

Distribution of Paradine Plains Cactus in Pinyon-Juniper Woodland on the North Kaibab Ranger District, Kaibab National Forest

ARTHUR M. PHILLIPS, III, DEBRA J. KENNEDY,
BARBARA G. PHILLIPS, and DIEDRE WEAGE

Abstract: Surveys for Paradine plains cactus (*Pediocactus paradinei* B. W. Benson) conducted for the Kaibab National Forest, North Kaibab Ranger District in 1992-94 qualitatively showed a fairly substantial population of scattered individuals in the pinyon-juniper woodland, and indicated that there might be a correlation between plant distribution and dripline of trees. This project was initiated in 1999 to test that possibility. Field surveys in July of 2000 showed an apparent sharp decrease in numbers of cacti since 1994, probably due to conditions caused by a drought from 1998 to the summer of 2000. The plants that were located showed no statistical correlation between dripline and distribution when both tree species were considered together; however, there was a positive correlation between juniper and *Pediocactus* distribution on the dripline, and a negative correlation between pinyon and *Pediocactus* on the dripline. Mycorrhizal association may be responsible for the positive correlation of juniper and *Pediocactus*. The small sample size due to low numbers of plants makes these conclusions preliminary.

Paradine plains cactus is a small endemic plant whose entire range is on the middle and lower eastern slopes of the East Kaibab Monocline. Its rarity has long been recognized, and it was a candidate for listing by the U.S. Fish and Wildlife Service for many years. It was proposed for threatened status in the Smithsonian Petition published July 1, 1975 (U.S. Fish & Wildlife Service 1975), and was reclassified as a Category 1 Candidate in the 1980 Notice of Review (U.S. Fish and Wildlife Service 1980, Phillips et al. 1981). This classification was maintained through the 1993 Notice of Review (U.S. Fish & Wildlife Service 1993), after which it was removed from USFWS consideration. It continues to be included in the Region 3 USDA Forest Service Sensitive Plants List.

In 1995-96 an interagency team prepared a conservation assessment for the species (USDA Forest Service 1996). The document was signed by the Kaibab National Forest, the Arizona Strip District-Bureau of Land Management, and the U.S. Fish and Wildlife Service in 1998. The Conservation Strategy section of the document called for annual monitoring and expanded research activities to better understand the biology and ecology of the species. This project was designed and funded to better understand aspects of the distribution and ecology of the species. Further information on the biology, ecology, and management of the species may be found in the conservation assessment.

Surveys for Paradine plains cactus were conducted by the senior author of this report in 1992-94 along the East Side Game Road (FR 220) and elsewhere within and adjacent to its known range (Phillips 1992-94) to prepare environmental assessments for road maintenance and grazing allotment reviews. It has long been known that the plant occurs in somewhat dense, isolated colonies on small islands of suitable habitat, often in openings in sagebrush along broad, open drainages. It also occurs as isolated, widely separated individuals or small groups in upland habitats with Colorado pinyon (*Pinus edulis*) and one-seed and Utah juniper (*Juniperus monosperma* and *J. osteosperma*). The 1992-94 surveys led to the thesis that overall, more plants occurred in woodland sites than in dense colonies in open habitats. Moreover, there appeared to be a correlation between the dripline of pinyon and juniper trees and the distribution of cacti. The purpose of this project was therefore to examine and evaluate the distribution patterns of Paradine plains cactus within the woodland.

Methods

The surveys carried out in 1992-94 were not quantitative; in most cases, presence of the species and mapping were the objectives. At any given site, after presence was established the surveyors moved on to the next site. Within areas where the plants were present, two observations were made: (1) the plants were more common than previously

reported, with individuals found at perhaps every third tree on average; and (2) where plants were present they favored the dripline around the outer edge of the tree canopy.

To test this correlation, a sampling design was developed to randomly select six blocks of trees within the known range, then randomly select a starting point within a selected block, and sample 20 consecutive trees from selected points. The number of trees necessary would be determined by testing for an adequate sample in the first block.

Two belts would be surveyed around each selected tree: one belt 1 m wide with its inner edge at the dripline, and a second belt 0.7 m wide concentric with and beyond the first belt (with a small buffer zone between the belts to prevent overlap). This would provide a survey around each tree of approximately equal area on and outside the dripline. Figure 1 shows a diagram of the survey method. Surveyors were provided with meter sticks, and the dripline was defined as the point where tree-related duff ends; this is usually an abrupt change. The number of cacti found in each belt was recorded, along with the species of tree (pinyon or juniper).

