Monitoring of Special Status Plants

in the

Algodones Dunes, Imperial County, California

1977, 1998, 1999, and 2000

Bureau of Land Management
California State Office
2800 Cottage Way
Sacramento, CA 95825
June 2001

Cover photograph of Algodones Dunes sunflower
(*Helianthus niveus* ssp. *tephrodes*)
by Debbie Sebesta

Contents

Preface

The author of this report is John Willoughby, State Botanist, Bureau of Land Management (BLM), California State Office. The study design was developed by the author in collaboration with Debbie Sebesta, BLM El Centro Field Office; Jim Dice, California Department of Fish and Game; and Steve Hartman, California Native Plant Society (CNPS). Kim Nicol and Glenn Black, both of the California Department of Fish and Game, also provided input during an initial meeting in February 1998. Sandy Vissman of the U.S. Fish and Wildlife Service reviewed an early version of the study proposal. The study design used in this study is a modification of that developed and implemented by WESTEC (1977).

The monitoring was coordinated by Debbie Sebesta and Jim Dice. Steve Hartman and Allen Barnes of CNPS assisted in garnering the support of the Society, which provided both paid personnel (funded through a contract with BLM) and volunteers to perform the monitoring in the northern part of the Algodones Dunes. The following individuals actually conducted the monitoring: 1998: Debbie Sebesta, Jim Dice, Susan Hobbs, Fred Sproul, Tim Nosal, Heather Townsend, Kim Nicol, Steve Hartman, Diana Hickson, Glenn Black, Kelly Goocher, Debbie MacAller, and Gary Wallace; 1999: Debbie Sebesta, Ileene Anderson, Cindy Burrascano, Michelle Cloud-Hughes, Jim Dice, Susan Hobbs, Debbie MacAller, Tim Nosal, Jim Ricker, Todd Spear, Fred Sproul, Diane Steeck, Gary Wallace, and Terry Weiner; 2000: Debbie Sebesta, Shannon Allen, Ileene Anderson, Jim Dice, Sheila Ferguson, Dave Guiness, Larry Hendrickson, Aaron Kania, Amy Kassameyer, Paul Kriz, Chris Knauf, Christian Layow, Rebecca Loomis, Kim Marsden, Brian Murdock, Tim Nosal, Susan Potts, Mike Powers, Jim Ricker, Fred Sproul, and Terry Weiner. Several people helped by driving the dune buggy used in the survey of the southern portion of the dunes: 1998: Florencio Bravo, Neil Hamada, Jeff Hyrcko, and Bob Bower; 1999: Steve Geyman and John Unger; 2000: John Unger and Mike Trost.

Fran Evanisko of the BLM California State Office provided valuable support in applying the ArcInfo Geographic Information System (ESRI 1998) to both the planning of the study and the analysis and presentation of the data collected. Ileene Anderson of CNPS and Shane Barrow, BLM California State Office, assisted with data entry for 1999 and 2000, respectively. Anne Knox, Shane Barrow, and Allison Sanger, all of the BLM California State Office, assisted in quality control of data entry.

Executive Summary

In 1998 the Bureau of Land Management (BLM) initiated a monitoring study of six rare plants of the Algodones Dunes, Imperial County, California. Monitoring was conducted in spring and summer 1998, spring 1999, and spring 2000. The study was designed to allow comparisons of plant abundance between 1998 and subsequent years and to compare those data to data collected in 1977 as part of an earlier study contracted by BLM. This report compares monitoring data from 1977, 1998, 1999, and 2000.

The major management issue in the Algodones Dunes concerns the effects of off-highway vehicle (OHV) use on the six rare dune plants, five of which are BLM special status plants, including Peirson's milk-vetch (*Astragalus magdalenae* var. *peirsonii*), listed as threatened by the U.S. Fish and Wildlife Service and as endangered by the State of California, and Algodones Dunes sunflower (*Helianthus niveus* ssp. *tephrodes*), listed as endangered by the State. The other plant species are: Borrego milk-vetch (*Astragalus lentiginosus* var. *borreganus*); Wiggins' croton (*Croton wigginsii*); giant Spanish-needle (*Palafoxia arida* var. *gigantea*); and sand food (*Pholisma sonorae*). A large portion of the dunes north of State Highway 78 has been closed to OHV use since 1972, but the remainder of the dunes remains open to OHV recreation.[1]

A total of 34 randomly selected transects through the dunes were surveyed by teams of two or more observers. Each transect consisted of contiguous cells 0.45 miles on a side. For each cell, observers placed each of the six species into one of five abundance classes, from 0 for not present to 4 for abundant (full descriptions of the abundance classes used are given in the body of the report).

A previous report (Willoughby 2000) compared the 1998 abundance class data to the 1977 data. This report compares the responses of the six plant species, as measured by abundance class data, over all four years of measurement.

Healthy populations of all six species remain in the open area, though the above-ground expression of populations of some of these species fluctuates dramatically with precipitation. As noted in Willoughby (2000), all six species were at least as abundant and widespread in 1998 as they were in 1977. This is a monitoring program, not research, and there are limitations to using this information to assess the effects of OHV use on the six plants. These limitations are

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[1] Interim closures of parts of open areas in the northern and southern portions of the dunes were implemented on November 3, 2000, in response to a lawsuit filed by the Center for Biological Diversity, the Sierra Club, and the Public Employees for Environmental Responsibility regarding the Endangered Species Act. Because all of the monitoring reported on in this document took place prior to these interim closures, the discussion in this report regarding parts of the dunes that are "open" or "closed" refers to the situation that existed prior to the interim closures.

discussed in the body of the report. Following is a species-by-species summary of monitoring findings.

Astragalus lentiginosus var. *borreganus*, an annual species, occurs only in the southern, open area of the dunes. It was slightly more abundant in 1998 than in 1977, but this difference is not significant. The plant was not found at all in 1999 and 2000, probably the result of insufficient precipitation for germination and establishment.

The response of *Astragalus magdalenae* var. *peirsonii*, a short-lived perennial, is closely tied to precipitation. It was most abundant in 1998, the highest rainfall year, and least abundant in 2000, the lowest rainfall year. Responses of this species were similar in both the closed and open areas across all four years of monitoring.

The abundance of *Croton wigginsii*, a relatively long-lived shrub or sub-shrub, does not fluctuate much from year-to-year in response to annual rainfall. Once established, it appears to be able to maintain its population over at least two low-rainfall years. The species was significantly more abundant in 1998 than in 1977, mostly as a result of increases in the open area. This could be the result of OHV disturbance in the open area (unlike the other species, this species responds well to moderate levels of disturbance), but is probably more likely the result of differential rainfall amounts between the northern and southern dunes during periods of establishment or of other unknown factors. Except for 1977 the responses of the species in the open and closed areas were parallel.

Abundance of *Helianthus niveus* ssp. *tephrodes*, a shrubby perennial, is similar in pattern to *Croton wigginsii*, in that it appears to maintain itself after establishment through years of below-normal precipitation. Its abundance was higher in 1998 than in 1977, and it maintained the 1998 level of abundance in 1999 and 2000. The higher abundance in 1998 was entirely the result of increases in the open area. The species declined in abundance in the closed area between 1977 and 1998; like the rest of the dunes the 1998 closed area values were maintained into 1999 and 2000. The disparate response of this species in the closed and open areas may be due to differential rainfall amounts in the northern and southern dune areas or to other unknown factors. Except for 1977 the responses in the open and closed areas were parallel.

The abundance of *Palafoxia arida* var. *gigantea*, an annual species, was anomalously high in the poor rainfall year, 2000, almost entirely as a result of high numbers in the closed area. Numbers in the open area tracked precipitation patterns extremely well and, except for 2000, abundance in the closed area correlated well with rainfall. It is unclear why abundance of this species was high in the closed area in 2000. There is some indication that habitat in the northern part of the dunes is more favorable for this species than that in the southern part. Except for 2000, responses of this species in the open and closed areas parallel one another.

Abundance of *Pholisma sonorae*, a root parasite, was highest in the worst rainfall year, 2000, and second highest in the best rainfall year, 1998; values for 1999 were very close to 1998. There is very poor correlation between annual rainfall and abundance. It is unclear why 2000 was a good year for the species. The high values in 2000 were the result of high values in the closed area. There were large differences in abundance between the closed and open areas in 1998 and 2000, with the closed area abundances much higher than those in the open area. The reason for these differences are unclear, but may be related to one or more factors, including differential detection rates in the two areas resulting from the plant's cryptic nature, possible OHV impacts in the open area, and better habitat in the northern part of the dunes.

As with the study reported in Willoughby (2000), which compared abundances between 1998 and 1977, the monitoring reported on here should not be interpreted to mean that OHV use is somehow "good" or even benign for the six species studied. The design of this study allows inferences to be made only to the entire dunes and to the large areas of the dunes within the open and closed areas. Although all six species, with the possible exceptions of *Palafoxia arida* var. *gigantea* and *Pholisma sonorae*, appear to be responding similarly in both the closed and open areas, this likely results from the fact that OHV use in the open area does not encroach–at least very intensively–on much of the habitat of the plants in relatively large portions of the open area away from OHV staging areas.

The report recommends additional research into the life histories, habitat preferences, and responses to OHV impacts of the six species to supplement the monitoring program and allow better interpretation of the monitoring data collected as part of this study.

Introduction

The Algodones Dunes (also called Imperial Sand Dunes) are an extensive system of sand dunes located in southeastern Imperial County, California. As shown in Map 1, they form an approximately 40 mile long belt trending in a northwesterly direction, ranging from 3 to 6 miles wide (WESTEC 1977). The dunes are almost completely public lands managed by the Bureau of Land Management. Most of the northern portion of the dunes (north of State Highway 78 which traverses the dunes in an approximate west to east direction above the latitudinal center of the dunes) is designated wilderness and closed to off-highway vehicle (OHV) use, while the southern portion of the dunes are open to OHV use (Map 2). [2] Some portions of the south dunes, south of State Highway 78 in the northern part of the open area and near Interstate 8 in the southern portion of the open area, receive very heavy use (up to 90,000 people visit the dunes during heavy use periods such as Thanksgiving and Easter weekends).

