

MONITORING REPORT

Pediocactus bradyi
Marble Canyon, Coconino Co., AZ

2008



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INTRODUCTION

The Brady Pincushion cactus, *Pediocactus bradyi* L. Benson, was listed endangered on November 26, 1979 (Fed. Reg. 41(117)). On the Navajo Nation it is considered to be in danger of extinction due to habitat overuse and destruction (Navajo Endangered Species List G2). There are 7 species and their varieties of *Pediocactus* in the United States, six of which are rare endemics of the Colorado Plateau. Three other species of *Pediocactus* are federally listed endangered (*Pediocactus peeblesianus* (Croizat) L. Benson var. *peeblesianus*, *P. knowltonii* L. Benson, *P. despaniii* Welsh and Goodrich). Two species are listed threatened (*Pediocactus sileri* (Engelm.) L. Benson, *P. winkleri* Heil). These cacti are narrow endemics, each occupying distinctive habitats on the Colorado Plateau.

Pediocactus bradyi is found only on soils derived from Moenkopi shale overlain with Kaibab limestone chips within the Great Basin Desertscrub Community (Brown 1994). The habitat is restricted to the Colorado Plateau at about 1200 m elevation near Marble Canyon, Coconino County, AZ, where it is found near the east and west rims of Marble Canyon. Management responsibilities are divided between the Navajo Nation, the Bureau of Land Management, and the Glen Canyon National Recreation Area. The average annual rainfall at nearby Lee's Ferry is 6.1 inches, based on 91 years of data collection. Precipitation can fluctuate widely, the lowest recorded annual precipitation was 2.01" in 2006, the highest was 10.83" in 1957 (Western Regional Climate Center 2007). Since its discovery in 1958 there has been a marked decline in plant numbers due to collecting and other factors. It has been considered to be one of the most desired cacti in the world for ornamental purposes (Phillips et. al. 1979). However, on the Navajo Reservation, negative impacts on Brady Pincushion cactus populations have been mostly caused by off-road-vehicle traffic, livestock trampling, herbivory, and the development of roads along with traffic associated with tourism (Roth 2004).

METHODS

Seven monitoring plots were established in 1991 near Marble Canyon in northwestern Arizona to obtain information on demographic characteristics and trends of the population and to evaluate various threats and the response to possible human disturbance. The plots were monitored annually during early spring from 1991 to 1994, then again annually during April since 1997. Recorded are the number of plants in each plot, vigor or health of each plant, diameter (cm) to determine size classes, and phenology (buds, flowers, post-flowers, immature fruits, mature fruits, aborted flowers/fruits), to determine reproductive effort. All plants including new recruits are tagged, numbered and mapped. During 1994 only the number of plants was recorded because at the time of monitoring the plants were already retracting into the soil and almost all plants were past fruiting/seed dispersal. This report summarizes the results from 1991 to the present.

RESULTS

In 1991, there were 106 cacti in the 7 monitoring plots (Table 1, Figure 1). During the winter of 1993/1994 a film crew severely disturbed the monitoring site causing a dramatic drop in plant numbers, decreasing the number of plants from 114 to 97. By 2008, 51% of the original cactus population had died since 1991. Only 21 new plants were recruited within the monitoring plots during 16 years of monitoring. Since 2000 the population has been on a slow but steady decline, by 2008 only 60 cacti were located in all 7 monitoring plots.

The drought of 2001/2002 had a severe impact on the *Pediocactus bradyi* population at Marble Canyon. Seventeen cacti died between the monitoring years of 2001 and 2003 (17%). This trend continued into 2008. Seven plants were declared dead in 2008 lowering the total number of

cacti to 60 in 2008. Cactus collectors likely dug out two plants and two were previously reported missing. No new plants were newly recruited from 2007 to 2008.

The overall health of the cacti as measured by appearance or vigor stabilized following the drought of 2002 (Figure 3). Despite the high number of dead cacti in during the previous 3 years, vigor of the surviving plants in 2008 was rated excellent for 93% of all plants, compared to only 45 and 53% following the drought in 2002 and 2003. Five percent of all plants were in good condition in 2008, 2% were rated in fair condition and none were in poor condition.