Because the plants were much less common than expected during the July 2000 surveys (see below), some modifications in the sampling method were necessary. It was not possible to run a test for adequate sample size, as there were no places with enough trees with plants for an adequate sample. The method used was to stop at random places within areas where the plants had been found during the earlier surveys, and for three people to fan out looking for plants. When or if

anyone found plants, all surveyors converged at that point, and data collection commenced. Consecutive trees were sampled using the technique described above. A minimum of eight trees was included at each site, and sampling continued until cacti were no longer found. The number of trees in each sample was therefore different.

The data were analyzed using several t-tests, which (1) compared the mean values of cacti per tree on the dripline and outside the dripline, and (2) tested the correlation of cacti with each species of tree. The data from the five survey blocks were arranged in a single database, which included tree species and number of *Pediocactus paradinei* on and outside the dripline. A total of 81 trees was included in the first t-test, and the mean value of cacti per tree was calculated for each belt (Table 1). A second t-test was performed in which the survey block that contained the highest occurrence of cacti and the block that contained the lowest occurrence of cacti (0) were excluded (Table 1). The purpose of the second test was to eliminate extreme values that could reflect a skewed distribution and mean. Analysis of a 20 percent trimmed mean reduced the impact of very large and very small values on the mean, and allowed for a more reliable measure of the central value for the sample set (Ott 1993).

A third t-test was performed in which the mean value of cacti on the dripline of pinyon was compared to the mean value of cacti on the dripline of juniper, and the mean values of cacti outside the driplines of each species was compared, in order to test the correlation of cacti with tree species (Table 1). All of the trees included in the survey were grouped by species and numbered,

Table 1. Summary of distribution of *Pediocactus paradinei* with respect to driplines of pinyon and juniper together, just pinyon, and just juniper.

	On Dripline			Outside Dripline		
	N (Pepa)	Mean/tree	SD	N (Pepa)	Mean/tree	SD
T-test #1						
Compare mean values	42	.5185	1.352	40	.4938	1.628
Sample size: 81 trees						
T-test #2						
Compare 20% trimmed mean values	15	.2419	.5635	12	.1935	.5680
Sample size: 62 trees						
T-test #3						
Compare mean values by species	3	.2000	.7746	13	.7333*	1.580
Sample size: 15 pinyon						
Sample size: 15 juniper	11	.8667*	2.6421	4	.2667	.7988

*Indicates significant correlation.