Because of concerns over potential adverse impacts from off-highway vehicles (OHVs), the Bureau of Land Management (BLM) in 1998 initiated a program to monitor the following six plant species, five of which are BLM special status plants:

Astragalus lentiginosus var. *borreganus* (Borrego milk-vetch)
Astragalus magdalenae var. *peirsonii* (Peirson's milk-vetch)
Croton wigginsii (Wiggins' croton)
Helianthus niveus ssp. *tephrodes* (Algodones Dunes sunflower)
Palafoxia arida var. *gigantea* (giant Spanish-needle)
Pholisma sonorae (sand food)

Astragalus magdalenae var. *peirsonii* is federally listed as threatened pursuant to the Endangered Species Act and as endangered by the State of California. *Helianthus niveus* ssp. *tephrodes* is listed as endangered and Wiggins' croton as rare by the State of California. *Palafoxia arida* var. *gigantea* and *Pholisma sonorae*, while not officially listed, are treated by California BLM as special status species by virtue of the fact they are considered to be rare and endangered by the California Native Plant Society (Skinner and Pavlik 1994; CNPS in press). *Astragalus lentiginosus* var. *borreganus* is neither listed nor a BLM special status species (CNPS includes the plant on its watch list); it is included here because it was surveyed in 1977.

[2] Interim closures of parts of open areas in the northern and southern portions of the dunes were implemented on November 3, 2000, in response to a lawsuit filed by the Center for Biological Diversity, the Sierra Club, and the Public Employees for Environmental Responsibility regarding the Endangered Species Act. Because all of the monitoring reported on in this document took place prior to these interim closures, the discussion in this report regarding parts of the dunes that are "open" or "closed" refers to the situation that existed prior to the interim closures.

The consulting firm WESTEC, under contract to BLM, conducted a study of these six plant species in 1977. BLM, using a similar study design, conducted monitoring of the plant species in 1998, 1999, and 2000. This document reports on the results of this monitoring, comparing these three years to one another and to the 1977 WESTEC data. A previous report, comparing the results of the 1998 monitoring to the 1977 WESTEC data was issued in November 2000 (Willoughby 2000); that report contains more background information and detail concerning the study design.

Methods

A grid was superimposed onto a map of the Algodones Dunes. The vertical and horizontal lines of the grid run (at least approximately) true north-south and west-east, respectively (Map 3). The cells formed by this grid are approximately 0.45 miles on a side. This grid was entered into the Geographical Information System (GIS), ArcInfo (ESRI 1998).

The 1977 study was conducted as follows. In the area open to off-highway vehicles (OHVs), WESTEC personnel, using a dune buggy, visited each of these cells by running transects west to east through the middle of each cell and rated each species into one of five density classes (counting zero as a class). It is unclear exactly how many cells WESTEC actually visited in the area closed to OHVs, but apparently many if not all of the cells in the closed area were ranked from a helicopter.

For all of the species except *Pholisma sonorae*, WESTEC used the following abundance (density) classes (the following descriptions come from WESTEC 1977; the abundance class 0, for no plants, is implied):

Abundance Class	Abundance Class Description
1	Presence of one or more plants occurring in low numbers, particularly adjacent to the observer, but not conspicuous farther away.
2	Presence of a moderate number of individuals of a species. Visible at a distance of up to 1/4 mile from the observer.
3	Presence of moderately high numbers of a species, forming a conspicuous element of the landscape.
4	Presence of very high numbers of a species, occurring throughout the quadrant (cell), representing some of the most dense populations encountered during the survey.

Because of the underground attachment of the parasitic plant, *Pholisma sonorae*, a different set of density classes was used for this species (WESTEC 1977; as in the table above, the abundance class 0 is implied):

Pholisma Abundance Class	Abundance Class Description
1	One to five inflorescences observed, most being dried inflorescences.
2	Six to 20 inflorescences observed, some still with flowers.
3	Over 20 inflorescences in the stand, but localized.
4	Over 30 inflorescences in stand, many in flowering state and well distributed in depression or vegetation habitat zone.

A random sample of 34 of the 66 west-east rows used in the WESTEC study was selected by BLM for monitoring in 1998, 1999, and 2000 (see Willoughby 2000 for details of the sampling design). West-east transects were run through the center of each of these 34 rows, sampling every cell in the row. Map 5 shows the positioning of these transects. Appendix 1, Table 3, shows the number of cells visited per transect and the number of those cells that are considered to be potential habitat for at least one of the target species.

Monitoring teams were given the latitude for each transect (only one latitude value per transect was necessary since transects were run due west to east) and longitudes corresponding to the beginning and ending points of each cell along the transect. Each team used a hand-held Geographic Positioning System (GPS) unit, which they used to stay on the transect latitude and to determine the beginning and ending points for each cell. Data were recorded separately for each cell along the transect. As observers entered a cell they tallied every adult plant encountered and–if not too numerous to tally–every seedling plant encountered. For each cell, observers also gave separate abundance class rankings for adults and seedlings of each species. *Pholisma sonorae* was not ranked in the same way; rather than differentiating between adults and seedlings, observers separated counts and abundance class values for fresh and dried inflorescences of this species. The following abundance class rankings, which differed somewhat from those used by WESTEC, were used in the 1998, 1999, and 2000 monitoring studies (reasons for modifying the WESTEC ratings are given in Willoughby 2000) .

All plants except *Pholisma sonorae*:

Abundance Class	Number of Plants
0	0
1	1-10
2	11-100
3	101-1000
4	1001-10,000
5	> 10,000

Pholisma sonorae:

Abundance Class	Abundance Class Description
0	No plants of the species were seen in the cell.
1	One to five inflorescences observed.
2	Six to 20 inflorescences observed.
3	Over 20 inflorescences in the stand, but localized.
4	Over 30 inflorescences in cell, and well distributed.

The closed area was sampled by teams of at least two observers who traversed each transect on foot. The open area was sampled by means of two persons riding a dune buggy, with one person driving and the other observing the target plant species. Teams consisted of botanists from BLM, the California Department of Fish and Game, the U.S. Fish and Wildlife Service, and the California Native Plant Society, which provided both paid personnel and volunteers.

Precipitation data were collected from the Western Regional Climate Center for the following weather stations: Brawley 2 SW, El Centro 2 SSW, Gold Rock Ranch, Imperial, Yuma Citrus Station, Yuma Proving Ground, and Yuma WSP AP. The location of these stations in relation to the dunes is shown on Map 4. Gold Rock Ranch is the closest station to the dunes, situated less than 5 miles from the eastern side of the dunes about one third of the way up the dunes from their southern end. The next three closest stations are the Yuma WSO AP, which is about 10 miles southeast of the southern tip of the dunes, the Yuma Citrus Station, which is about 10 miles south-southeast of the southern tip of the dunes, and Brawley 2 SW, which is a little less than 20 miles west of the northern half of the dunes. Imperial and El Centro 2 SSW are about 25 miles and 35 miles, respectively, west of the dunes.

Precipitation data were collected for the growing seasons immediately preceding the four study periods: 1976-1977, 1997-1998, 1998-1999, and 1999-2000. Growing season was defined as the period between July and June. Although the months of May and June fall after much of the monitoring has taken place, essentially no precipitation fell during those months during the years of the study. Both Gold Rock Ranch and Yuma WSP AP stopped collecting weather data in 1996. The Yuma Citrus Station was missing data for the months Jan-May 1999; thus it was dropped from analysis for monitoring year 1999.

Two remote area weather stations (RAWS) were installed in the dunes in fall 2000, one at Cahuilla Ranger Station in the northwest part of the dunes and one at Buttercup Campground in the southern part of the dunes (Map 6). These began collecting weather data on November 16, 2000, so data from these stations are not available for the growing seasons preceding the monitoring reported on here.

Results and Analysis

The following tables show the dates the transects were surveyed in 1998, 1999, and 2000.

Transect monitoring dates in 1998:

Transect	Date	Transect	Date	Transect	Date	Transect	Date
1	17 April	10	15 April	19	28 June	28	13 Aug
2	17 April	11	10 April	20	29 June	29	11 Aug
3	17 April	12	9 April	21	29 Aug	30	1 Aug
4	16 April	13	9 April	22	29 Aug	31	1 Aug
5	16 April	14	9 April	23	28 Aug	32	29 July
6	15 April	15	21 April	24	28 Aug	33	28 July
7	15 April	16	21 April	25	15 Aug	34	28 July
8	15 April	17	21 April	26	15 Aug		
9	15 April	18	28 April	27	13 Aug		

Transect monitoring dates in 1999:

Transect	Date	Transect	Date	Transect	Date	Transect	Date
1	16 April	10	31 Mar	19	14 April	28	28 April
2	29 Mar	11	31 Mar	20	14 April	29	28 April
3	7 April	12	30 Mar	21	15 April	30	6 May
4	6 April	13	30 Mar	22	15 April	31	6 May
5	2 April	14	30 Mar	23	16 April	32	7 May
6	1 April	15	8 April	24	16 April	33	7 May
7	1 April	16	8 April	25	26 April	34	7 May
8	1 April	17	13 April	26	27 April		
9	31 Mar	18	13 April	27	27 April		

Transect monitoring dates in 2000:

Transect	Date	Transect	Date	Transect	Date	Transect	Date
1	7 April	10	4 April	19	10 April	28	14 April
2	7 April	11	4 April	20	10 April	29	14 April
3	6 April	12	5 April	21	11 April	30	19 April
4	5 April	13	5 April	22	11 April	31	19 April
5	3 April	14	6 April	23	12 April	32	19 April
6	3 April	15	4 April	24	12 April	33	20 April
7	3 April	16	4 April	25	20 April	34	20 April
8	4 April	17	5 April	26	13 April		
9	4 April	18	5 April	27	13 April		

Bar Graphs of Mean Transect Abundance Class Totals

Figures 1-17 are bar graphs showing mean transect abundance class totals for each of the 6 species. Except for *Astragalus lentiginosus* var. *borreganus*, which was not found in any year in the closed area, there are 3 bar graphs for each species, showing mean abundance class total values for the entire dunes, the closed area, and the open area, respectively.

