Organ Pipe Cactus and Senita Cactus

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Objectives

The overall objective applied to all special status plant monitoring is to understand population dynamics and provide insight into potential problems or threats faced by species so that efficient and effective management actions can be undertaken (Ruffner Associates 1995). A specific objective for the columnar cacti, articulated more recently, is to determine if productivity (indicated by stem growth) of organ pipe and senita cactus plants is changing over time; if change in productivity is detected, then possible causal agents will be evaluated (Petterson 1998).

Introduction

Organ Pipe Cactus National Monument is fairly unique in the presence of 3 species of columnar cactus including organ pipe (*Stenocereus thurberi*), senita (*Pachycereus schottii*), and saguaro (*Carnegia gigantea*). The organ pipe and senita cactus are of particular interest because they are at their northern distributional limits and because they were instrumental in the establishment of the monument. The organ pipe is widespread on rocky slopes and upper bajadas throughout the monument, with greatest population densities on southwestern, southeastern, and southern slopes where freezing temperatures are least likely to occur (Parker 1987). Senita is restricted to the southern boundary on sandy plains and warm rocky slopes.

Population trends for organ pipe cactus demonstrate that regeneration over the last century has been irregular, with brief episodes of recruitment during anomalous wet periods such as the 1910s and 1920s. Episodes of recruitment have generally corresponded to wet periods with mild winters, and poor regeneration has coincided with prolonged drought (Parker 1993). Concerns for these species have generally included freezing temperatures and land use changes (Johnson et al. 1991).

Flowering peaks and fruit set timing for organ pipe cacti in OPCNM are different than populations further south in Sonora, exhibiting a pollination system adapted to a higher reliance on endangered lesser long-nosed bats (*Leptonycteris curasoae*). Maximum fruit set requires the joint contributions of bats, birds, and bees and if one or more of these pollinators decline, reduction in fruit set could occur (Fleming et al. 2001).

Project History

In 1970, Park Ranger Fred Goodsell selected 31 organ pipe cacti and 9 senita cacti for long-term growth monitoring. The organ pipe cacti were part of a population growing on a steep, south-southeast facing rocky slope in the central Puerto Blanco Mountains near Baker Mine. Eight of the senita cacti plants were located near Lost Cabin Mine and one was located along a wash on the floor of Senita Basin in the southern Puerto Blanco Mountains. These individuals represented a wide range of sizes but were small enough to allow access for stem measurements. Therefore, this sampling effort was biased towards smaller size classes of organ pipe cactus, in particular, plants less than 15-20 m total stem length (Figure 3-1). The individuals were permanently tagged. Monument personnel measured the annual growth of these individuals from 1970 to 1997, 2000, and 2002 to 2003. Monitoring of some individuals in the original study ended sooner due to mortality or severely reduced vigor.

The original organ pipe plot established by Fred Goodsell was placed in characteristic habitat for the species within 8 km of OPCNM headquarters. The plot was located on a steep, S-SE facing hillslope in the central Puerto Blanco Mountains (average slope angle and aspect of 24° and 162° respectively), at 595 – 615 m elevation. The geologic substrate is metaquartz porphyry. The newer Bates Mountains organ pipe plot is located

