 plots since 2002. Total fruit production was 265 and 361 in 2004 and 2005, respectively (Table 2-5). Combined with flower data, this translates to fruit set rates of 75.1 and 84.0%, for 2004 and 2005, respectively.

### **Growth**

Analyzing growth as a mean annual % change in height was misleading as some of the change represents change in level of hydration and not true growth (Table 2-6, Figure 2-6). A look at long-term individual growth trajectories (Figure 2-6b) is more informative. Data on individual plants indicates that seedlings reach maturity at widely different rates. For example, plant number 54 on plot 1 grew from 4 to 28 mm height in 4 years, whereas number 73 only grew from 3 to 10 mm in 8 years and seemed to stagnate for the next 5 years.

Precipitation data from the Acuña Site climate station are presented in Table 2-7 and Figure 2-7. The wettest and driest 12 months preceding a census were for 1993 and 1990, respectively. There was zero precipitation for October-March (cool season), preceding the 2002 census and only 0.3 inches for the April-September (warm season)

preceding the 2003 census.

### **Discussion**

The pronounced decline in acuña cactus numbers from 1980 - 1981 and 1988 - 2005 is a serious concern for park managers. Although some patterns are evident in the data such as low precipitation seasons followed by seedling mortality, there is no single factor that can explain all declines. Several factors relating to mortality and reproduction are discussed below.

Johnson (1992) found that fruit-set per flower was not limited by either pollinators or resources, yet flower production was limited by water availability, and ovule numbers varied seasonally with resource availability.

Johnson et al. (ca 1991) determined that seedling survival was dependent on summer precipitation. However, this result was based on analysis of only 4 years of data. A similar comparison of 1988-2000 data, regressing % annual mortality of 1-10 mm height individuals on previous April-September precipitation totals, yields an insignificant result ( $R^2=0.05$ ,  $N=12$ ,  $P=0.48$ ). Two major outliers are for high mortality and wet summers preceding the 1993 and 1995 censuses.

In 2004, the old skeletons were removed from pots that had acuña cactus growing in the OPCNM nursery. These had produced many offspring, now ranging from seedling to golf ball size. After the protective lattice was removed, all of the acuña were soon decimated by a white-throated woodrat (*Neotoma albigula*). Petryszyn and Russ (1996) indicated that the Acuña Site had an unusually high cricetid rodent abundance. Buskirk's discussion on the 1981 acuña decline reported that the majority of mortality in the larger size classes were evidenced by scattered spines, and speculated the decline may be due to small mammal predation. Small mammal population growth during wet years may be a concern for the rare cactus.

Johnson (1991) stated that the opuntia

borer, *Moneilema gigas*, may be responsible for considerable mortality of larger acuña specimens. These cerambycid beetle larvae typically consume the cactus flesh and sever the root and stem, causing the plant to fall over. Johnson also noted that large plants, not producing flowers, invariably contained a large beetle larva. Many large acuña specimens on ORPI plots have been noted with bore holes on the sides or uprooted. Table 2-8 provides notes on the condition and fate of 7 abnormal acuña specimens on plot 4 in 1997.

Flower production between 1988 and 1991 was positively correlated with adult size (Johnson 1991) and with winter precipitation (AGFD 2004). Johnson (1991) reported 97.5% (39/40) fruit set at ORPI in 1988, somewhat higher than the 75.1 and 84.0%, we obtained for 2004 and 2005, respectively. Like many other cacti, the acuña cactus is pollinated by anthophorid, halictid, and megachilid bees (Johnson 1991). Late in the flowering season, seed production may be limited by a lack of pollinators due to competition with the hedgehog cactus (*Echinocereus engelmannii*). It is not clear if lower fruit set in 2004 and 2005 is due to pollinator availability or some other factor. Another factor affecting reproduction is seed and fruit predation by the pyralid moth larva, *Yosemitia graciella* (Johnson 1991).