The graphs were generated using the program SYSTAT (SPSS 2000). Each graph compares mean total abundance class values for all cells along the transects. Abundance class values for each of the cells along a transect were added together and this total value used to characterize the transect. The mean of all the transect totals for the area compared (entire dunes, closed area, and open area) was then computed, along with a 95% confidence interval, shown as an error bar on the graphs. [3]

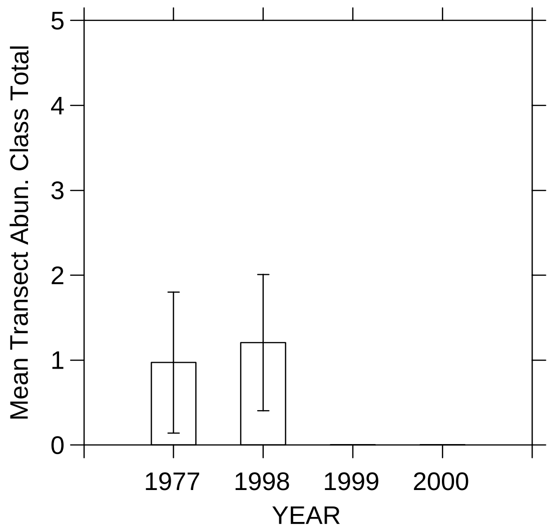

Figure 1. *Astragalus lentiginosus* var. *borreganus* mean transect abundance class total values for entire dunes. Error bars are 95% confidence intervals.

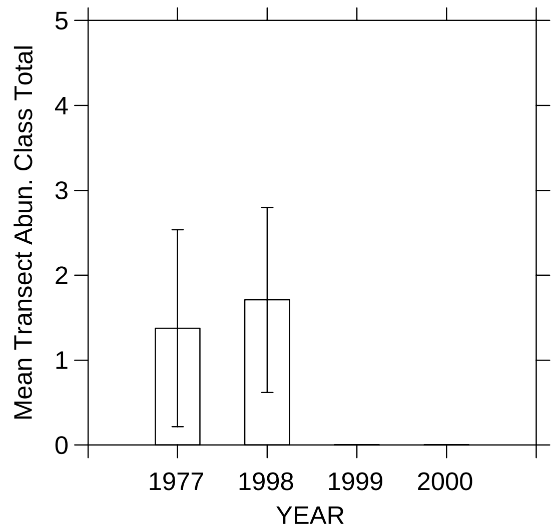

Figure 2. *Astragalus lentiginosus* var. *borreganus* mean transect abundance class total values for open area. Error bars are 95% confidence intervals.

[3] Willoughby (2000) used transect abundance class means rather than totals in comparing 1998 and 1977 data. The former approach involved adding abundance class values for each cell along a transect and dividing by the total number of cells for that transect to compute a mean abundance class value for the transect. That approach was not used here for two reasons. One is that the area for each transect is unequal (i.e., the number of cells along each transect varies) and, because of this, standardizing individual transect values by dividing transect abundance class totals by the number of transect cells leads to a biased estimator (Stehman and Salzer 2000; the amount of bias introduced in this particular case is rather small). The second, more important reason, is that one of the goals here (as opposed to those of Willoughby 2000) is to compare transect values for the open and closed areas across years. Because transects varied in the area of potential habitat covered, the use of transect abundance class totals removes this source of variation from analysis. Say, for example, a transect has 3 cells occupied by species X, with abundance class values of 1, 2, and 3. The transect abundance class total is therefore 1+2+3=6, a total that does not depend on the number of cells in the transect. In contrast, the abundance class mean for this transect would be 6/8= 0.75, 6/10=0.60, or 6/15=0.40 if the number of cells along the transect were 8, 10, or 15, respectively.

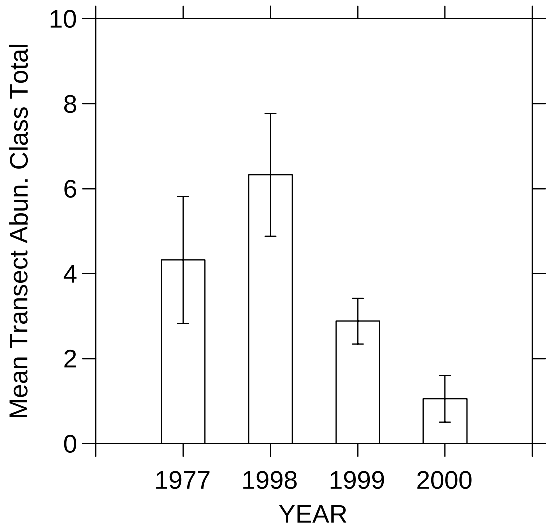

Figure 3. *Astragalus magdalenae* var. *peirsonii* mean transect abundance class total values for entire dunes. Error bars are 95% confidence intervals.

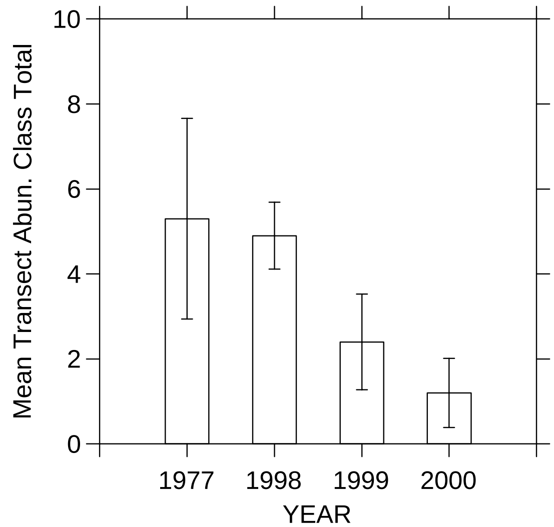

Figure 4. *Astragalus magdalenae* var. *peirsonii* mean transect abundance class total values for closed area. Error bars are 95% confidence intervals.

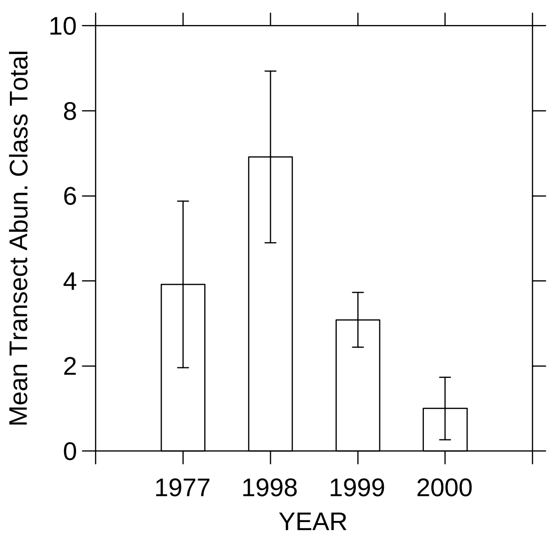

Figure 5. *Astragalus magdalenae* var. *peirsonii* mean transect abundance class total values for open area. Error bars are 95% confidence intervals.

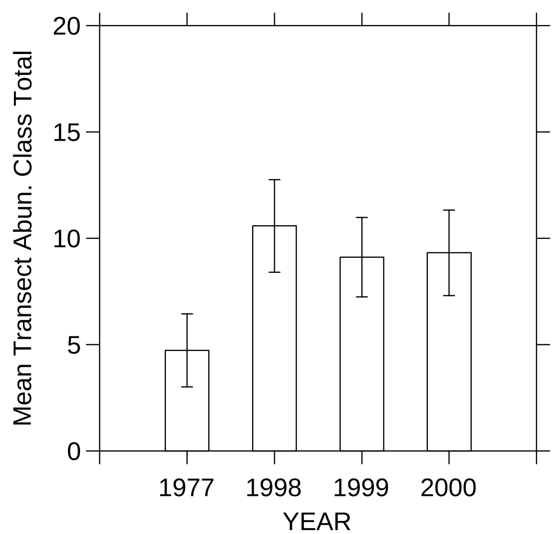

Figure 6. *Croton wigginsii* mean transect abundance class total values for entire dunes. Error bars are 95% confidence intervals.

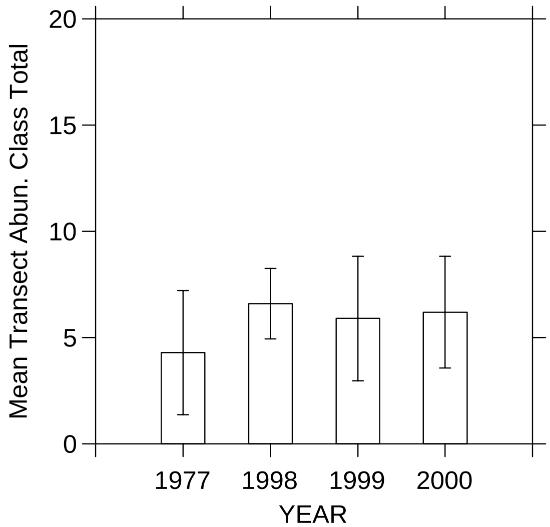

Figure 7. *Croton wigginsii* mean transect abundance class total values for closed area. Error bars are 95% confidence intervals.