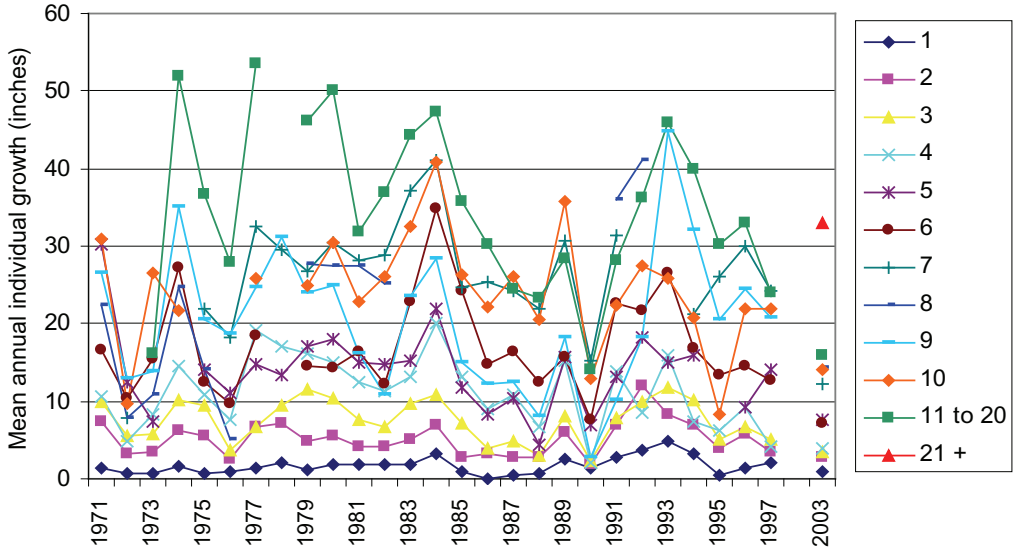

Figure 3-1. Mean annual individual growth of organ pipe cactus, grouped by number of stems, at the Baker Mine plot, Organ Pipe Cactus N.M.

on a S-SE facing hillslope 1.4 km west of Bates Well, at 421 - 468 m elevation on a conglomerate and brecchia substrate.

In 1990, as a part of the Special Status Plants project, additional plots were set up for the purpose of assessing intersite variability in growth rates. A new study plot containing 20 organ pipe cacti was established in the Bates Mountains. Four additional senita cacti were selected for monitoring on the original southern Puerto Blanco Mountains plots, including 2 at Lost Cabin Mine and 2 at Senita Basin. Also, to increase the sample of small organ pipe cacti in the Baker Mine plot, 8 plants under 1 m tall were added to the monitoring program in 1995, and 2 more added in 1996. There were recently 36 organ pipe cactus individuals under investigation at the Baker Mine study site. In 2005, growth monitoring was discontinued in favor of exploring new study designs to address broader ecological questions for columnar cacti in the monument.

Methods

Each stem of every study plant was identified with a tag indicating plant number and arm number. As stems grew, they became too long and/or curved to be measured from the base, so a wooden peg was inserted approximately 1 m (3 ft) from the base, or in a solid, fleshy part of the arm. Each stem was measured to the nearest 0.25 inch, from the base or peg to the stem tip. When new arm buds appeared, their position (e.g., NW), parent stem number, and bud length were recorded. All measurements and condition notes were recorded on a standard data form. Measurement data were entered into a spreadsheet for calculation of annual growth and graphing results. In 1996 and 2002, slides were taken of each plant in each study site for long-term repeat photography.

Rowlands (1999) determined that number of stems was a better factor for predicting growth than was plant size (sum of stem lengths), so stem number is used here to establish size classes. For this report, annual stem growth is defined as the current year's length minus the previous year's length; annual plant (individual) growth is defined as the sum of annual stem growth for all stems on that individual; and number of stems is defined as the number of stems included in the calculation of annual plant growth. Since the 1996 results were reported (Rowlands 1999),

growth measurements of organ pipe and senita cactus were obtained in 1997, 2000 and 2002-2004.

Regression analysis was performed on each stem-number class to determine if there was any significant change over time.

Results

The 3 organ pipe plants monitored at Dos Lomitas were last measured in 1997 and are not included in this summary; nor are the 3 organ pipe specimens at Senita Basin, which were last measured in 2002, because there were no annual growth increments to report. For organ pipe cactus, annual plant growth was averaged across individuals in the same stem number class and presented in Tables 3-1 and 3-2 for the Baker Mine and Bates Mountains sites respectively. Graphical representations of these data reductions (Figures 3-1 and 3-2), provide an easy means to compare growth between years and stem number classes and to scan for extreme events. Annual plant growth for senita cactus is presented in Figure 3-3.

Extreme, low growth events appear in census years 1972, 1976, 1990, 1995, and 2003. High growth events appear in census years 1979, 1984, and 1993. The patterns are less clear for senita cactus due to the small sample size. These extreme growth events can be compared to number of freezing days (Figure 3-4) and amounts of winter and summer precipitation (Figure 3-5) occurring in the previous 1-2 years.