The lack of reproductive effort was unprecedented in the 2002 and 2003 monitoring years, then again following the extremely dry winter of 2005/2006 (Figures 4 & 5, 6). None of the cacti were flowering or reproducing in 2002, while in 2003 and 2006 only 6 and 7 cacti were found with reproductive structures (Table 3, Figure 4). Following the record rainfall year of the winter 2004/2005, 61% of all cacti found were reproductive in the spring of 2005. Sixty-six reproductive structures were found on 40 of the 66 cacti. In 2008 65% of all plants were reproductive. Fifty-nine reproductive structures were found on 39 of the 60 cacti (Table 3, Figure 5). Notable for 2006 was the fact that all reproductive structures found on the cacti were flowers, none were in fruit. The last time any significant number of flowers was recorded for this population was in 1993, when 14 flowers were found among the cacti. In 2008, the overwhelming majority of the 59 reproductive structures were mature fruits and aborted buds. Only one flower was found and one plant with 2 buds. Monitoring plots have been consistently monitored between the 14th and 18th of April every year since 1997.

Analyses of size class distributions indicate a loss of large diameter plants from the population following the severe disturbance caused by the film crew and the combined effects of drought stress and insect damage (Table 2, Figure 2). The number of plants in diameter size classes above three centimeters decreased from 45 plants in 1993 to 33 in 1997. By 2002 only 11 plants were over 3.00 cm in diameter. This trend seemed to reverse from 2003 to 2004, when 18 plants had a diameter larger than 3.00 cm. However, by 2008 only 13 large diameter cacti were found in the monitoring plots. Since the 1998 monitoring year the majority of cacti have placed in the 2 – 2.99 cm diameter category. Prior to 1998 the majority of plants were evenly distributed between the 2 – 2.99 cm and the 3 – 3.99 cm categories. Recruitment of seedlings remains low. During the past seven monitoring years only one or two seedlings were found each year. Highest recruitment numbers were achieved in 1991 and 1993, with 5 and 8 seedlings respectively. None were found in 2008.

CONCLUSION

The combined effects of drought and an insect attack during 2001/2002 had a severe impact on this *Pediocactus bradyi* population. Combined mortality in the 2 years following the drought was 27% of the population. This type of decline had only been seen once in the sixteen monitoring years, during the massive ground disturbance of 1993/94. Recruitment also continues to be very low since the disturbance of 1993/94. Hopes for an increase in seedling numbers due to high reproductive rates in 2001 and 2005 did not materialize. Higher than average rainfall during the winters of 2000/2001 (6.44 inches) and again in 2004/2005 (6.84 inches) did not lead to increased recruitment into the population.

Several main factors impacted the cactus population at the Marble Canyon overlook from 2001 to 2003. A stunt jumper attempted to jump across a canyon within half a mile of the overlook. Increased traffic at the overlook might have contributed to trampling and driving over the cacti. Cactus borer beetles continue to negatively impact the cacti at this location, particularly when combined with drought stress. High mortality rates, low vigor and low reproductive rates were noted reservation-wide on *Pediocactus* as well as *Sclerocactus* in response to the extreme drought conditions combined with insect attacks during the winter of 2001/2002.

The amount of precipitation received during the winter months (October through March) correlates directly to the amount of reproductive effort observed annually during spring monitoring. Reproductive effort is highest following winters with more than 6 inches of total rainfall as measured ca. 7 miles to the north at Lee's Ferry. Less than 2 inches of rain (1.26 in) was received in the winter of 2001/2002, resulting in zero reproductive effort the following spring (2002).

Annual monitoring results from 3 monitoring sites for *Pediocactus bradyi* on BLM lands along the east rim of Marble Canyon reported similar findings for reproductive effort following the drought from 2002 through 2004 (Hughes, 2002, 2003, 2004). None of the monitored cacti were flowering on BLM lands in 2002, few in 2003 with an average reproductive year in 2004.

Of the nine plants not relocated in 2005, 5 were found alive in 2006, 2 were again not relocated and 2 were found dead. In 2005 locating the cacti in the monitoring plots was difficult due to the excessive amount of annual exotic plant covering the plots during the survey period. This can be attributed to the unusual amount of rainfall recorded at Lee's Ferry in February of 2005 (3.03 in). The impacts exotic species to germination and seedling establishment during high rainfall years are unclear but may be considerable.