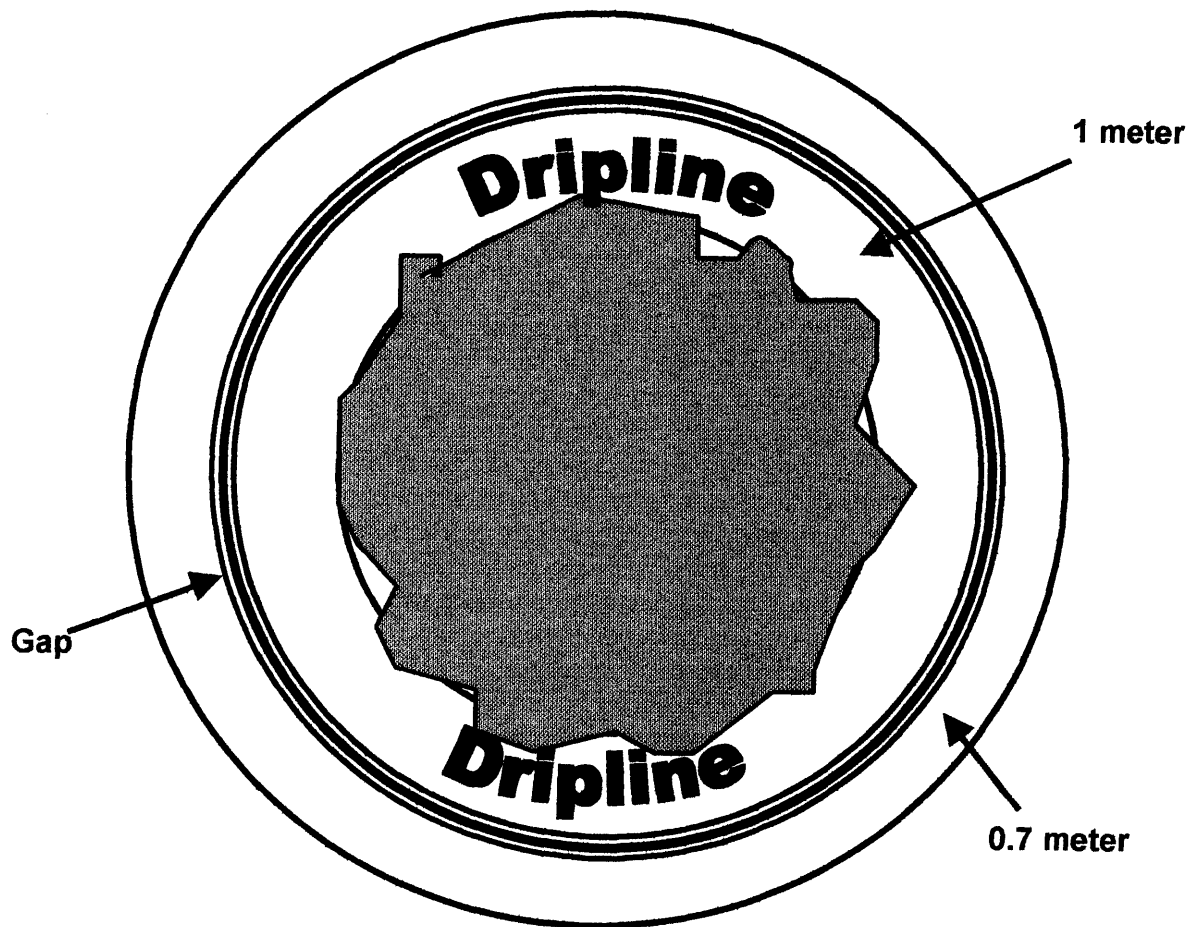


Figure 1. Diagram depicting the survey method used to search for *Pediocactus paradinei* on and outside the dripline around pinyon and juniper trees.

and using a random number generator, 15 trees of each species were selected for analysis. Equal sample sizes were chosen to approximate equal variance between each (Ott 1993).

The null hypothesis for the comparison of mean values of cacti on the dripline and cacti outside the dripline (for both the entire database and the 20% trimmed mean) was that the mean value of cacti on the dripline equals the mean value outside the dripline ($H_0: M_1 - M_2 = 0$). The null hypothesis for the comparison of mean values of cacti on the dripline of pinyon and cacti on the dripline of juniper was that the mean value of cacti on the dripline of pinyon equals the mean value on the dripline of juniper ($H_0: M_p - M_j = 0$). The same null hypothesis was used for the comparison of mean values of cacti outside the driplines of each tree species.

Results

During the first field trip in 2000 it became apparent that population levels of Paradine plains cactus were much reduced from their 1992-94 values. Although the previous surveys were neither quantitative nor comprehensive, they were sufficient to suggest consistent, if scattered, distribution in several areas of the woodland.

In early July of 2000, searches were carried out for six person-days at 12 locations along the East Side Game Road, and a total of three plants was found, each in a different area. In late July, surveys were continued for eight person-days with searches at 15 sites, four of which were positive for plants. Surveys using the method described above were completed around 8-30 trees at each site.

Statistical analysis was performed on data collected at five sites (including one that was nega-