The mean sample size for stem-number classes 1-10 at Baker Mine is 2.54. As individual plants grow and add stems, they move into and then out of a given stem-number class. Changes in the composition of samples probably add some noise to the pattern. However, the extreme events are probably real.

Regression analyses, performed on the Baker Mine data summaries, do not reveal any highly significant trends (Table 3-3). Most, 8 out of 11, stem-number classes show a slight but insignificant decline in growth. The 11-20 stem-number class shows the greatest, but still only marginally significant, decline in growth (R^2=0.15, P=0.055, N=25).

The highest-ever recorded annual stem growth was 16.75" between 1990 and 1991 on a stem at the Baker Mine plot. In general, the newer stems

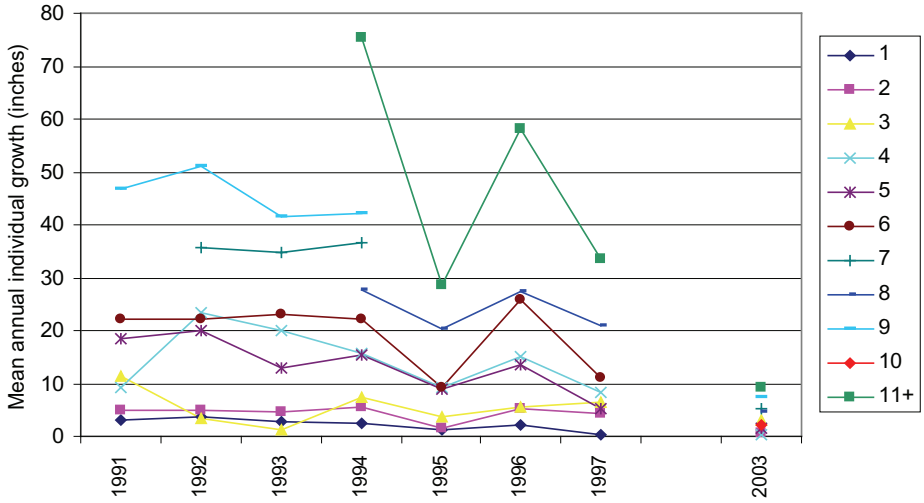

Figure 3-2. Mean annual individual growth of organ pipe cactus, grouped by number of stems, at the Bates Mountains plot, Organ Pipe Cactus N.M.