Vigor of the remaining cacti has remained high since 2004 and was at its highest in 2008. Unfortunately 2 cacti were reported dug out in 2008, presumably by cactus collectors. During 1995 a fence was constructed by the Navajo Fish & Wildlife Department (NFWD) to prevent further degradation of the site and to allow the population to recover by preventing access by the general public. A locked, 8 foot wide metal gate was placed to allow access for the local land user and NFWD personnel. Small classes of livestock were still able to enter the preserve. During December of 1996 NFWD employees discovered that the fence posts and the fence had been lifted to allow vehicles to pass through. During the 1997 survey in April the gate had been torn out, opening the road once again to all vehicle traffic. The Navajo Fish & Wildlife Department has replaced the fence and the gate in 2001. A new sign has been erected explaining why the site is closed to vehicle traffic. In an attempt to prevent further vandalism, the gate remained unlocked. In 2001 a stunt jumper attempted to jump across a tributary to Marble Canyon. This brought increased traffic to the monitoring site and tire tracks were evident within the monitoring plots. In 2006 the NNDFW has received a "Partners for Fish & Wildlife" grant from the U.S. Fish & Wildlife Service to install a low running cable between the road and the rim of the canyon to prevent further damage to the plants within the monitoring plots. This fence was installed in the spring of 2008, preventing vehicle traffic from entering the monitoring plots.

This monitoring site is located at a remote site at the western boundary of the Navajo Nation. Because the site is relatively easy to access from a paved road, it is very prone to vandalism. The population of Brady's Pincushion cactus located at this scenic overlook is extremely vulnerable to human caused disturbance and it is questionable whether it is possible to protect it from extirpation. Fourteen years after the disturbance caused by a film crew, recovery is still eluding this population of cacti. Soils at the entire site including cactus habitat were likely severely compacted during the filming, restricting recovery and seedling recruitment well into the future. Drought related impacts resulted in further setbacks to their recovery. The combination of anthropogenic & natural disturbances continues to negatively impact this population of an already depressed species known for its low reproductive effort, recruitment and susceptibility to insect herbivory and rot (Hughes 2004, Roth 2005).

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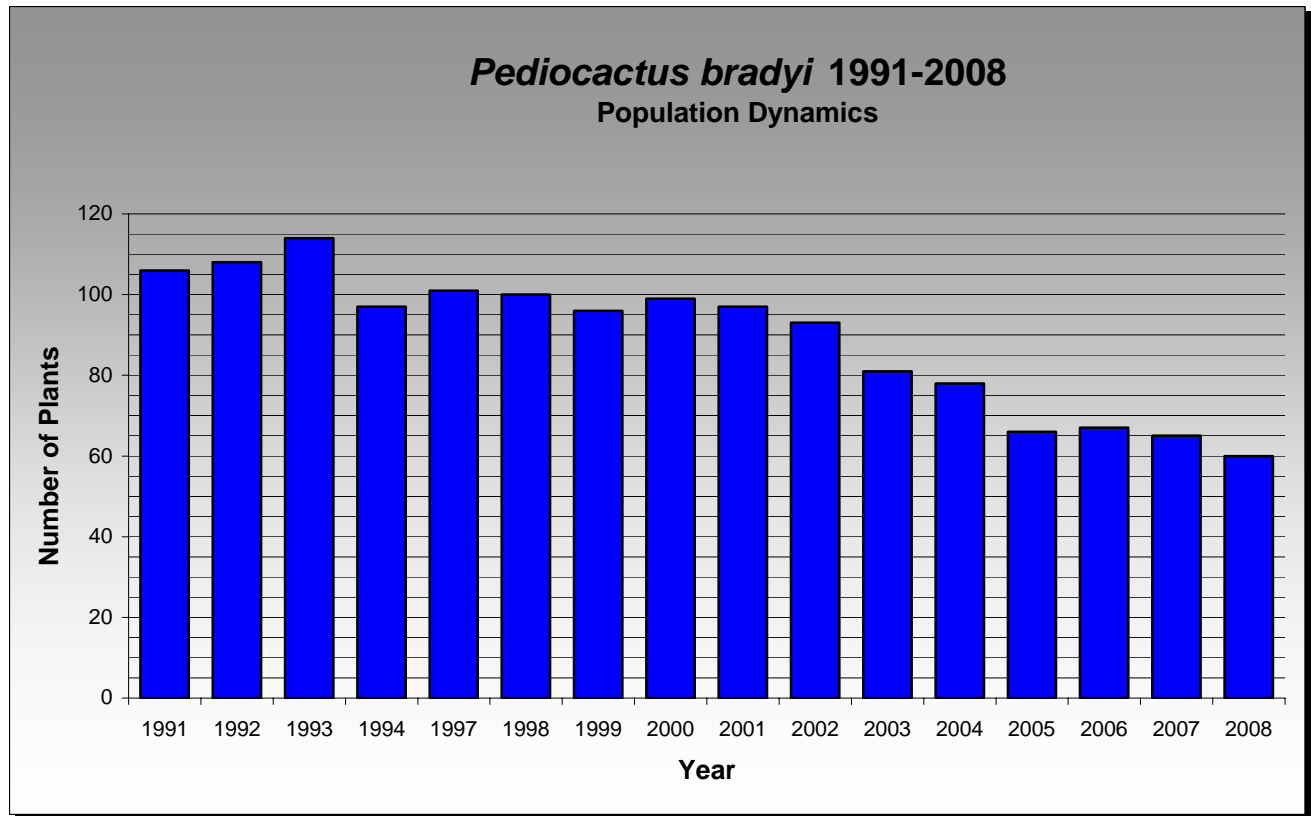