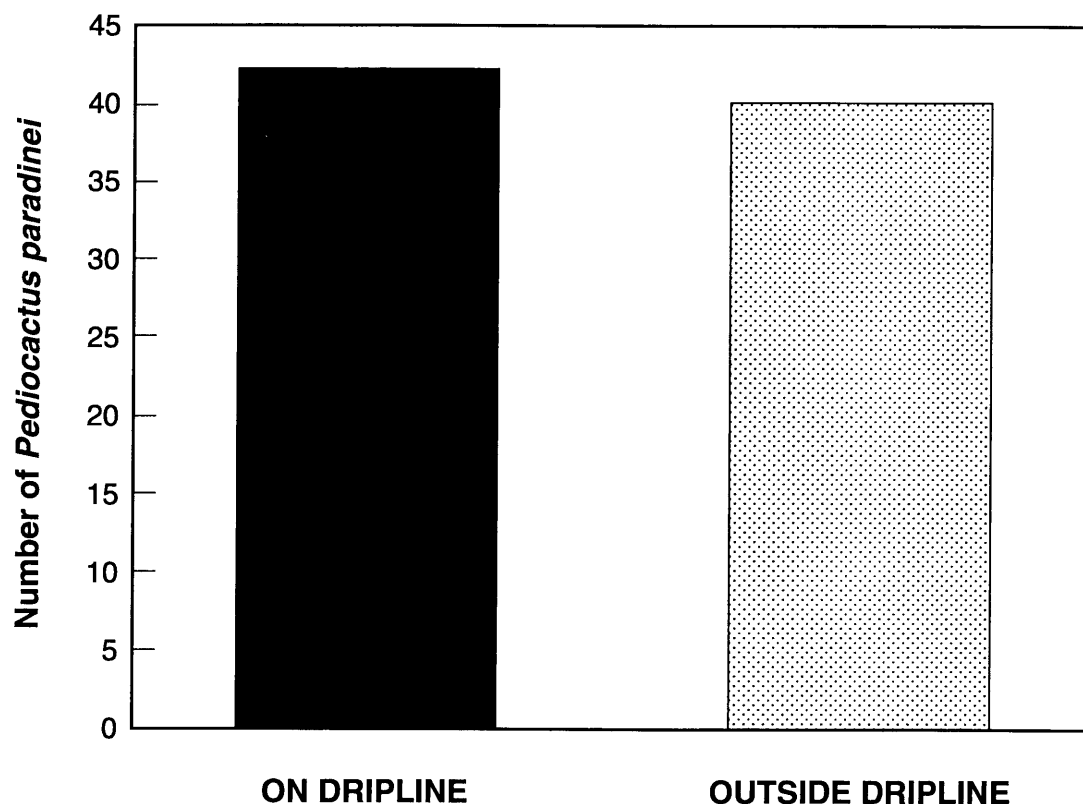


Figure 2. Number of *Pediocactus paradinei* on the dripline and outside of the dripline of pinyon and juniper trees at five sites.

tive). There were probably several reasons for the reduction in population, including severe drought for the preceding 2 years, herbivory by various rodents and rabbits due to lack of other available forage and water, and covering of plants by sheetwash during a severe storm the day before surveys commenced on the first trip. Paradine plains cactus plants retract below the surface of the ground by shrinking the size of the plant body, accordion-style, during times of protracted water stress. This makes them more difficult to locate, and after a storm resulting in sheetwash they may be covered with silt until sufficient moisture is available for the plants to swell and extend above the ground surface. The effects of these factors, and possibly other unknown factors causing a population reduction during the proceeding 6 years, are unknown. The previous surveys were conducted from late May to early September, so seasonal differences alone should not account for the reduction. The number of plants located during the first

trip was not sufficient to obtain data for analyzing the dripline theory. During the second trip data were collected using the method described.

Statistical Analysis

The results reported here must be considered preliminary because the number of trees where cacti were found was too small a sample for adequate statistical evaluation. Statistical tests were performed to determine trends, and cannot be considered definitive.

The two t-tests, which compared the mean value of cacti on the dripline and the mean value of cacti outside the dripline, showed no statistically significant difference in mean values, and the null hypothesis was therefore accepted (Figures 2 and 3). The t-test comparing the mean value of cacti on and outside the dripline of pinyon trees with the mean value of cacti on and outside the dripline of juniper trees showed a statistically significant difference in mean values of cacti both on