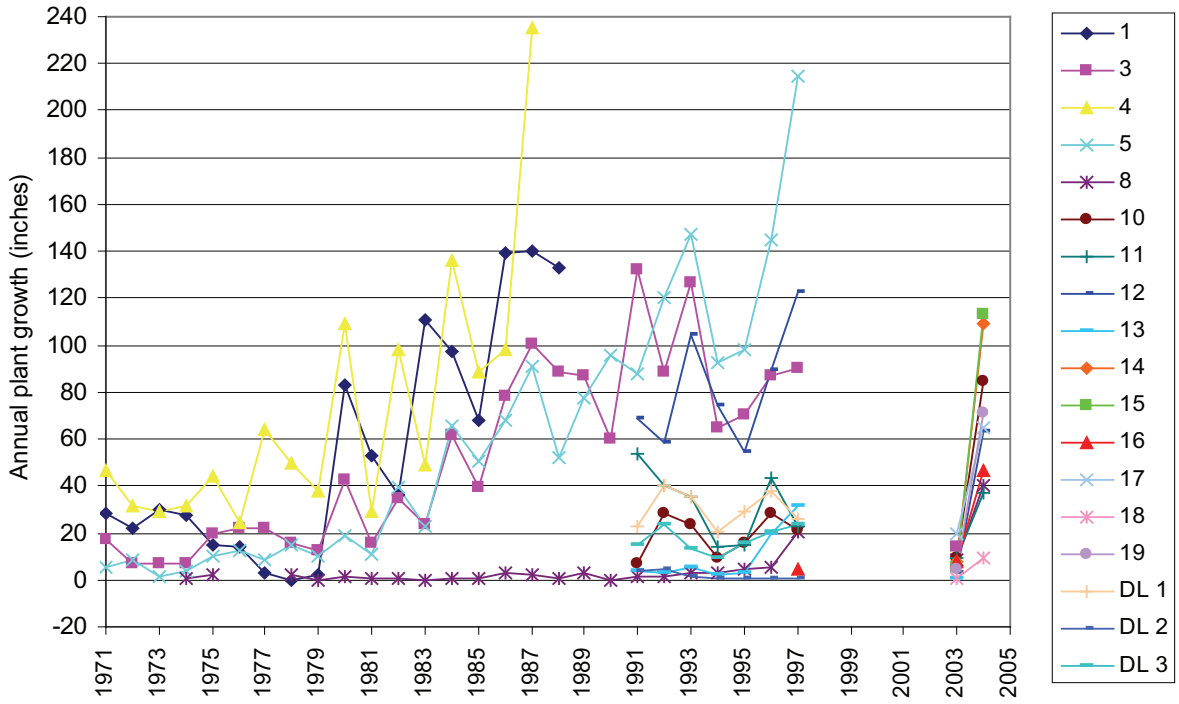

Figure 3-3. Mean annual growth (inches) of individual senita cactus monitored at Organ Pipe Cactus N.M.

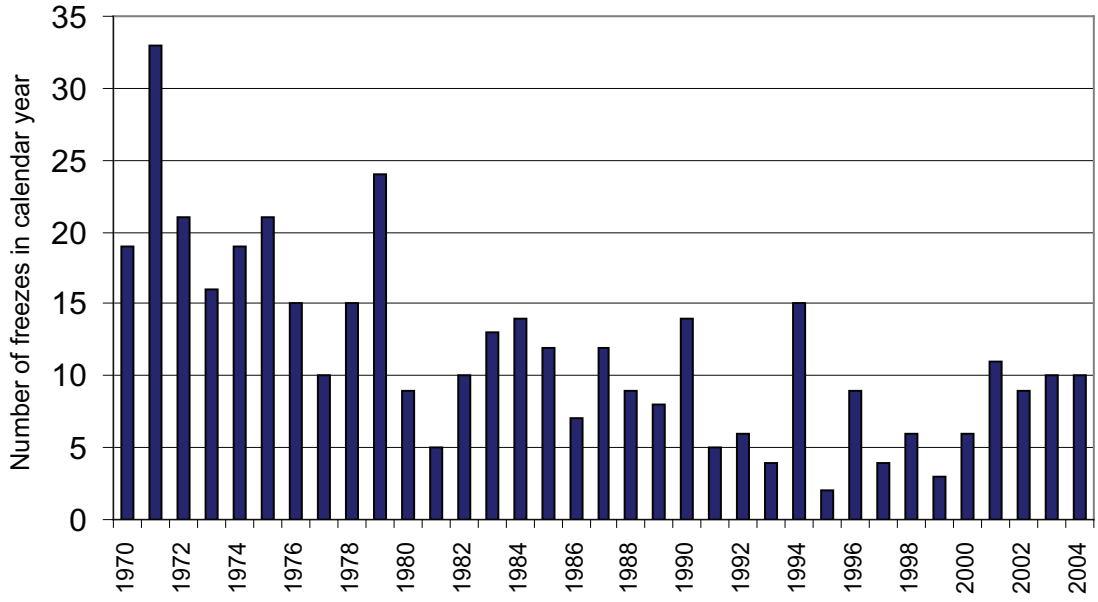

Figure 3-4. Number of days with temperatures at or below freezing at Organ Pipe Cactus N.M. headquarters.