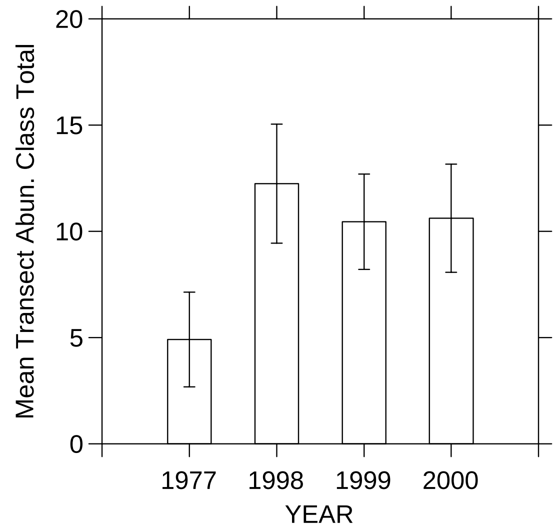

Figure 8. *Croton wigginsii* mean transect abundance class total values for open area. Error bars are 95% confidence intervals.

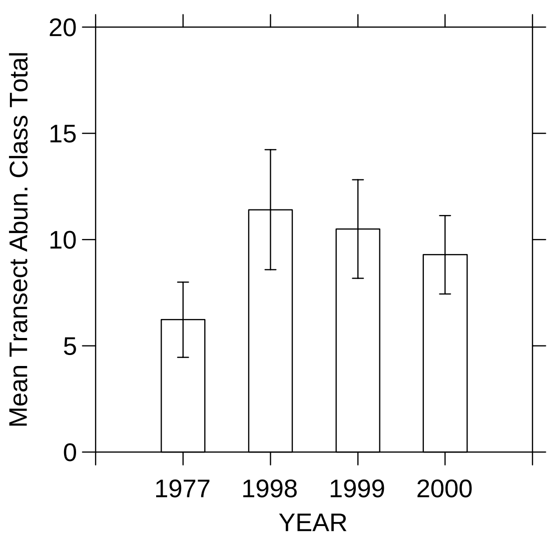

Figure 9. *Helianthus niveus* ssp. *tephrodes* mean transect abundance class total values for entire dunes. Error bars are 95% confidence intervals.

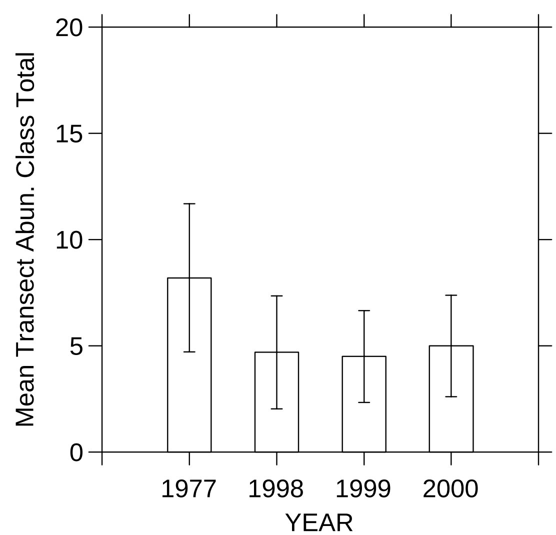

Figure 10. *Helianthus niveus* ssp. *tephrodes* mean transect abundance class total values for closed area. Error bars are 95% confidence intervals.

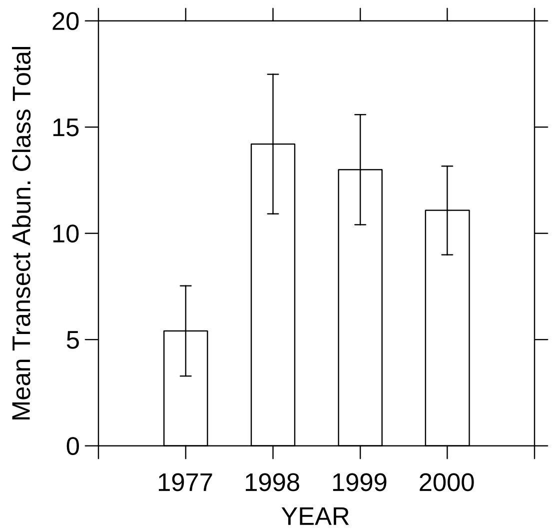

Figure 11. *Helianthus niveus* ssp. *tephrodes* mean transect abundance class total values for open area. Error bars are 95% confidence intervals.

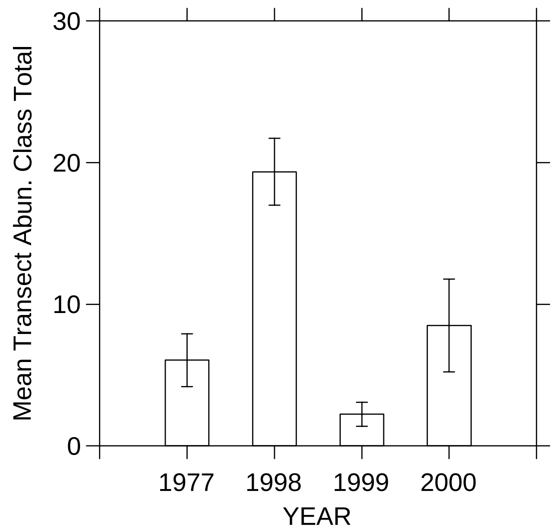

Figure 12. *Palafoxia arida* var. *gigantea* mean transect abundance class total values for entire dunes. Error bars are 95% confidence intervals.

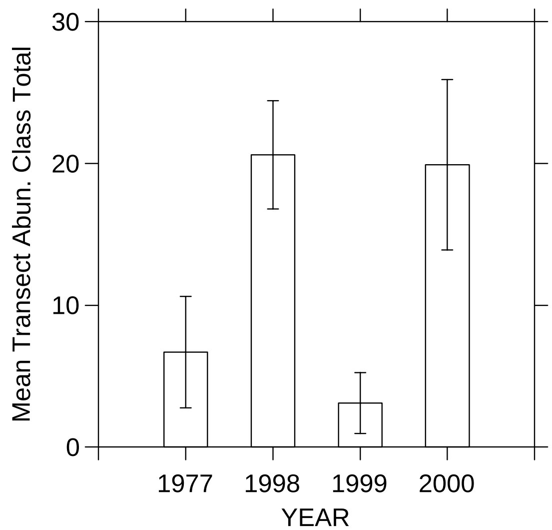

Figure 13. *Palafoxia arida* var. *gigantea* mean transect abundance class total values for closed area. Error bars are 95% confidence intervals.

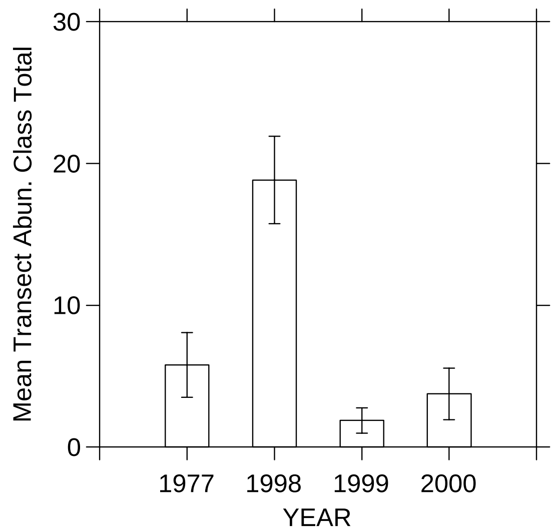

Figure 14. *Palafoxia arida* var. *gigantea* mean transect abundance class total values for open area. Error bars are 95% confidence intervals.

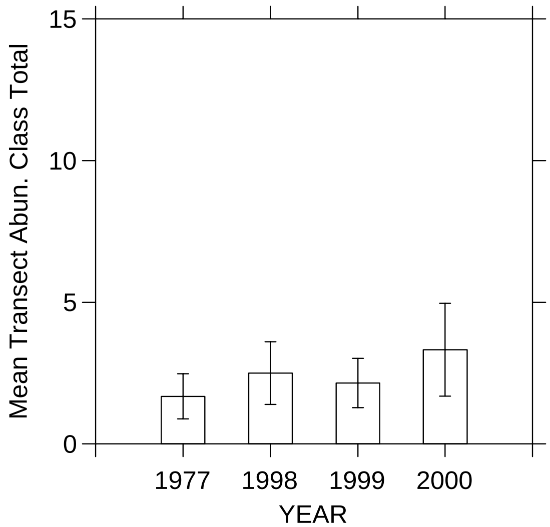

Figure 15. *Pholisma sonorae* mean transect abundance class total values for entire dunes. Error bars are 95% confidence intervals.

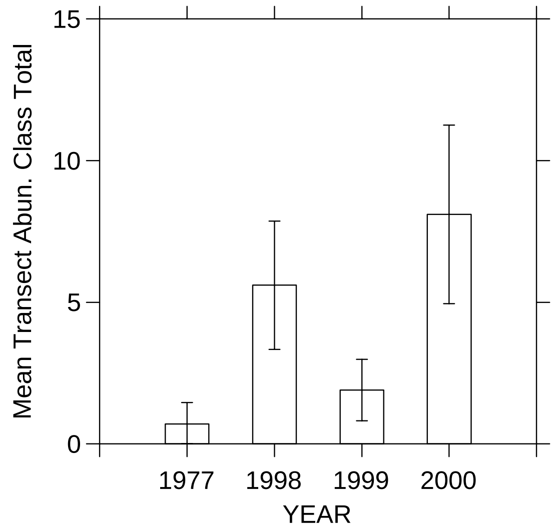

Figure 16. *Pholisma sonorae* mean transect abundance class total values for closed area. Error bars are 95% confidence intervals.