Figure 1. Number of *Pediocactus bradyi* plants in 7 monitoring plots at Marble Canyon, Coconino County, AZ, from 1991 to 2008.

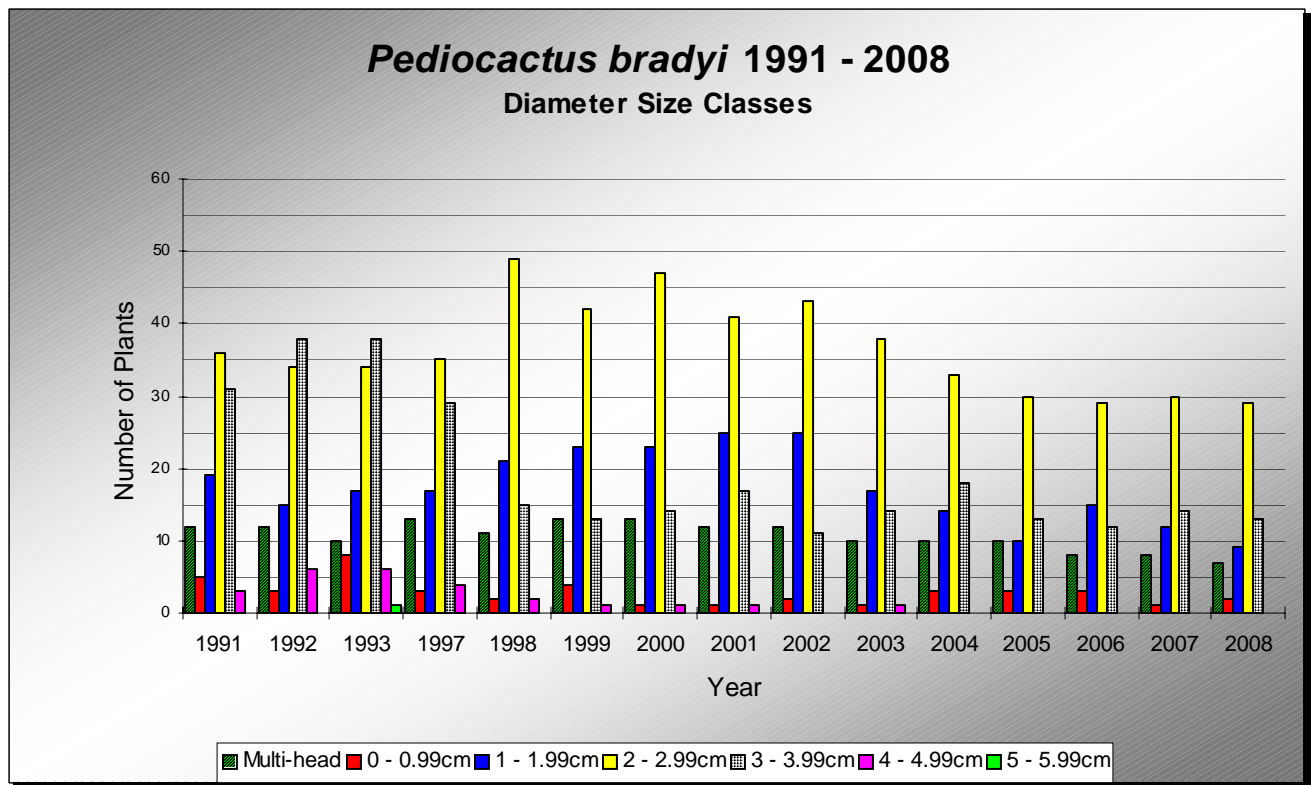


Figure 2. Diameter size class distribution for *Pediocactus bradyi* in 7 monitoring plots at Marble Canyon, Coconino County, AZ, from 1991 to 2008.