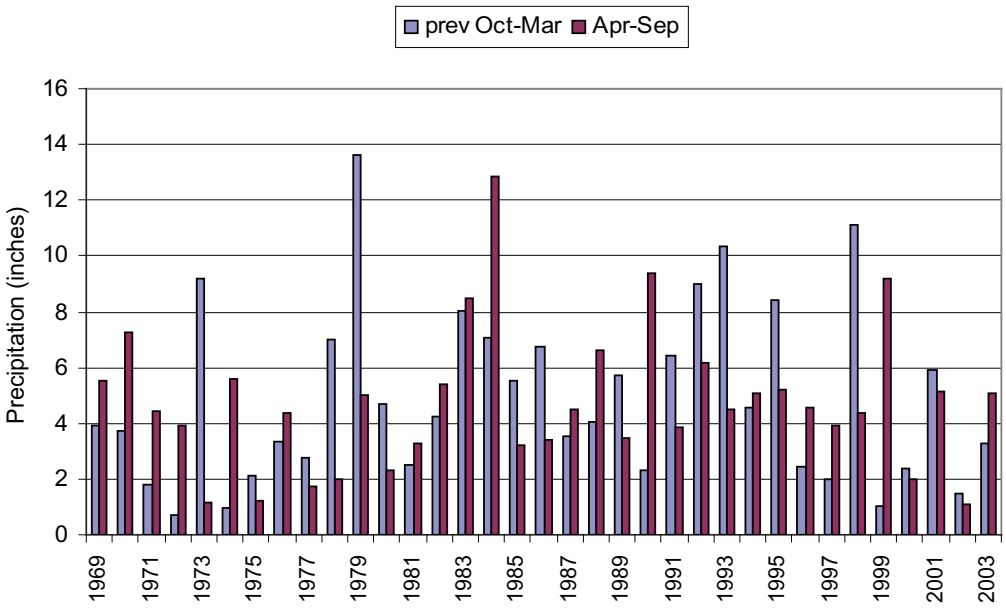

Figure 3-5. Winter and summer precipitation recorded at Organ Pipe Cactus N.M. headquarters. Example: 1980 precipitation values from Oct 1979-Mar 1980; Apr 1980-Sep 1980; compare to growth reported in 1981 census.

grew at a much faster rate than older stems, and frequently accounted for most of the overall plant growth in a year. The new stems generally grow from the base of the plant.

Discussion

Parker (1988) used analysis of variance and regression analysis of the 1970-1983 data to relate growth in organ pipe and senita cactus to plant size, age, and climate. She determined that plant size and number of stems explained much of the variation in annual growth. Variation in mean growth rates between years was positively correlated with previous winter (November-April) precipitation and negatively correlated with number of days with temperatures at or below freezing (November-March). Freezing had a more prolonged effect on senita.

Determining climate relations is not only important for understanding the distribution limits of organ pipe and senita cactus, but also in predicting possible changes in their status and distribution within the monument that may derive from climatic trends. Long-term data on temperature at ORPI indicate a significant decline in the frequency of freezing days (R^2=0.46, P<0.0001, for 1969-2003).

Winter freeze-kill is believed to be the limiting factor for the northern distribution of the organ pipe cactus (Felger and Lowe 1967, Parker 1988). One might very well predict that the species will become more widespread throughout the monument and elsewhere in southern Arizona if the incidence of freezes continues to remain low or decrease even further. However, Felger and Lowe (1967) also suggested that the general decrease in summer as well as annual precipitation from southeast to northwest may limit western distribution.

The marginally significant decline in growth for the 11-20 stem-number class may warrant further statistical analysis. It may be noteworthy that most (8 of 11) stem number classes exhibited declining growth rates, despite the lack of statistical significance for individual classes. A

complete reexamination of the entire data set with both auto and cross-correlation of cactus growth data and climatic variables was suggested by Rowlands (1999).

Growth monitoring may continue at a reduced frequency. The protocol developed by Ruffner Associates (1995) recommended every 5 years. Monument staff have expressed interest in exploring other options for monitoring columnar cacti that would address a wider array of ecological questions.

Recommendations

- Relocate Kathleen Parker's repeat photo sites, and possibly vegetation plots, to assess mortality and recruitment since 1986.
- Use stem growth data, climate data and repeat photos for interpretive displays/ presentations on organ pipe cactus growth patterns and response to precipitation.
- Design a columnar cacti monitoring protocol to determine long-term recruitment and phenology trends on different landscape gradients in the monument. Such a protocol could be linked to the Sonoran Desert Network vital signs phenology monitoring program, and integrated into lesser-long nosed bat pollination studies.

Acknowledgements

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Literature Cited

Felger, R.S. and C.H. Lowe. 1967. Clinal variation in the surface-volume relationships of the columnar cactus *Lophocereus schottii* in northwestern Mexico. Ecology 48:530-535.