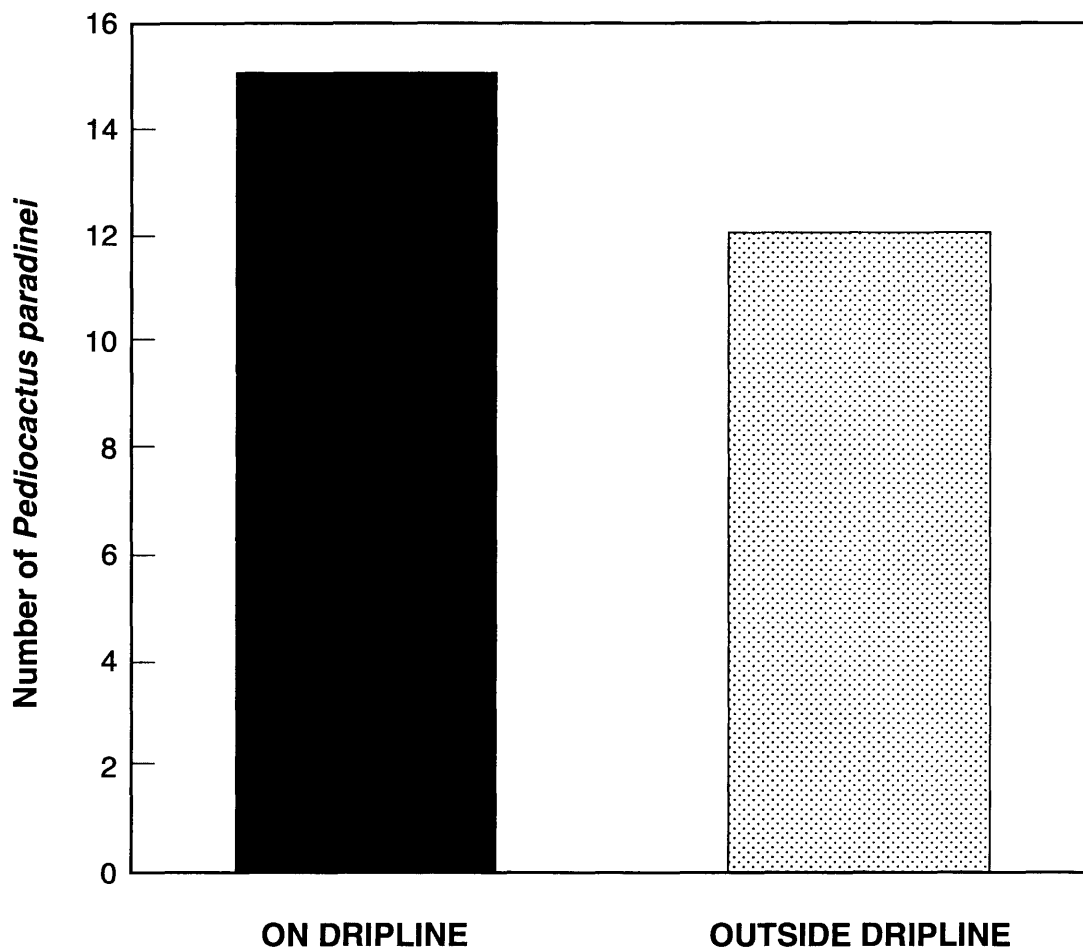


Figure 3. Number of *Pediocactus paradinei* on the dripline and outside of the dripline of pinyon and juniper trees at three sites.

and outside the dripline (Figure 4). Therefore, the null hypothesis was rejected.

The results of the statistical analysis indicate no significant association of Paradine plains cactus with the driplines around pinyon and juniper when the data are combined for associated tree species. However, when the association of pediocacti with pinyon and juniper was analyzed separately, the results indicate that the association of cacti on the dripline of juniper is significantly stronger than that of cacti on the dripline of pinyon. Additionally, the association of cacti outside the dripline of pinyon is significantly stronger than that of cacti outside the dripline of juniper.

Mycorrhizal Association

All species of *Pediocactus* except *P. sileri* are mycorrhizal; that is, their roots are colonized by vesicular-arbuscular mycorrhizae (VAM), fungi associated with the roots of certain plants that benefit the plants by enhancing nutrient absorp-

tion and water uptake (Milne 1987 and references cited by Milne). The association with mycorrhizae may enhance the ability of plants to live in harsh environments, such as the rocky, droughty soils where pediocacti are frequently found. Juniper, grasses, and pediocacti are among plants that are endomycorrhizal; pinyons are not. The indication is that pediocacti may be preferentially associated with juniper in the pinyon-juniper woodland because both cacti and junipers are endomycorrhizal.

Conclusions

1. The small number of cacti found in woodland habitats during this study is cause for concern, and is a trend that has also been noted in monitoring plots in the past 2 years. Drought is probably an overall causative factor resulting in the death of some pediocacti; cactus predation is a secondary effect caused by the stress of drought on rodents and rabbits. Because surveys were not conducted between 1994 and 2000, it is not known