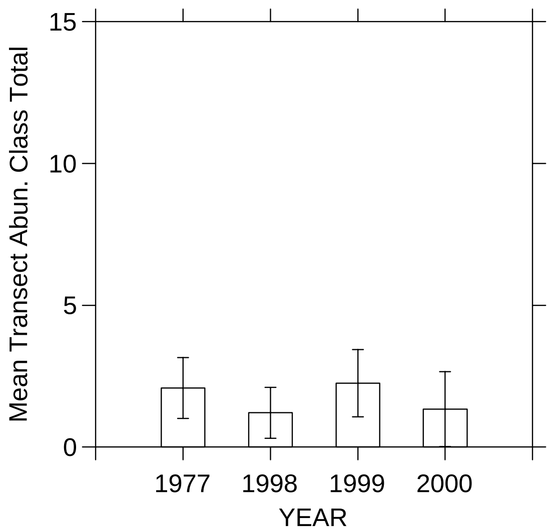

Figure 17. *Pholisma sonorae* mean transect abundance class total values for open area. Error bars are 95% confidence intervals.

Trends in Closed versus Open Areas

Figures 18-22 show the trends by OHV area (closed or open) in mean transect abundance class totals over the four years monitored (1977, 1998, 1999, and 2000) for *Astragalus magdalenae* var. *peirsonii*, *Croton wigginsii*, *Helianthus niveus* ssp. *tephrodes*, *Palafoxia arida* var. *gigantea*, and *Pholisma sonorae*, respectively (no graph is presented for *Astragalus lentiginosus* var. *borreganus* because that species does not occur in the closed area).

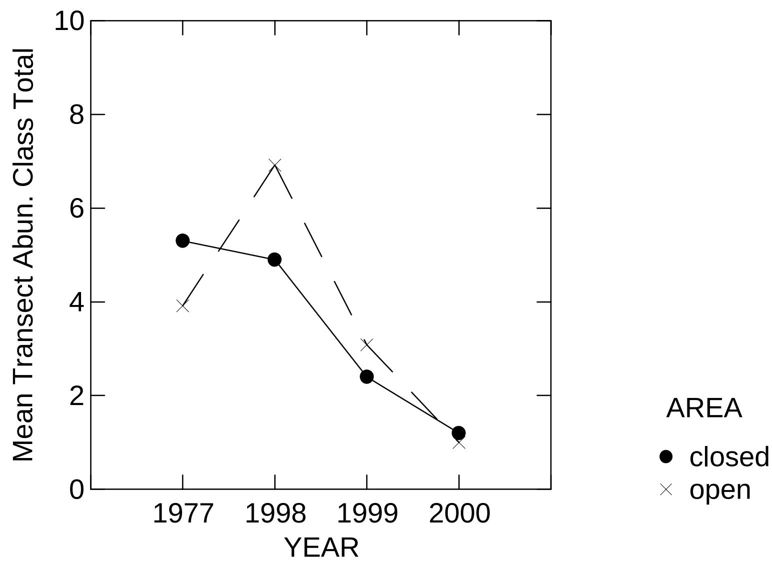

Figure 18. Comparison of *Astragalus magdalenae* var. *peirsonii* mean transect abundance class totals for closed and open areas in 1977, 1998, 1999, and 2000.

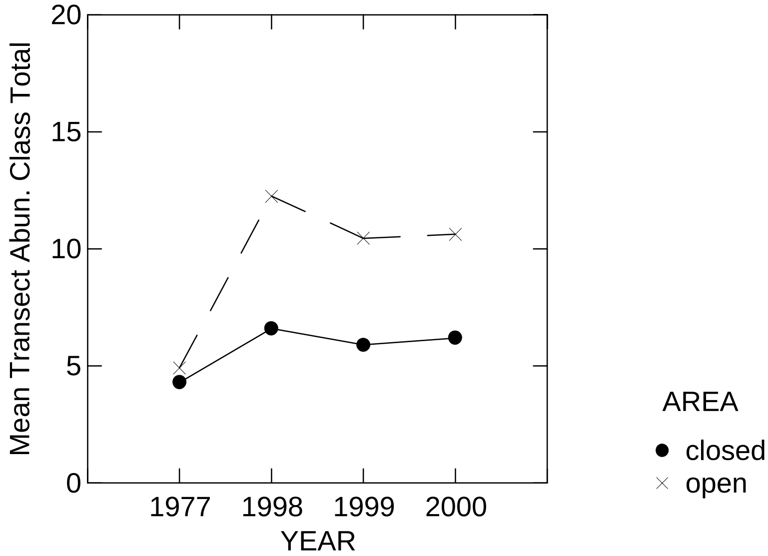

Figure 19. Comparison of *Croton wigginsii* mean transect abundance class totals for closed and open areas in 1977, 1998, 1999, and 2000.

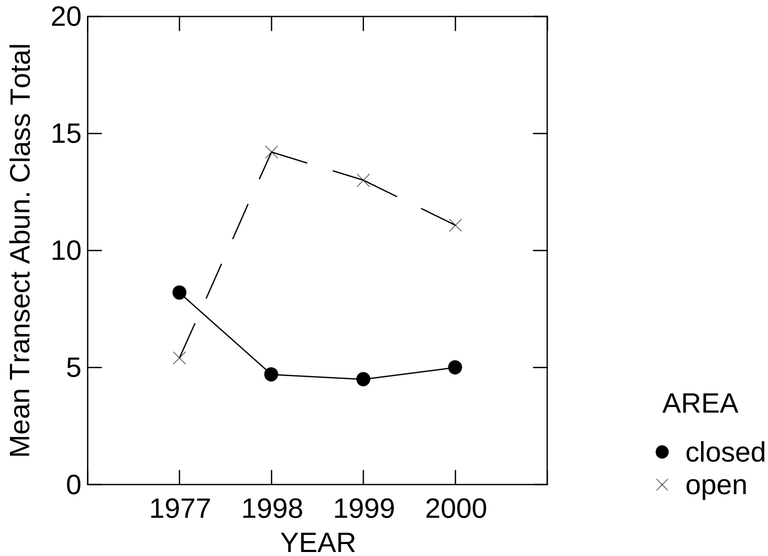

Figure 20. Comparison of *Helianthus niveus* ssp. *tephrodes* mean transect abundance class totals for closed and open areas in 1977, 1998, 1999, and 2000.

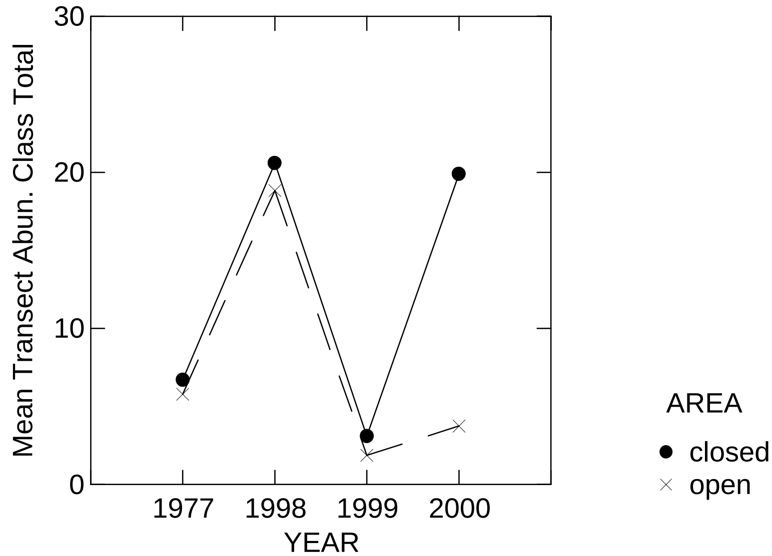

Figure 21. Comparison of *Palafoxia arida* var. *gigantea* mean transect abundance class totals for closed and open areas in 1977, 1998, 1999, and 2000.

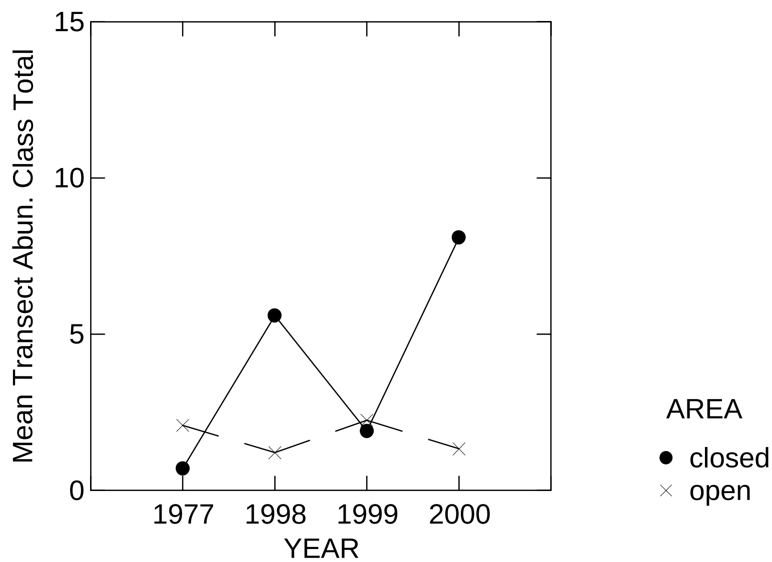

Figure 22. Comparison of *Pholisma sonorae* mean transect abundance class totals for closed and open areas in 1977, 1998, 1999, and 2000.

If OHV use has affected the abundance of these five plant species in the large areas of the dunes that were the target of this study, the trend lines formed by connecting the four years' abundance class values would not be parallel to one another (although there may be factors other than OHV use responsible for a lack of parallel response–see the Discussion section). The null hypothesis that the lines are parallel can be tested by looking for a significant interaction effect between area (closed versus open) and year in a multivariate repeated-measures analysis of variance (von Ende 1993), also called a profile analysis of repeated measures (Tabachnick and Fidell 2001), where year is the within-subjects factor and OHV area (closed or open) is the between-subjects factor. A significant area x year interaction is evidence against the parallelism hypothesis. [4]

The multivariate repeated-measures analysis of variance also tests whether plant abundance class totals change significantly between years. A significant result means that one or more of the years is different from the others.