Fleming, T.H., C.T. Sahley, J.N. Nolland, J.D. Nason, and J.L. Hamrick. 2001. Sonoran Desert columnar cacti and the evolution of generalized pollination systems. Ecological Monographs 71(4), p. 511-530.

Johnson, R. A., M. A. Baker, D. J. Pinkava, N. Trushell, and G. A. Ruffner. 1991. Special status plants of Organ Pipe Cactus National Monument, Arizona; Sensitive Ecosystems Project. Final report submitted to National Park Service at Organ Pipe Cactus National Monument, Arizona.

Parker, K.C. 1987. Site-related demographic patterns of organ pipe cactus populations in southern Arizona. Bulletin of the Torrey Botanical Club 114(2), p. 149 – 155.

Parker, K.C. 1988. Growth rates of *Stenocereus thurberi* and *Lophocereus schottii* in southern Arizona. Botanical Gazette 335-346.

Parker, K.C. 1993. Climatic effects on regeneration trends for two columnar cacti in the northern Sonoran Desert. Annals of the Association of American Geographers, 83(3), p. 452-474.

Petterson, J. 1998. ORPI EMP monitoring objectives and associated protocols: evaluations and recommended modifications. Unpublished Report. Organ Pipe Cactus National Monument, Arizona. 27 p.

Rowlands, P.G. 1999. Organ pipe and senita cactus. Organ Pipe Cactus National Monument. Ecological Monitoring Program annual report 1996. Organ Pipe Cactus National Monument, Arizona. 182 p.

Ruffner Associates. 1995. Special-status plants monitoring protocol for the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona. P. 1:1-39 in Organ Pipe Cactus National Monument Ecological Monitoring Program Monitoring Protocol Manual. Special Report No. 11, Cooperative Park Studies Unit, The University of Arizona, Tucson.

Table 3-1. Mean annual individual growth (inches) from previous year of organ pipe cactus, grouped by number of stems, at the Baker Mine plot, Organ Pipe Cactus N. M. Numbers include mean, standard deviation, and number of plants in each stem class.

	Number of stems																	
	1			2			3			4			5			6		
1971	1.50	1.25	7	7.47	2.59	4	10.00	2.38	3	10.55	2.98	5	30.25		1	16.63		2
1972	0.71	0.39	7	3.30	0.57	5	5.50	2.54	3	4.90	1.51	5	12.50		1	10.50		1
1973	0.69	0.43	4	3.36	1.32	7	5.83	2.75	3	8.20	2.46	5	7.50		1	15.50		1
1974	1.63	0.72	4	6.25	2.70	7	10.08	6.45	3	14.60	3.39	5			0	27.13		2
1975	0.75	0.54	4	5.46	2.21	7	9.42	4.14	3	10.94	5.25	4	14.13		2	12.50		1
1976	0.88	0.66	4	2.57	1.21	7	3.58	4.48	3	7.63		2	11.06	2.68	4	9.75		1
1977	1.50	0.74	4	6.58	3.47	6	6.58	2.67	3	19.13		2	14.81	2.90	4	18.50		1
1978	2.13	0.48	4	7.20	2.19	5	9.44	2.13	4	17.00		2	13.38	1.23	4			0
1979	1.25	0.66	3	4.88	1.97	4	11.45	3.59	5	16.08	7.26	3	17.00	6.97	3	14.50		1
1980	1.92	0.63	3	5.50	2.19	4	10.40	2.34	5	15.08	6.33	3	17.92	4.94	3	14.25		1
1981	1.88		2	4.15	1.29	5	7.70	0.62	5	12.50		2	15.06	6.38	4	16.50		1
1982	1.75		2	4.20	1.27	5	6.70	1.65	5	11.25		1	14.75	5.95	5	12.25		1
1983	1.75		2	5.05	0.82	5	9.80	2.00	5	13.25		1	15.13	4.04	4	22.88		2
1984	3.13		2	6.90	4.70	5	10.94	3.18	4	20.00		2	22.00	2.27	4	34.88		2
1985	0.88		2	2.75		2	7.11	3.86	7	13.25		2	11.75	3.25	3	24.17	12.39	3
1986	0.00		1	3.33	1.81	3	3.90	2.66	5	8.92	2.27	3	8.33	0.29	3	14.88	5.59	4
1987	0.50		1	2.88	1.93	3	4.75	0.95	5	10.75		2	10.33	5.80	3	16.45	6.93	5
1988	0.75		1	2.87	0.33	3	3.10	1.45	5	6.69		2	4.38	2.55	3	12.51	7.02	5
1989	2.50		1	5.96	3.18	3	8.00	2.25	5	15.32		2	15.67	10.45	3	15.65	1.33	4
1990	1.50		1	1.94		2	2.36	1.75	6	1.99		1	6.97	4.24	4	7.69	4.72	4
1991	2.75		1	6.99		1	7.93	4.29	4	13.79	2.44	3	13.08	11.25	3	22.56	11.35	4
1992	3.75		1	12.00		1	9.92	3.50	3	8.44	4.75	4	18.25		2	21.60	9.47	5
1993	4.75		1	8.25		1	11.88		2	15.90	4.40	5	15.00		1	26.63	9.84	6
1994	3.13		2	7.00		1	10.13		2	7.44	3.47	4	16.00		1	16.92	7.07	6
1995	0.38		2	4.00		1	5.13		2	6.31	2.57	4			0	13.43	8.29	7
1996	1.38	0.48	4	5.67	2.50	3	6.58	3.38	3	9.31	5.97	4	9.25		1	14.64	6.69	7
1997	2.15	1.57	5	3.50		2	5.05	2.94	5	4.25	2.61	3	14.13		2	12.75	8.01	7
2003	1.00		1	2.80	2.99	5	3.50		2	4.00		1	7.56	4.37	4	7.14	3.68	7