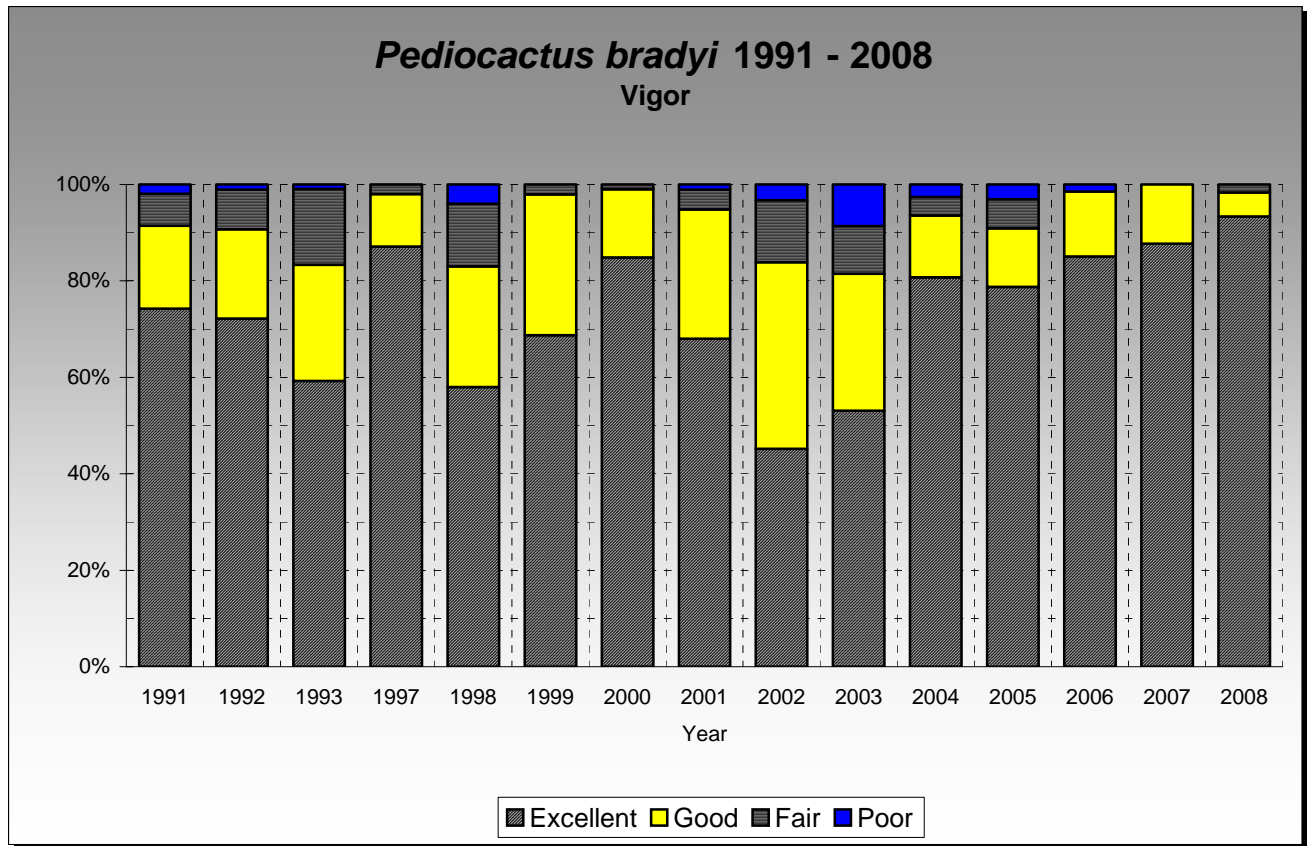


Figure 3. Vigor of *Pediocactus bradyi* plants in 7 monitoring plots at Marble Canyon, Coconino County, AZ, from 1991 to 2008.