Finally, germination, establishment, and ultimately, the distribution of acuña appear to be related to local soil properties (Johnson 1991). Soil pH of 6.0-7.5 was found at acuña substrates, and available soil B, available Cu and exchangeable Mg were all significantly higher than in areas not inhabited by the cactus (Johnson 1990). Despite the occurrence of acuña populations on gravelly ridges, local distribution is limited to finer soils where adequate moisture is available during germination and establishment.

Although serious declines have been documented by 1977 – 2005 acuña monitoring, fluctuations in population size may be a natural history adaptation to insect outbreaks and elevated predator levels-- low density metapopulations

may help avoid detection (Rutman, pers. communication).

## Recommendations

- Relate existing acuña data to climate data to determine relationships. Analyze archived Buskirk data from 1982 – 1986. Determine if the fluctuations in the acuña data are similar to the normal fluctuations one would see in other cacti populations. Conduct a literature review for recent data that indicate declines in other cacti populations due to the prolonged drought.
- Revise the acuña cactus monitoring protocol to better address factors relating to reproduction and mortality.
- Systematically survey and map occupied habitat; compare with Buskirk and Ruffner Associates survey maps to detect any significant expansion or contraction of distribution and range.
- Conduct studies of predators such as cricetine rodents, *Moneilema gigas*, and *Yosemitia graciella* to better understand their relationships to acuña cactus. Determine if other species are impacting the cactus. Consider resurrecting the Acuña Site rodent monitoring grid or establishing a new one.
- Experiment with methods to protect acuña cactus from predators such as exclosures around cacti.
- Determine the genetic and environmental sources of variation in fruit set and low seed set.
- Continue to discourage visitor access to the population by maintaining the road as a narrow and rough trail, without obvious pullouts near the population.

- Employ law enforcement strategies that discourage undocumented alien traffic and off-road vehicle activity in acuña cactus habitat.

### Acknowledgements

Charles Conner, Ami Pate, Sue Rutman, Bryan Milstead, Jim Petterson, Tim Tibbitts, Nancy Favour, Tom Potter, Peter Rowlands, and many seasonal employees and volunteers.

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Table 2-1. Comparison of acuña cactus size distribution from 1988 to 2005 on all monitoring plots combined at Organ Pipe Cactus N.M. Full intensive seedling search in 1988-1994; half intensive seedling search in 1995-2002, 2004; No intensive seedling search in 2003, 2005.

Height Class (mm)	1988	1989	1990	1991	1992	1993	1994	1995	1996
1-30	114	168	181	281	249	198	180	195	123
31-60	58	49	65	54	47	53	55	60	59
61-90	35	39	39	38	43	38	46	41	42
91-120	28	30	25	34	37	28	23	28	32
121-150	10	11	11	25	24	17	21	21	15
151-180	2	3	2	9	13	9	7	4	12
181+	1	1	1	5	4	2	2	7	4

Height Class (mm)	1997	1998	1999	2000	2001	2002	2003	2004	2005
1-30	123	107	80	66	54	61	35	17	10
31-60	50	30	45	32	38	35	22	20	18
61-90	34	32	12	21	21	19	19	18	19
91-120	18	22	7	9	11	12	13	18	19
121-150	5	10	1	4	5	1	8	9	13
151-180	3	3	1	0	1	0	1	2	2
181+	0	2	0	1	1	1	1	1	2