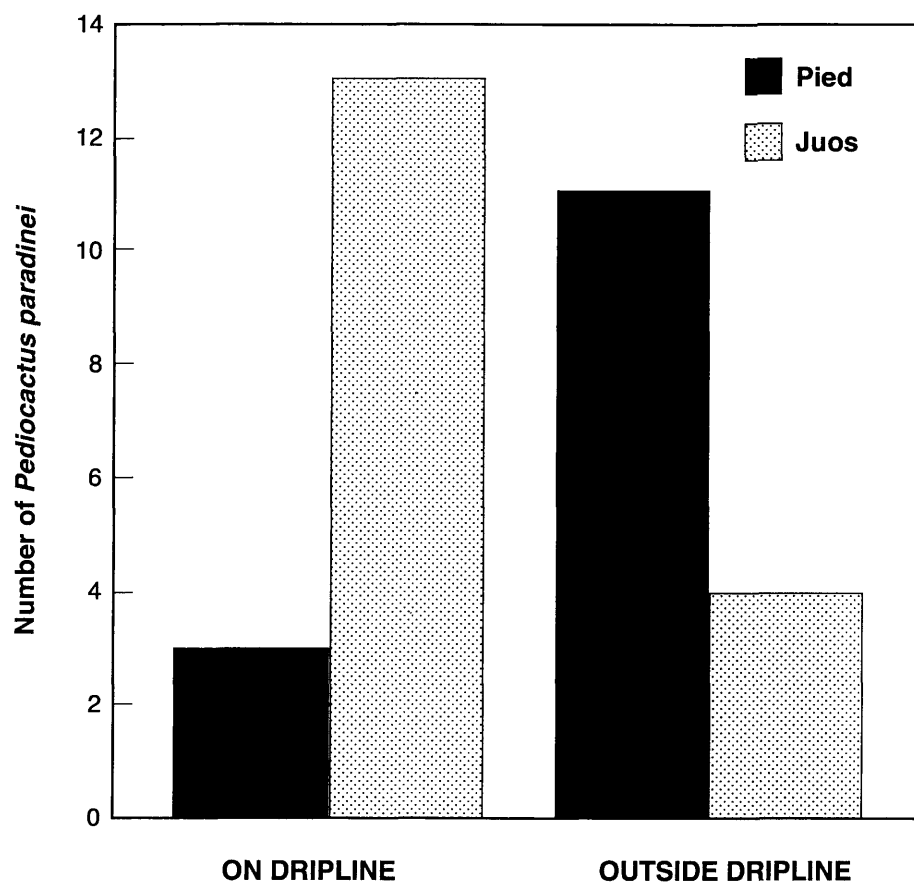


Figure 4. Number of *Pediocactus paradinei* on the dripline and outside of the dripline of a random sample of 15 pinyon and 15 juniper trees.

when the population decline may have started in the woodland.

2. Seasonal effects have had an unknown impact on the apparent rarity of the cacti. Because they tend to retract into the soil during periods of water stress, and then may be covered with soil by sheetwash during severe storms, it is possible that some plants were not visible during these surveys. This should be investigated during the next spring growing season that follows a winter with adequate precipitation.

3. Due to the small number of plants that could be located, the sample size is too small to be statistically significant, and the results reported here indicate only trends and not firm conclusions. A larger sample should be examined during a time of more favorable weather conditions to ascertain whether the population has decreased, as this survey suggests, or whether the plants were simply invisible. A larger sample is also needed to confirm the indication that there is no statistical corre-

lation of Paradine plains cactus with pinyon and juniper taken together, and that the cacti are preferentially associated with the dripline around junipers.

4. The apparent decrease in numbers of such a rare plant is cause for concern about its status. If this is confirmed, the Conservation Assessment and Strategy should be amended, and management actions should be initiated to ensure the stability of the remaining population.

Acknowledgments

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Literature Cited

- Milne, J. 1987. The ex-situ conservation of six rare species of *Pediocactus*. Report for Conservation Grant IC-50235-85 submitted to Center for Plant Conservation, Boston, and Kaibab National Forest.
- Ott, R. L. 1993. An introduction to statistical methods and data analysis. 4th ed. Duxbury Press, Belmont, CA.
- Phillips, A. M., III. 1992-94. Field survey reports on *Pediocactus paradinei*, submitted to North Kaibab Ranger District, Kaibab National Forest, Fredonia, AZ.
- Phillips, A. M., III, B. G. Phillips, and N. Brian. 1981. Status report: *Pediocactus paradinei*. Report submitted to U.S. Fish & Wildlife Service, Albuquerque, NM.
- USDA Forest Service. 1996. Paradine plains cactus conservation assessment and strategy on the North Kaibab Ranger District, Kaibab National Forest, and the Arizona Strip District, Bureau of Land Management.
- U.S. Fish & Wildlife Service. 1975. Threatened or endangered fauna or flora. Review of status of vascular plants and determination of "critical habitats." Federal Register 40(127): 27824.
- U.S. Fish & Wildlife Service. 1980. Endangered and threatened wildlife and plants: Review of plant taxa for listings as endangered or threatened species. Federal Register 45(242): 82480.
- U.S. Fish & Wildlife Service. 1993. Notice of review of plant taxa for listing as threatened or endangered species. Federal Register 58(188): 51188.