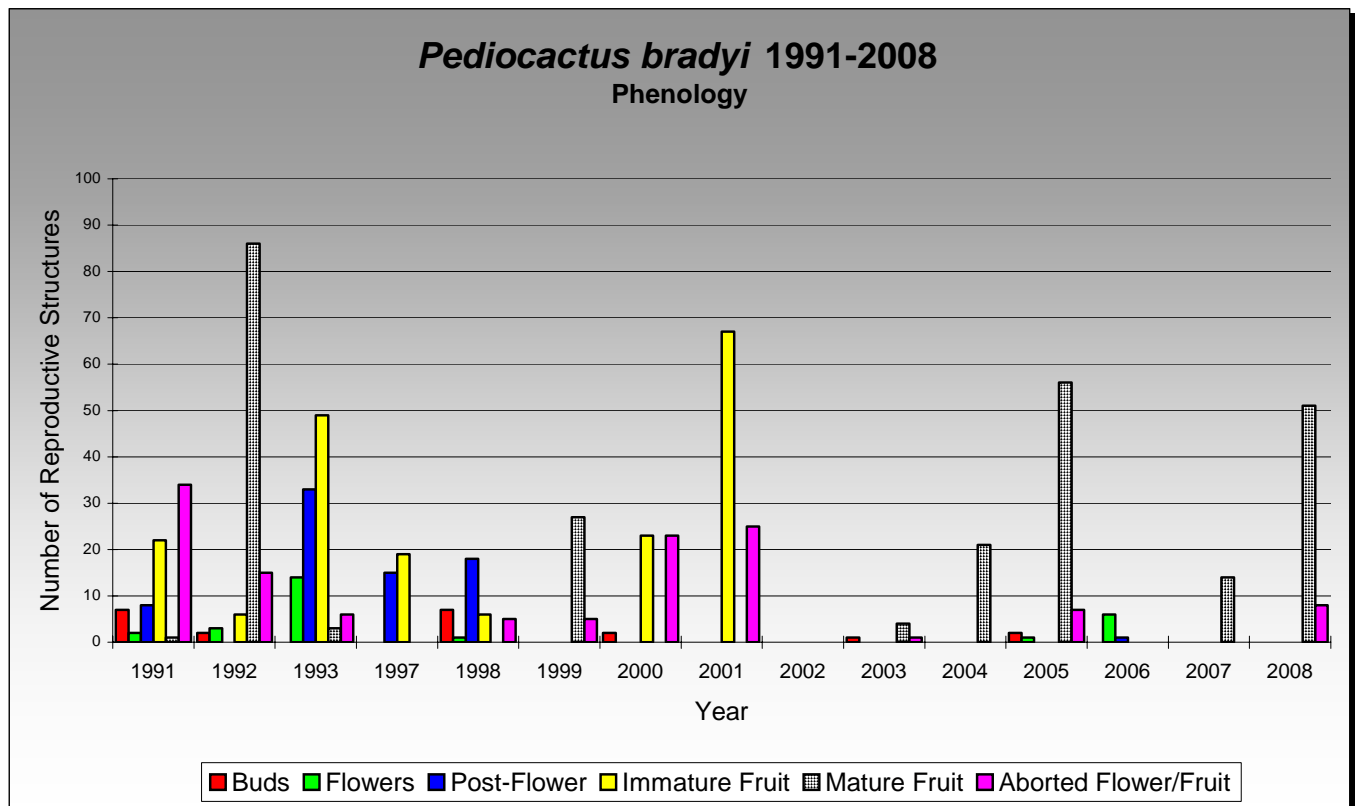


Figure 4. Phenology of *Pediocactus bradyi* plants in 7 monitoring plots at Marble Canyon Coconino County, AZ, from 1991 to 2008.