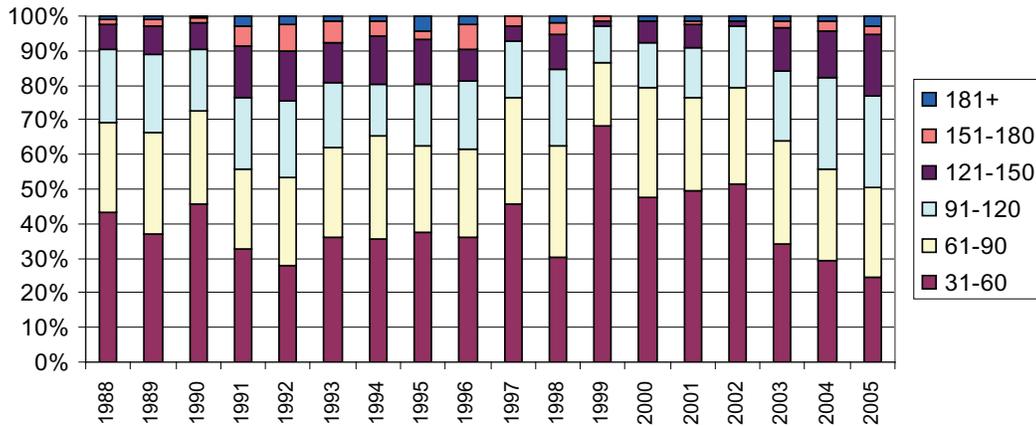


Figure 2-1. Percent composition of acuña cactus size classes from 1988 to 2005, on all monitoring plots combined at Organ Pipe Cactus N.M. 1-30 mm class excluded due to inconsistent sampling.

Table 2-2. All acuña cactus greater than or equal to 25 mm height on monitoring plots at Organ Pipe Cactus N.M.

Year	Plot 0	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Total
1988	8	18	28	19	47	23	143
1989	9	21	31	17	50	24	152
1990	9	23	35	17	50	24	158
1991	15	30	38	17	52	24	176
1992	20	35	41	17	59	24	196
1993	16	35	36	18	48	16	169
1994	18	39	35	18	45	16	171
1995	19	47	41	17	47	15	186
1996	17	44	41	15	48	16	181
1997	16	23	35	11	47	2	134
1998	15	21	30	12	37	1	116
1999	12	20	22	11	16	1	82
2000	13	19	13	15	15	2	77
2001	13	19	14	17	18	5	86
2002	13	19	14	17	17	5	85
2003	10	17	13	13	18	5	76
2004	9	17	11	13	17	5	72
2005	9	17	11	13	20	5	75

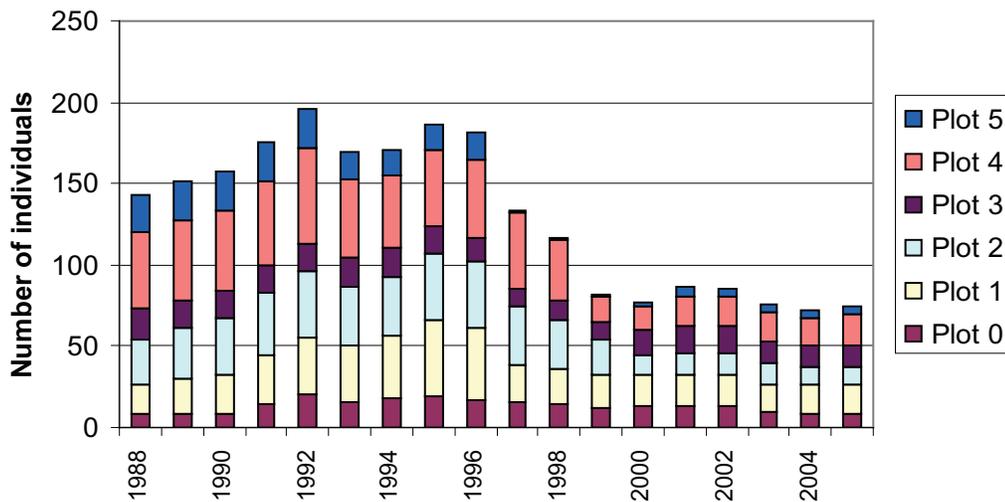


Figure 2-2. All acuña cactus greater than or equal to 25 mm height on monitoring plots at Organ Pipe Cactus N.M. Figure 2-2. All acuña cactus greater than or equal to 25 mm height on monitoring plots at Organ Pipe Cactus National Monument.

Table 2-3. All acuña cactus greater than or equal to 31 mm height on plots 0 and 1 at Organ Pipe Cactus N.M. (1977-1981 data from Buskirk (1981).)