The results of the area x year interactions are summarized in Table 1 for all species except *Astragalus lentiginosus* var. *borreganus*. Pillai's trace test statistic was used to determine significance; this statistic is recommended by Scheiner (1993) over other common multivariate test statistics (although for these data, another commonly used test statistic, Wilks' Lambda, yields the same *P* values). A Pillai's trace test statistic resulting in a *P* value smaller than 0.05 is considered here as evidence for a significant area x year interaction. Table 1 also shows the results of testing for a significant effect of year on the abundance class totals.

Table 1. Results of multivariate repeated-measures analysis of variance on transect abundance class totals for 1977, 1998, 1999, and 2000. Abbreviations are: ASMAP = *Astragalus magdalenae* var. *peirsonii*; CRWI2 = *Croton wigginsii*; HENIT = *Helianthus niveus* ssp. *tephrodes*; PAARG = *Palafoxia arida* var. *gigantea*; PHSO = *Pholisma sonorae*; df = degrees of freedom. Single, double, and triple asterisks correspond to significance at $P < 0.05$, $P < 0.01$, and $P < 0.001$, respectively.

Species	Hypothesis df	Error df	Test of Year	Test of Year x Area
ASMAP	3	30	$P = 0.000$ ***	$P = 0.190$
CRWI2	3	30	$P = 0.000$ ***	$P = 0.028$ *
HENIT	3	30	$P = 0.326$	$P = 0.000$ ***
PAARG	3	30	$P = 0.000$ ***	$P = 0.000$ ***
PHSO	3	30	$P = 0.003$ **	$P = 0.000$ ***

[4] Note that testing the parallelism hypothesis is different from testing to see if the mean transect abundance class totals for the two areas are equal. Because the two areas differ in the nature of their habitat–higher dunes in the southern, open area than in the northern, closed area–there is no reason to think that abundance class values would ever have been equal, independent of the effects of OHV use or anything else.

Growing Season Precipitation

Figures 18 through 25 show total growing season precipitation preceding each of the four monitoring periods for the seven weather stations in the vicinity of the dunes and for the average of all weather stations. Table 2 shows the percent of the long-term mean growing season precipitation for each growing season, each station, and the average of all stations. The two RAWS stations installed in the dunes in fall 2000 (Map 6) began recording data on November 16, 2000. Between that date and March 16, 2001, 1.40 inches of precipitation were recorded at Cahuilla in the northwest part of the dunes and 2.67 inches were recorded at Buttercup in the southern part of the dunes.

Table 2. Percent of long-term mean precipitation by growing season for 7 weather stations in the vicinity of the Algodones Dunes.

Weather Station	Percent of Long-Term Mean Precipitation by Growing Season			
	1976-1977	1997-1998	1998-1999	1999-2000
Brawley 2 SW	200%	156%	13%	17%
El Centro	125%	184%	33%	39%
Gold Rock Ranch	132%	No data	No data	No data
Imperial	153%	192%	79%	58%
Yuma WSO Airport	65%	No data	No data	No data
Yuma Citrus Station	74%	262%	No data	35%*
Yuma Proving Ground	101%	201%	72%	34%
Average	121%	199%	49%	37%

* Missing 5 days data in March

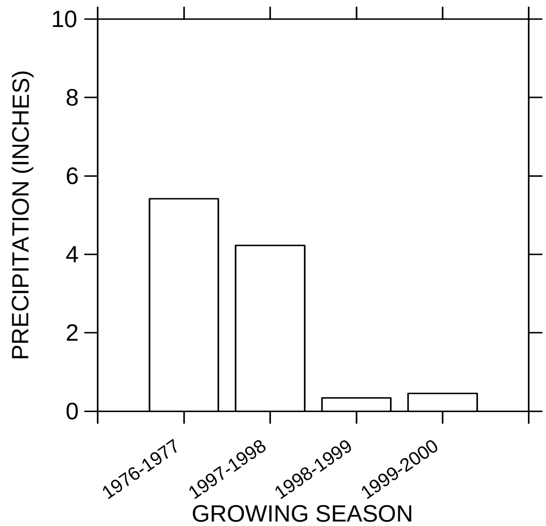

Figure 18. Total growing season (July-June) precipitation at Brawley 2 SW.

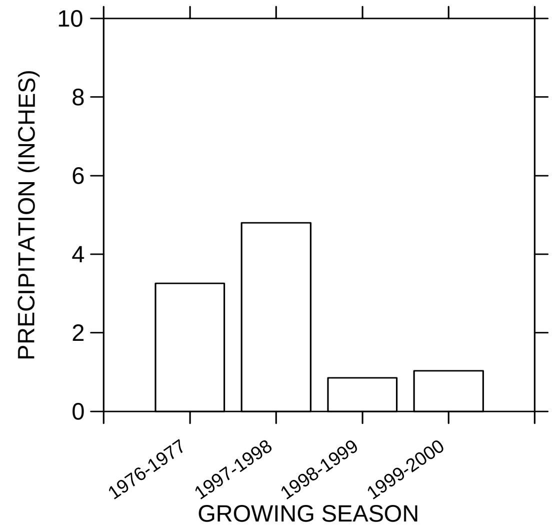

Figure 19. Total growing season (July-June) precipitation at El Centro.

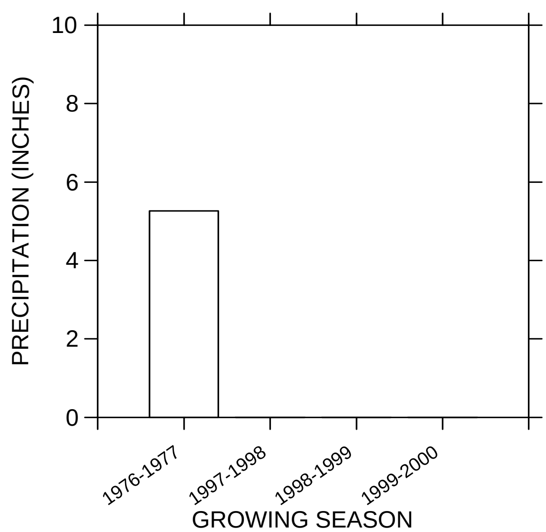

Figure 20. Total growing season (July-June) precipitation at Gold Rock Ranch (data available for 1976-1977 only).

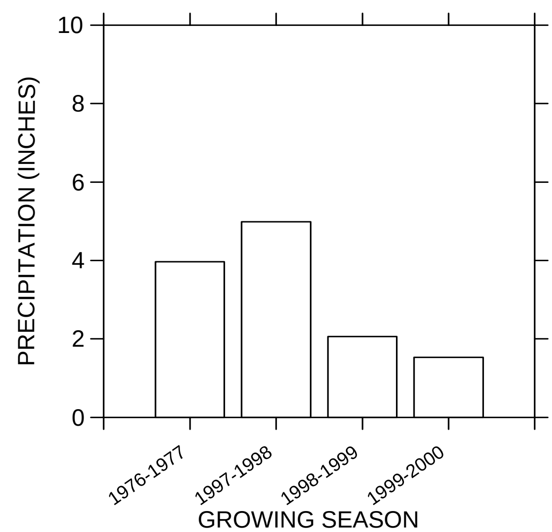

Figure 21. Total growing season (July-June) precipitation at Imperial.

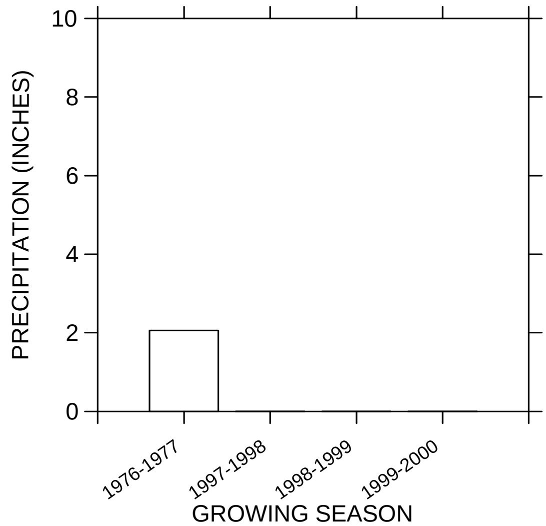

Figure 22. Total growing season (July-June) precipitation at Yuma WSO AP (data available for 1976-1977 only).

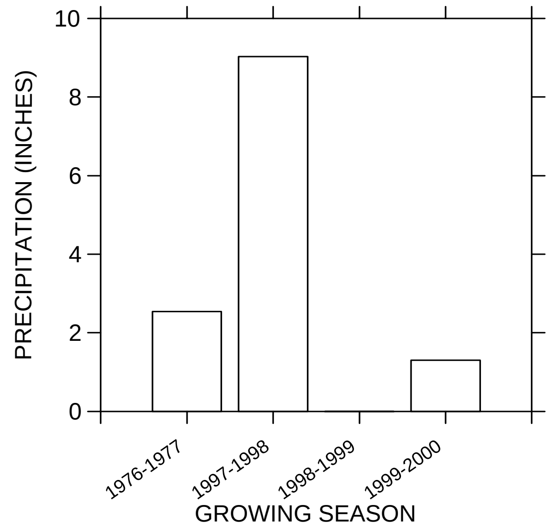

Figure 23. Total growing season (July-June) precipitation at Yuma Citrus Station. Data for 1998-1999 are not included because station is missing data for January through May. Data for 1999-2000 are incomplete because 9 days are missing for February and 5 days are missing for March.

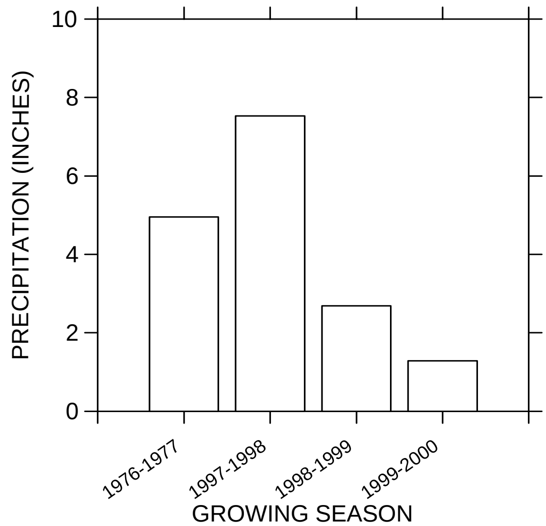

Figure 24. Total growing season (July-June) precipitation at Yuma Proving Ground.