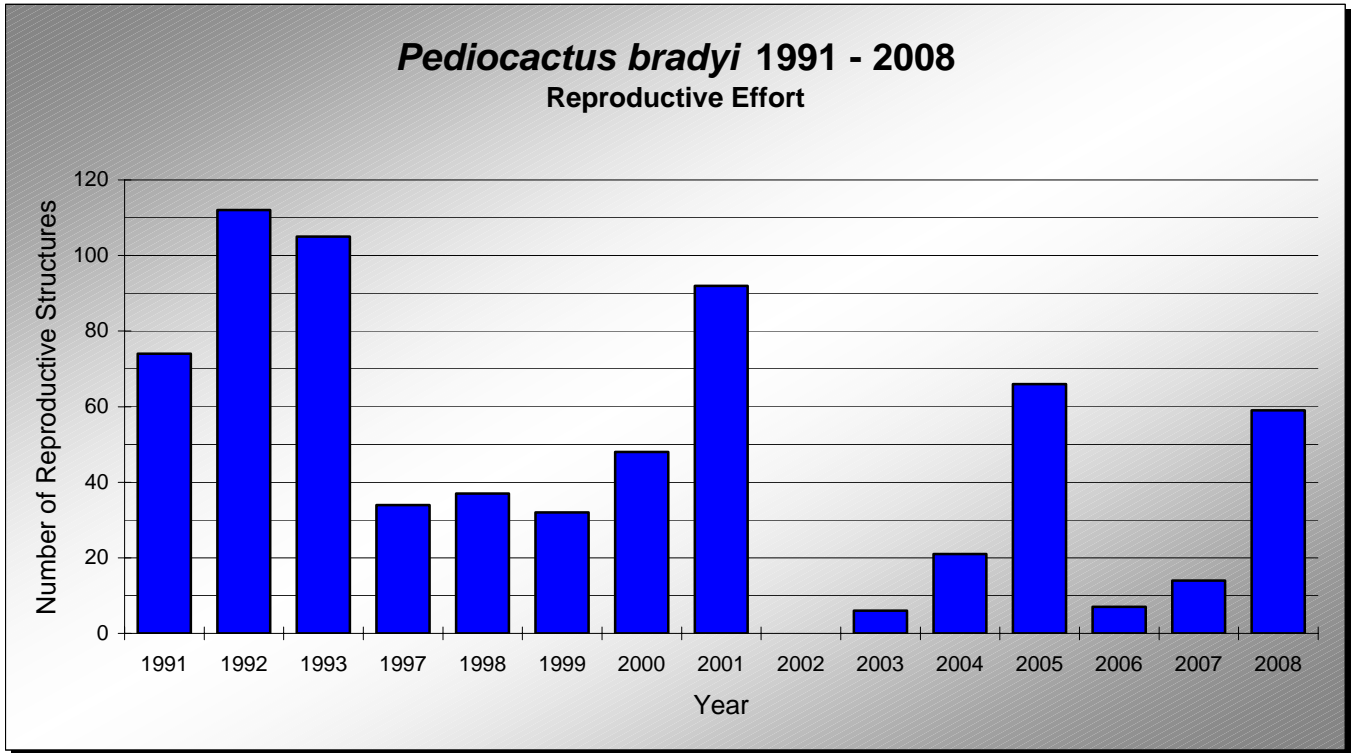


Figure 5. Reproductive effort of *Pediocactus bradyi* plants in 7 monitoring plots at Marble Canyon, Coconino County, AZ, from 1991 to 2008.