Year	Plot0	Plot1	Year	Plot0	Plot1
1977	34	73	1994	16	33
1978	27	68	1995	14	37
1979	26	75	1996	16	41
1980	24	74	1997	14	16
1981	21	44	1998	11	18
			1999	10	17
1988	7	13	2000	13	16
1989	9	18	2001	12	16
1990	9	20	2002	12	15
1991	12	26	2003	8	16
1992	15	28	2004	9	17
1993	14	29	2005	9	17

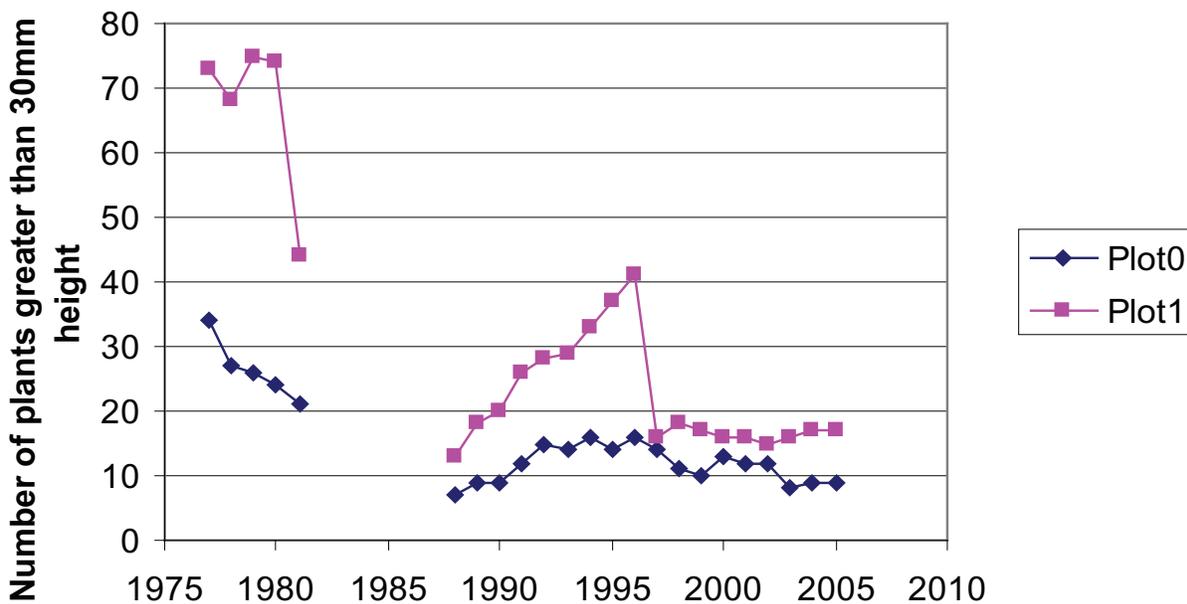


Figure 2-3. All acuña cactus greater than or equal to 31 mm height on plots 0 and 1 at Organ Pipe Cactus National Monument.

Table 2-4. Annual mortality of acuña cactus since previous census on monitoring plots at Organ Pipe Cactus N.M.

From Year	To Year	Alive	Dead	1-10 mm	Alive	Dead	11-40 mm	Alive	Dead	41+ mm
1988	1989	57	5	8.77	75	4	5.33	105	7	6.67
1989	1990	101	24	23.76	85	5	5.88	116	5	4.31
1990	1991	103	5	4.85	99	3	3.03	122	7	5.74
1991	1992	155	59	38.06	148	7	4.73	141	9	6.38
1992	1993	109	45	41.28	157	48	30.57	150	30	20.00
1993	1994	101	25	24.75	114	6	5.26	131	8	6.11
1994	1995	100	27	27.00	101	2	1.98	133	12	9.02
1995	1996	107	53	49.53	107	28	26.17	141	6	4.26
1996	1997	58	16	27.59	88	11	12.50	141	48	34.04
1997	1998	71	23	32.39	72	14	19.44	90	22	24.44
1998	1999	61	27	44.26	52	3	5.77	93	32	34.41
1999	2000	41	6	14.63	56	1	1.79	49	12	24.49
2000	2001	23	7	30.43	56	6	10.71	54	2	3.70
2001	2002	8	1	12.50	54	4	7.41	69	1	1.45
2002	2003	17	8	47.06	54	15	27.78	58	10	17.24
2003	2004	11	9	81.82	35	11	31.43	53	1	1.89
2004	2005	3	2	66.67	23	0	0.00	59	0	0.00