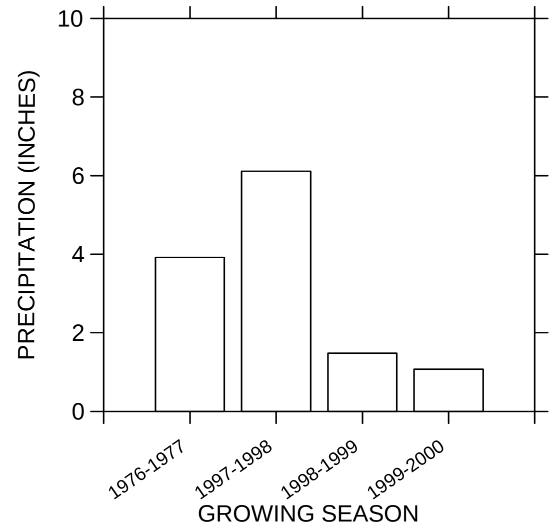

Figure 25. Average total growing season (July-June) precipitation for all weather stations in vicinity of the Algodones Dunes. The following weather stations are included in this analysis. 1976-1977: all above; 1997-1998: all except Gold Rock Ranch and Yuma AP; 1998-1999: all except Gold Rock Ranch, Yuma AP, and Yuma Citrus Station; 1999-2000: all except Gold Rock Ranch, Yuma AP, and Yuma Citrus Station.

Discussion

As Table 2 and Figure 25 show, average growing season precipitation for the weather stations in the vicinity of the dunes was above normal for the growing seasons immediately preceding monitoring in 1977 and 1998 (121% and 199% of the long-term mean, respectively) and well below normal for the growing seasons immediately preceding monitoring in 1999 and 2000 (49% and 37% of the long-term mean, respectively). As the figures and table show, there is considerable within-year variation in the amount of precipitation received by the seven stations. This strongly implies that the growing-season precipitation may differ within the dunes themselves. The remote area weather stations installed in fall 2000 will be used in future years to assess the within-dunes variability in precipitation. Data recorded between November 16, 2000, and March 16, 2001, indicate a gradient of decreasing precipitation from the southern to the northern dunes. This gradient may be responsible for some of the differences observed in plant abundance values in the northern, mostly closed part of the dunes and the southern, open part of the dunes. This is discussed further below. RAWS data will become increasingly important in interpreting trends in abundance of the six species; because, however, they are unavailable for any of the growing seasons that are the focus of this report, the average of the weather stations will be used for interpretation of abundance class data.

Interestingly, only the abundance classes for the two *Astragalus* species, and to a lesser extent, *Palafoxia arida* var. *gigantea*, seemed to track the annual pattern of rainfall for these four growing seasons. *Astragalus lentiginosus* var. *borreganus* (ASLEB) was not found at all in the two low rainfall years of 1999 and 2000 and abundance of *Astragalus magdalenae* var. *peirsonii* (ASMAP) was directly proportional to the amount of rainfall in each of the four years. Except for much higher than expected abundance class values in 2000, *Palafoxia arida* var. *gigantea* abundance also tracked rainfall fairly well. Further discussion on the apparent relationships of the six plant species to growing season precipitation is given in the individual species discussions below.

Astragalus lentiginosus* var. *borreganus

Entire dunes. *Astragalus lentiginosus* var. *borreganus* (ASLEB) abundance was essentially the same in 1977 and 1998 (Figure 1). No plants at all were found in either 1999 or 2000, a statistically significant decline from 1998 and 1977 levels. Presumably no plants were found in 1999 and 2000 because precipitation was insufficient for growth and establishment. This taxon is mostly an annual species (apparently it can sometimes behave as a very short-lived perennial), so it is not surprising that the very low rainfall prior to monitoring in 1999 and 2000 resulted in the establishment of no ASLEB individuals (or at least too few individuals to detect with monitoring). Regression analysis of mean abundance class on average precipitation for the four growing seasons was not possible for ASLEB because of the zero abundance class values for 1999 and 2000.

Closed area. ASLEB does not occur in the closed area.

Open area. The same trends and interpretations given under "entire dunes," above, apply to ASLEB in the open area (Figure 2).

Comparison of closed and open areas. No comparison is possible because this taxon does not occur in the closed area.

Astragalus magdalenae* var. *peirsonii

Entire dunes. *Astragalus magdalenae* var. *peirsonii* (ASMAP) abundance was closely tied to precipitation throughout the four years of monitoring. As Figure 3 shows, ASMAP abundance was highest in 1998, second highest in 1977, third highest in 1999, and lowest in 2000. This is exactly how the four growing seasons ranked in terms of average precipitation (Figure 25). Regression analysis of ASMAP abundance class values for the entire dunes on average precipitation yields an r^2 value of 0.91, meaning that 91% of the variability in ASMAP abundance class for each year is explained by the average precipitation for that year. Not too much stock should be placed on this r^2 value and the ones given below because there are only four pairs of data points in each regression; the values are reported here only to suggest possible trends.

The multivariate repeated-measures analysis of variance (Table 1) shows that the effect of year on transect abundance class totals is highly significant; given the pattern of the yearly differences shown in Figure 3, this again points to the dependency of this species on annual precipitation.

ASMAP is apparently a short-lived perennial, so its response to the amount of rainfall in the growing seasons preceding the four monitoring periods is predictable under the following interpretation. Recruitment was likely high in 1998 and low to nonexistent in 1999 and 2000. Transect abundance class totals declined by almost 50% between 1998 and 1999 and by about 33% between 1999 and 2000, presumably through mortality of the plants established in 1998. Under this interpretation one would expect a large number of seedlings in 1998, but few of the plants observed were classified as seedlings in any of the years 1998-2000. This is likely because by the time of monitoring most of the ASMAP individuals had grown large enough that observers did not consider them to be seedlings.

Closed area. Like the situation in the entire dunes, ASMAP abundance is apparently closely tied to precipitation ($r^2 = 0.79$). Interestingly, while the entire dunes and open areas experienced significant increases in abundance between 1977 and 1998, the abundance in the closed area was similar in both 1977 and 1998 (as shown in Figure 4, however, the 95% confidence interval around the estimate of the 1977 mean is very wide, so this similarity may just be an artifact of sampling).

Open area. The changes in abundance in the open area very closely mirror those in the entire dunes, including the rather close tie to precipitation ($r^2 = 0.88$).

Comparison of closed and open areas. The multivariate repeated-measures analysis of variance (Table 1) shows that the year x area interaction effect on transect abundance class totals is not significant, leading to acceptance of the null hypothesis that the response of the species over the years monitored was similar (parallel) in both the closed and open areas. This parallel response is evident in Figure 18. Abundance class values were higher in the open area in 1998 and 1999, about the same in 2000, and higher in the closed area in 1977 (Figure 18). The 2000 similarity probably results from the poor rainfall year; only 86 plants were tallied in the entire dunes, 20 in the closed area and 66 in the open area (Table 5, Appendix 1). Thus, conditions were unfavorable for growth throughout the dune system, resulting in similar low numbers in the closed and open areas.

Rainfall in 1998 was much more favorable to the species, resulting in higher abundance class values in the open area than in the closed area. This disparity also existed in 1999, but was smaller. This may mean that the southern dunes have more favorable habitat for ASMAP, but the reverse pattern observed in 1977 argues against this hypothesis. It is possible that more precipitation fell in the southern part of the dunes in 1998 and 1999 than in the northern part. There is some evidence for such a trend from RAWS data collected between November 16, 2000 and March 16, 2001: 1.40 inches of precipitation were recorded at Cahuilla in the northwest part of the dunes and 2.67 inches were recorded at Buttercup in the southern part of the dunes. The higher abundance class values in the closed area in 1977 may have resulted from higher rainfall in the northern dunes during that year. In any event, differences between open and closed areas were not great in any year and, as previously stated, ASMAP responded similarly in both areas over the four years.

Croton wigginsii

Entire dunes. *Croton wigginsii* (CRWI2) mean transect abundance class totals in 1977 were about half that of 1998; values for 1999 and 2000 were similar to those for 1998 (Figure 6). This apparently is not the result of the application of different abundance class definitions in 1977, because the mean transect frequencies showed a similar pattern between 1977 and 1998 (Willoughby 2000, Figure 17). The increase between 1977 and 1998 may represent a real increase in the population size of this species in the dune system. Most of this increase came in the open area. This is the only one of the six species studied that appears to respond well to moderate disturbance (Romspert and Burk 1979), which raises the possibility that the increase is the result of OHV activity in the open area. A similar pattern, however, was observed for *Helianthus niveus* ssp. *tephrodes* (discussed below), a species less tolerant of disturbance. There is evidence from recently collected RAWS data that the southern dunes, where most of the open area is, at least sometimes receive greater precipitation than the northern dunes, where the closed area is. Thus, the different responses of the closed and open areas could be the result of a precipitation difference between the two areas in years of recruitment and not related at all to OHV use. It is, of course, also possible that the increase is related to other, unknown factors.

CRWI2 abundance in a given year is virtually unrelated to the growing season precipitation immediately preceding that year, as evidenced by the r^2 value of 0.001 obtained by regressing CRWI2 transect abundance class totals on average precipitation. This is likely because CRWI2 is a relatively long-lived species. Once established in a good recruitment year, it is able to survive periods of below-average precipitation. As Table 5 in Appendix 1 shows, about 22 percent of the total plants tallied in 1998 were seedlings, a reflection of the much higher growing season precipitation immediately preceding the 1998 monitoring.[5] By contrast, fewer than one percent of the total plants tallied in 1999 and 2000 were seedlings. It seems possible that most of the 1998 seedlings persisted into 1999 and 2000.