Table 3-1, continued. Mean annual individual growth (inches) of organ pipe cactus, grouped by number of stems, at the Baker Mine plot, Organ Pipe Cactus N. M. Numbers include mean, standard deviation, and number of plants in each stem class.

	Number of stems																	
	7			8			9			10			11 to 20			21 +		
1971			0	22.38		2	26.63		2	31.00		1			0			0
1972	7.75		1	7.75		1	12.83	1.70	3	9.75		1			0			0
1973			0	10.75		2	13.88		2	26.50		1	16.25		1			0
1974			0	24.75		2	35.13		2	21.75		1	52.00		1			0
1975	22.00		1	14.00		2	20.50		2			0	36.63		2			0
1976	18.25		1	5.00		1	18.67	2.57	3			0	28.00		2			0
1977	32.63		2			0	24.75	12.92	3	25.75		1	53.50		2			0
1978	29.50	6.54	3			0	31.04	11.65	6			0			0			0
1979	26.88		2	27.75		2	24.00		1	24.88		2	46.13		2			0
1980	30.50		1	27.42	14.74	3	25.00		1	30.38		2	50.00		2			0
1981	28.25		1	27.50		2	16.25		2	22.88		2	31.88		2			0
1982	28.75		1	25.25		1	10.75		1	26.19	16.59	4	37.00		2			0
1983	37.25		1			0	23.63		2	32.50	13.24	4	44.25		2			0
1984	41.00		1			0	28.38		2	40.83	24.45	3	47.42	10.79	3			0
1985	24.75		1			0	15.00		2	26.25	16.64	3	35.75	8.95	3			0
1986	25.50		1			0	12.25		2	22.25	19.28	3	30.17	6.95	3			0
1987	24.25		1			0	12.57		2	26.17	11.25	3	24.38	8.36	3			0
1988	21.89		1			0	8.08		2	20.52	8.76	3	23.19	11.53	3			0
1989	30.69		2			0	18.12		2	35.82	9.52	3	28.44	10.14	3			0
1990	15.31		2			0	2.69		2	12.86	6.76	3	14.00	6.41	3			0
1991	31.37		1	36.03	8.04	3	10.18		2	22.31		2	28.18	19.33	4			0
1992			0	41.00		2	18.33	11.66	3	27.50		2	36.17	20.28	5			0
1993			0			0	44.75	7.83	3	25.75	12.10	3	45.92	10.82	6			0
1994	21.25		1			0	32.00		2	20.67	16.41	3	39.82	20.88	7			0
1995	26.00		1			0	20.63		2	8.38		2	30.19	13.89	8			0
1996	30.00		1			0	24.38		2	22.00		2	33.06	18.54	8			0
1997	24.25		1			0	20.75		2	22.00		2	23.91	12.80	8			0
2003	12.25		2	14.42	4.48	3			0	14.00		1	15.81	11.93	8	32.92	16.57	3