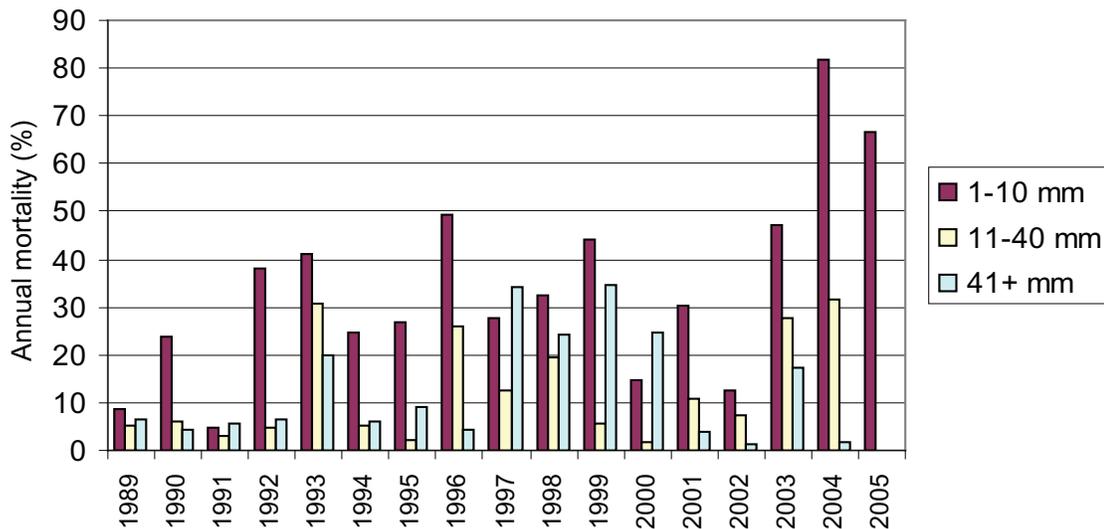


Figure 2-4. Annual mortality of acuña cactus since previous census on monitoring plots at Organ Pipe Cactus N.M.

Table 2-5. Mean number of flowers (a) and fruit (b) at each acuña cactus plot at Organ Pipe Cactus N.M.

Year	Plot 0	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Total
<b>a. Flowers</b>							
1988	2	47	56	95	0	0	200
1989	13	74	77	93	152	168	577
1990	13	59	65	63	131	123	454
1991	22	115	128	93	232	205	795
1992	44	155	154	62	254	233	902
1993	43	149	165	79	187	171	794
1994	9	62	82	44	102	103	402
1995	23	114	139	45	139	154	614
1996	18	111	109	21	113	122	494
1997	8	11	45	2	84	8	158
1998	48	89	175	34	234	0	580
1999	12	8	30	2	15	0	67
2000	23	5	8	6	34	8	84
2001	57	69	60	47	83	9	325
2002	12	5	12	4	28	2	63
2003	28	26	26	17	41	5	143
2004	64	70	70	52	77	20	353
2005	69	81	76	66	103	35	430
<b>b. Fruit</b>							
2004	50	59	41	49	50	16	265
2005	67	65	55	63	85	26	361