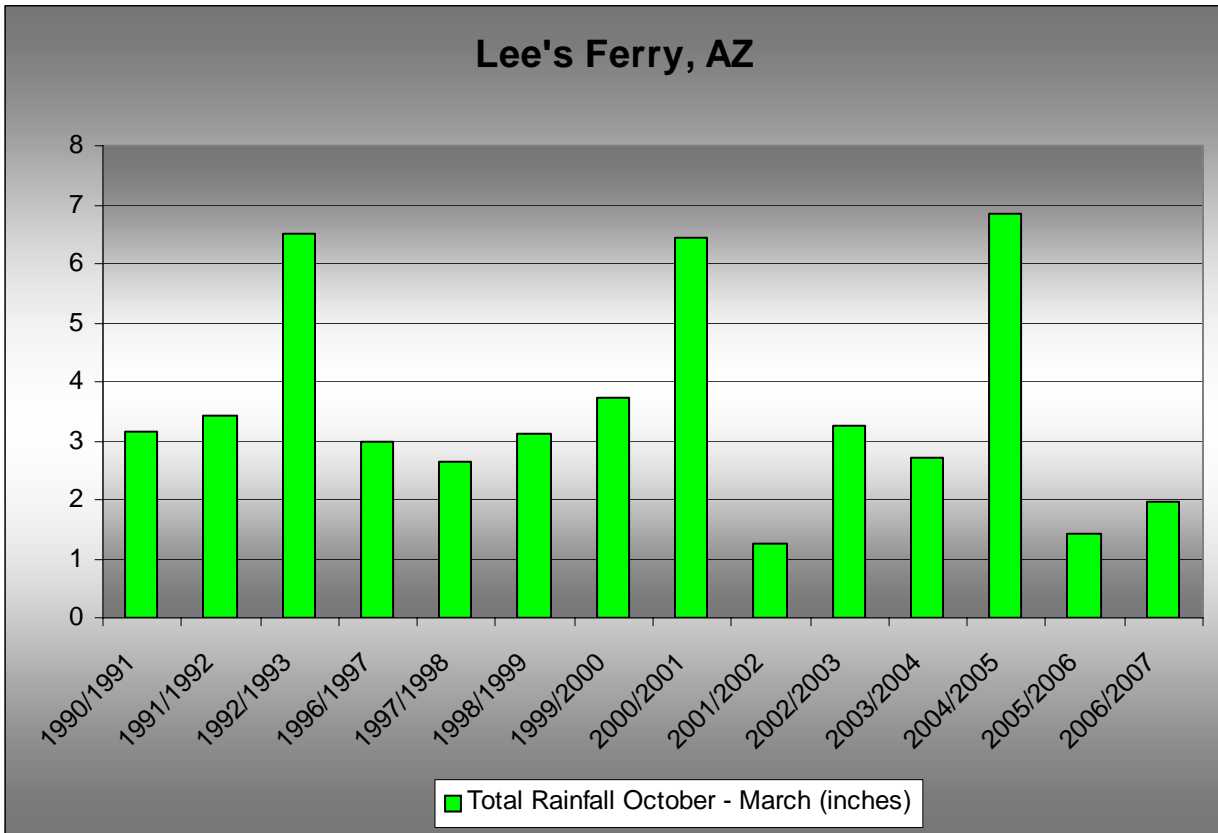


Figure 6. Total rainfall at Lee's Ferry, AZ, between October and March (Western Regional Climate Center 2008).

Plot #	1991	1992	1993	1994	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
1	12	12	13	12	12	12	12	12	12	12	9	10	8	7	6	6
2	12	13	11	11	12	13	13	13	13	12	11	12	11	10	11	11
3	19	19	20	16	16	16	15	15	14	14	12	12	12	13	13	13
4	18	19	20	20	19	19	18	20	19	19	18	16	11	10	11	10
5	15	15	17	16	21	17	17	16	17	15	14	12	12	11	7	7
6	23	23	25	19	18	20	18	18	17	17	13	12	8	12	12	10
7	7	7	8	3	3	3	3	5	5	4	4	4	4	4	5	3
Total	106	108	114	97	101	100	96	99	97	93	81	78	66	67	65	60

Table 1. Total number of *Pediocactus bradyi* plants in 7 monitoring plots at Jackass Canyon from 1991 to 2008.

Size class	1991	1992	1993	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Multi-head	12	12	10	13	11	13	13	12	12	10	10	10	8	8	7
0 - 0.99cm	5	3	8	3	2	4	1	1	2	1	3	3	3	1	2
1 - 1.99cm	19	15	17	17	21	23	23	25	25	17	14	10	15	12	9
2 - 2.99cm	36	34	34	35	49	42	47	41	43	38	33	30	29	30	29
3 - 3.99cm	31	38	38	29	15	13	14	17	11	14	18	13	12	14	13
4 - 4.99cm	3	6	6	4	2	1	1	1	0	1	0	0	0	0	0
5 - 5.99cm	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Total # of plants	106	108	114	101	100	96	99	97	93	81	78	66	67	65	60

Table 2. Size class distribution for *Pediocactus bradyi* at 7 monitoring plots at Jackass Canyon from 1991 to 2008.

Phenology	1991	1992	1993	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Bud	0	7	2	0	0	7	0	2	0	0	1	0	2	0	0
Flower	0	2	3	14	0	1	0	0	0	0	0	0	1	6	0
Post-Flower	8	0	33	15	18	0	0	0	0	0	0	0	1	0	0
Immature Fruit	22	6	49	19	6	0	23	67	0	0	0	0	0	0	0
Mature Fruit	1	86	3	0	0	27	0	0	0	4	21	56	0	14	51
Aborted Flower/Fruit	34	15	6	0	5	5	23	25	0	1	0	7	0	0	8
Total	74	112	105	34	37	32	48	92	0	6	21	66	7	14	59

Table 3. Phenology of *Pediocactus bradyi* plants in 7 monitoring plots at Jackass Canyon, from 1991 to 2008. Figures represent the number of reproductive structures, not the number of plants.