Table 3-2. Mean annual individual growth (inches) of organ pipe cactus, grouped by number of stems, at the Bates Mountains plot, Organ Pipe Cactus N. M. Numbers include mean, standard deviation, and number of plants in each stem class.

	Number of stems																	
	1			2			3			4			5			6		
1991	3.19	1.98	6	5.06	1.55	4	11.50		2	9.37		1	18.53	4.58	4	22.06		2
1992	3.60	1.91	5	5.05	1.59	5	3.50		1	23.50		2	19.88		2	22.13		2
1993	2.75	1.79	4	4.69	1.23	4	1.25	4.75	3	20.13		2	13.00		1	23.17	5.84	3
1994	2.44	1.14	4	5.50	2.27	4	7.38		2	15.83	12.36	3	15.50		1	22.25		2
1995	1.13		2	1.46	1.22	6	3.58	1.42	3	9.25		2	9.00		1	9.33	2.52	3
1996	2.13		2	5.29	3.09	6	5.50		2	15.17	8.38	3	13.50		1	25.92	4.76	3
1997	0.42	0.29	3	4.17	2.70	3	6.50	1.46	4	8.42	5.08	3	5.25		1	11.17	4.54	3
2003			0	0.75		1	3.08	3.45	3	0.25	0.61	5	1.50	0.90	3			0

Table 3-2, continued. Mean annual individual growth (inches) of organ pipe cactus, grouped by number of stems, at the Bates Mountains plot, Organ Pipe Cactus N. M. Numbers include mean, standard deviation, and number of plants in each stem class.

	Number of stems									
	7		8		9		10		11+	
1991		0		0	46.75	1		0		0
1992	35.75	1		0	51.13	2		0		0
1993	34.75	1		0	41.63	2		0		0
1994	36.75	1	27.75	1	42.25	1		0	75.25	1
1995		0	20.25	1		0		0	28.63	2
1996		0	27.25	1		0		0	58.13	2
1997		0	21.00	1		0		0	33.50	2
2003	5.25	1	4.50	2	7.52	2	2.25	1	9.38	2

Table 3-3. Regression statistics for a) mean annual individual growth of organ pipe cactus, grouped by number of stems, at the Baker Mine plot, and b) annual number of freezings days and winter and summer precipitation near headquarters, Organ Pipe Cactus National Monument.

	Intercept	Slope	R	R^2	Adjusted R^2	N	F	Sig
a) stems								
1	-70.513	0.036	0.287	0.0823	0.0470	28	2.332	0.139
2	-1.435	0.003	0.013	0.0002	-0.0383	28	0.004	0.949
3	163.626	-0.079	0.241	0.0581	0.0218	28	1.603	0.217
4	388.251	-0.190	0.346	0.1195	0.0856	28	3.527	0.072
5	407.599	-0.198	0.317	0.1007	0.0632	26	2.687	0.114
6	126.641	-0.055	0.075	0.0056	-0.0341	27	0.142	0.710
7	159.239	-0.067	0.071	0.0050	-0.0423	23	0.106	0.748
8	-901.683	0.466	0.405	0.1643	0.0884	13	2.163	0.169
9	99.386	-0.040	0.034	0.0012	-0.0388	27	0.030	0.865
10	483.469	-0.231	0.264	0.0699	0.0294	25	1.727	0.202
11 to 20	1122.004	-0.548	0.388	0.1508	0.1139	25	4.085	0.055
b) climate								
Freezes	883.765	-0.439	0.677	0.4584	0.4420	35	27.933	8.0E-06
Winter PPT	-37.277	0.021	0.068	0.0047	-0.0255	35	0.155	0.696
Summer PPT	-31.995	0.018	0.075	0.0057	-0.0245	35	0.188	0.667