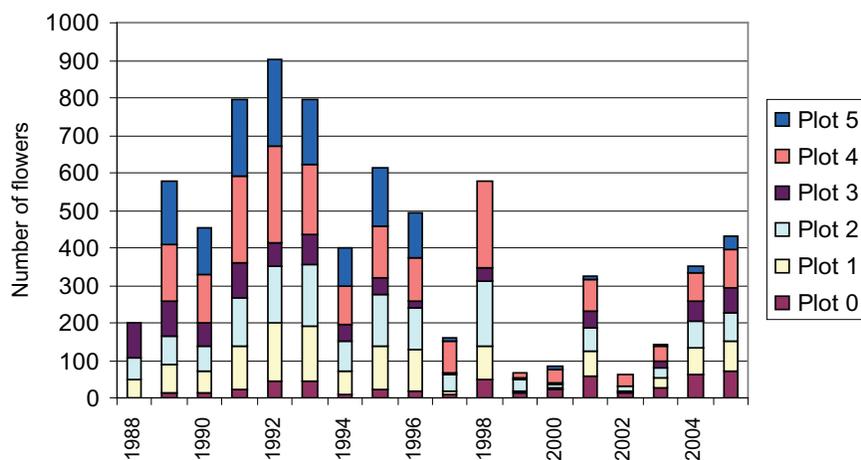


Figure 2-5. Mean number of flowers at each acuña cactus plot at Organ Pipe Cactus N.M. (not counted on plots 4&5 in 1988).

Table 2-6. Mean annual growth of acuña cactus as percent increase in height on monitoring plots at Organ Pipe Cactus N.M.

To Year	Plot 0	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	6-plot mean
1989	36.9%	28.0%	15.1%	11.0%	17.5%	39.4%	24.6%
1990	22.4%	1.8%	7.9%	17.6%	9.7%	-1.9%	9.6%
1991	64.3%	86.2%	51.7%	59.7%	35.2%	61.4%	59.7%
1992	34.5%	15.8%	25.2%	28.9%	29.4%	3.3%	22.8%
1993	18.8%	22.3%	6.5%	15.2%	6.2%	22.0%	15.2%
1994	5.2%	13.2%	12.2%	10.4%	7.9%	8.2%	9.5%
1995	21.5%	23.2%	47.1%	30.5%	18.5%	32.7%	28.9%
1996	15.9%	15.5%	4.0%	14.8%	6.0%	1.5%	9.6%
1997	-7.3%	-6.7%	-13.4%	-14.7%	-1.0%	-0.1%	-7.2%
1998	72.7%	56.4%	60.5%	70.8%	45.9%	75.3%	63.6%
1999	-21.3%	-14.4%	-28.0%	-11.8%	-8.7%	-20.5%	-17.5%
2000	51.3%	44.9%	84.4%	70.7%	42.5%	61.6%	59.2%
2001	24.1%	18.6%	21.4%	24.8%	18.1%	35.2%	23.7%
2002	-12.2%	-13.1%	-14.8%	-9.0%	-9.6%	-18.1%	-12.8%
2003	23.5%	47.4%	3.9%	29.7%	10.9%	50.2%	27.6%
2004	6.8%	10.2%	2.6%	11.5%	12.8%	17.4%	10.2%

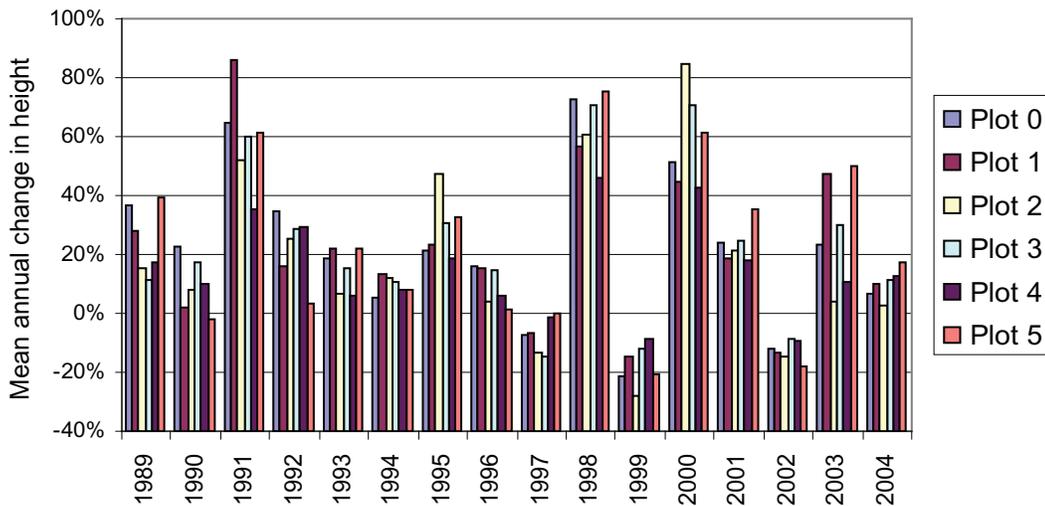


Figure 2-6a. Mean annual growth of acuña cactus as percent increase in height on monitoring plots at Organ Pipe Cactus N.M..

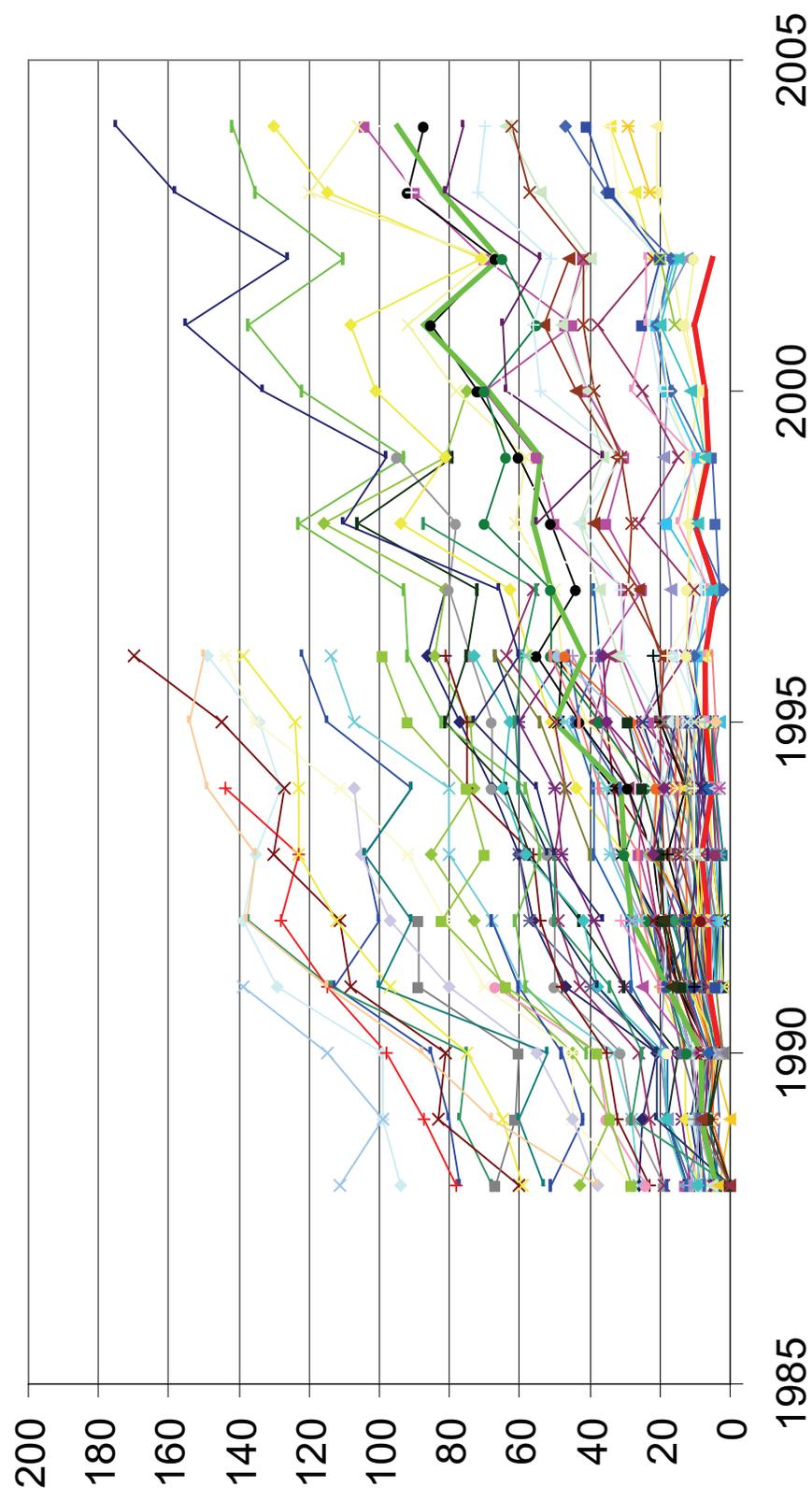


Figure 2-6b. Individual growth trajectories of acuña cactus on plot 1 at Organ Pipe Cactus N.M. Plant 54 indicated by thick green line, plant 73 by thick red line.

Table 2-7. Rainfall since previous census (inches) at the Acuña Habitat climate station, Organ Pipe Cactus N.M.

From Year	To Year	Apr-Sep	Oct-Mar	Apr-Mar
1988	1989	3.8	5.3	9.1
1989	1990	1.6	1.5	3.2
1990	1991	6.7	6.2	12.9
1991	1992	2.0	7.4	9.3
1992	1993	5.7	10.1	15.8
1993	1994	3.0	3.5	6.5
1994	1995	2.2	6.2	8.3
1995	1996	5.0	2.4	7.4
1996	1997	6.7	0.6	7.3
1997	1998	3.5	7.0	10.5
1998	1999	2.8	1.1	3.9
1999	2000	5.3	1.4	6.7
2000	2001	0.7	5.5	6.2
2001	2002	5.1	0.0	5.1
2002	2003	0.3	3.2	3.6
2003	2004	8.1	2.4	10.5
2004	2005	2.8	7.9	10.7

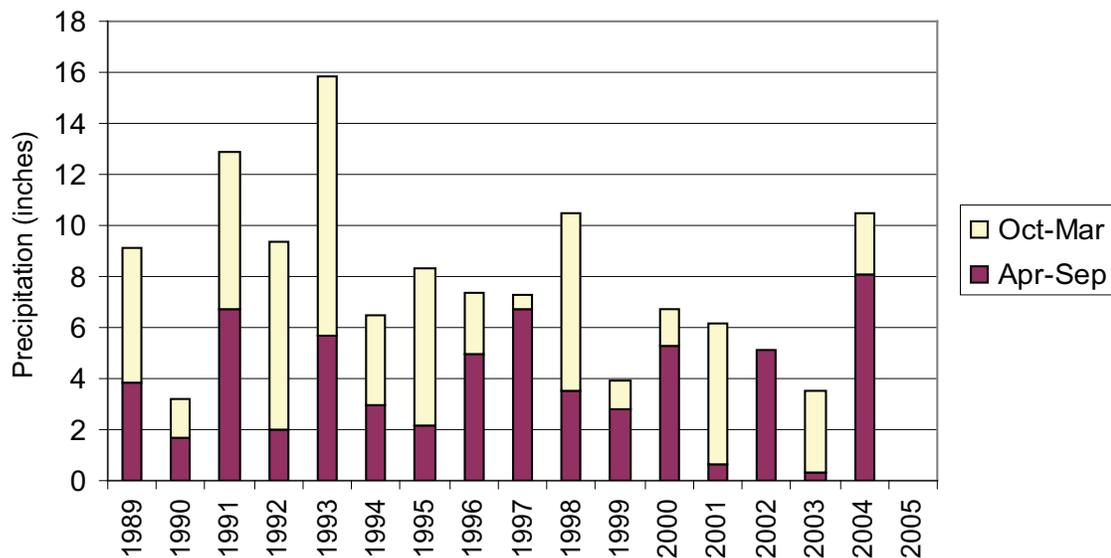


Figure 2-7. Rainfall since previous census (inches) at the Acuña Habitat climate station, Organ Pipe Cactus N.M.

Table 2-8. Example of condition notes and fate of unhealthy acuña cactus individuals at plot 4 in 1997, Organ Pipe Cactus N.M.

Plant #	Height	Condition	Flowers	Fate (between census periods)
20	55	bore hole	no	uprooted (1998-1999)
30	90	bore hole	no	dead (1997-1998)
35	126	bore hole	yes	uprooted (1997-1998)
73	96	bore hole	yes	dead (1997-1998)
19	156	base damaged	yes	dead (1997-1998)
52	89	base damaged	no	dead (1997-1998)
13	81	“dying”	no	dead (1997-1998)