The multivariate repeated-measures analysis of variance (Table 1) shows that the effect of year on transect abundance class totals is highly significant. This, however, is the result of the 1977 values being much lower than the values for the other three years. If 1977 is removed from the analysis, the effect of year is no longer significant.

Closed area. Unlike the situation in the open area and the entire dunes, CRWI2 mean transect abundance class totals in 1977 were only slightly lower than those for 1998, 1999, and 2000 (Figure 7). This could be the result of lower recruitment of individuals into the population in the closed area compared to the open area, which may result from a lower level of disturbance in the closed area but also may be because precipitation in the northern dunes, where the closed area occurs, was lower than in the southern dunes, where most of the open area is.

Open area. The trend in mean transect abundance class totals for the open area (Figure 8) is very similar to that observed in the entire dunes.

Comparison of closed and open areas. The multivariate repeated-measures analysis of variance (Table 1) shows that the year x area interaction effect on transect abundance class totals is significant, leading to rejection of the null hypothesis that the response of the species over the years monitored was similar (parallel) in both the closed and open areas. As Figure 19 illustrates, this lack of parallelism is the result of the single year 1977, when values for the closed and open areas were very similar. After 1977, the values diverge, with the open area having consistently higher values than the closed area. Removal of 1977 from the analysis leads to acceptance of the null hypothesis of parallelism ($P = 0.241$) .

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[5] Slightly more than 50 percent of the plants tallied in the closed area in 1998 were classified as seedlings, while only about 17 percent of the plants tallied in the open area were considered to be seedlings. This difference, however, appears to result from the fact that most of the 1998 monitoring in the open area occurred much later in the year than the monitoring in the closed area; consequently, plants that may have been classified as seedlings earlier in the year were now considered by observers to be adults. Open-area transects 1-4 and 15-18, all read about the same time as the closed-area transects, yielded tallies with 30 percent seedlings.

Helianthus niveus **ssp.** ***tephrodes***

Entire dunes. *Helianthus niveus* ssp. *tephrodes* (HENIT) mean transect abundance class totals were significantly higher in 1998 than in 1977; the 1998 levels were maintained approximately, with only slight decreases, into 1999 and 2000 (Figure 9). As discussed below, all of this increase is the result of a large increase in the values for the open area between 1977 and 1998. It is unclear why this species would increase so dramatically between 1977 and 1998. The absence of abundance data for the years between 1977 and 1998 makes it difficult to interpret such an increase.

HENIT abundance in a given year is almost unrelated to the growing season precipitation immediately preceding that year ($r^2 = 0.015$). This is likely because, like CRWI2, HENIT is a relatively long-lived species. Once established in a good recruitment year, it is able to survive periods of below-average precipitation. As Table 5 (Appendix 1) shows, about 14 percent of the total plants tallied in 1998 were seedlings, a reflection of the much higher growing season precipitation immediately preceding the 1998 monitoring. By contrast, only four percent of the total plants tallied in 1999 were classified as seedlings, and less than one percent of those tallied in 2000 were seedlings. It seems possible that most of the 1998 seedlings persisted into 1999 and 2000, with some mortality.

The multivariate repeated-measures analysis of variance (Table 1) shows that the effect of year on transect abundance class totals is not significant.

Closed area. Unlike the situation in the open area and the entire dunes, HENIT mean transect abundance class totals decreased between 1977 and 1998, with the 1998 levels approximately maintained in 1999 and 2000 (Figure 10). This could be the result of lower recruitment of individuals into the population in the closed area compared to the open area, but the reason for lower recruitment is unclear. There is nothing to indicate that HENIT responds favorably to disturbance, so the lower recruitment in the closed area may be independent of any effects of OHV use. It is possible that there may have been higher precipitation in the southern dunes, where most of the open area is, than in the northern dunes, where the closed area occurs. As noted previously, recently collected RAWS precipitation data shows that this pattern at least sometimes occurs. Absent abundance class values for the years between 1977 and 1998, it is impossible to accurately interpret the difference in response between the closed and open areas.

Open area. The trend in mean transect abundance class totals for the open area (Figure 11) is very similar to that observed in the entire dunes, except that the increase in abundance class totals between 1977 and 1998 is even more dramatic.

Comparison of closed and open areas. The multivariate repeated-measures analysis of variance (Table 1) shows that the year x area interaction effect on transect abundance class totals is highly significant, leading to rejection of the null hypothesis that the response of the species over the years monitored was similar (parallel) in both the closed and open areas. As Figure 20 illustrates, this lack of parallelism is the result of the single year 1977, when values for the closed area were higher than for the open area, a pattern that was reversed in 1998, 1999, and 2000. After 1977, the values diverge, with the open area having consistently higher values than the closed area. Removal of 1977 from the analysis leads to acceptance of the null hypothesis of parallelism ($P = 0.372$). As discussed under closed area, above, the reasons for this reversal in pattern between 1977 and 1998 and subsequent years is unclear, but could be the result of differential rainfall between north and south.

Palafoxia arida* var. *gigantea

Entire dunes. *Palafoxia arida* var. *gigantea* (PAARG) mean transect abundance class totals were highest in the best rainfall year, 1998, which one would expect of a predominantly annual plant species. Surprisingly, however, totals were second highest in 2000, the worst of the four rainfall years, rather than in 1977 as would be expected of the second highest rainfall year. Instead, 1977 abundance class totals ranked third, with 1999 values last (Figure 12). Despite this somewhat aberrant behavior, there was somewhat good correlation between abundance class values and precipitation over the entire dunes ($r^2 = 0.623$). The higher than expected values for 1999 are mostly the result of high values recorded in the closed area.

The multivariate repeated-measures analysis of variance (Table 1) shows that the effect of year on transect abundance class totals is highly significant, which is to be expected for an annual plant dependent on precipitation.

Closed area. PAARG values for the closed area essentially mirror those for the entire dunes (Figure 13), except that the abundance class values for 2000 are much higher, almost as high as those for 1998. As a consequence, the correlation between growing season precipitation and abundance class values is much lower in the closed area ($r^2 = 0.10$). It is unclear why 2000 would have been a good year for PAARG in the closed area, unless the plants there were responding to a weather event not evident from the weather data reviewed, although if this were the case, one would expect a similar response from *Astragalus magdalenae* var. *peirsonii*, which did not occur.

Open area. PAARG abundance patterns for the open area are more in line with what one would expect for an annual plant species and the growing season precipitation that occurred during the period of monitoring, with abundance class totals highest in 1998 and second highest in 1977, although 2000 is higher than 1999 (Figure 14). There is rather good correlation ($r^2 = 0.84$) between PAARG abundance class totals and growing season precipitation in the open area.

Comparison of closed and open areas. PAARG mean transect abundance class totals are very similar for the open and closed areas in 1977, 1998, and 1999, only diverging in 2000, when the values for the closed area increased much more than those for the open area. It appears from the raw data that PAARG is more common in the northern part of the dunes, independent of whether the area is closed or open. In 1998 the total number of plants tallied in the northern part of the dunes (north of Highway 78) was 27,901, 24,675 in the closed area and 3,226 in the northern open area, while only 6,748 plants were tallied in the southern open area (Table 4, Appendix 1). To put this difference in better perspective, the average number of plants tallied per transect was about 1,993 plants per transect north of Highway 78 and only 337 plants per transect south of Highway 78. This same pattern held in 2000, with tallies of 13,208 (943 plants/transect) in the dunes north of Highway 78 and 725 (36 plants/transect) south of Highway 78. Data for 1999 show the opposite pattern, with only 89 plants tallied for the entire area north of Highway 78 (6 plants/transect) and 1,369 tallied south of Highway 78 (68 plants/transect). Almost all of these southern plants, however, were tallied along the single transect 31, where 1,300 plants were recorded. [6] Thus, except for transect 31, numbers were very low throughout the dunes in 1999.

The multivariate repeated-measures analysis of variance (Table 1) shows that the year x area interaction effect on transect abundance class totals is highly significant, leading to rejection of the null hypothesis that the response of the species over the years monitored was similar (parallel) in both the closed and open areas. As Figure 21 illustrates, this lack of parallelism is the result of the single year 2000, when values for the closed area were much higher than for the open area. Removal of 2000 from the analysis leads to acceptance of the null hypothesis of parallelism (the P value is a very high 0.954, reflecting the very high correspondence between open and closed area values in 1977, 1998, and 1999).

Pholisma sonorae

Entire dunes. *Pholisma sonorae* (PHSO) mean transect abundance class totals were highest in the worst rainfall year, 2000, and second highest in the best rainfall year, 1998, although 1999 values were very close to 1998. Although the high values in 1998 might have been predicted based on the high rainfall, the even higher numbers in 2000 would not have been expected given the low rainfall of that year. Not surprisingly, there is very poor correlation between abundance class values and precipitation over the entire dunes ($r^2 = 0.013$). This correlation, though probably not real, is actually *negative*. This poor negative correlation also occurs in the closed and open areas when those are considered separately. The higher abundance class values for 1998 and 2000 are the result of very high values in the closed area.

The multivariate repeated-measures analysis of variance (Table 1) shows that the effect of year on transect abundance class totals is significant. This significance is the result of large abundance class values in the closed area for 1998 and 2000 compared to small values in 1977 and 1999. This is discussed further below.

Closed area. Except for 1999, PHSO values for the closed area are much different from the values for the entire dunes (Figure 16). In 1977 values were lower in the closed area than in the

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[6] All of these 1,300 plants were tallied in two cells, with the data sheet indicating "300+" and "1000+" seedlings of this species in cells 11 and 12, respectively; these tallies were recorded as simply 300 and 1000 in the database.

entire dunes. This may be the result of an incomplete survey of the closed area in 1977 by the WESTEC team. WESTEC apparently used a helicopter survey to either rate abundance of species and/or to determine where to land and assess plant abundance. While this may have worked for the other target plants, this is a very poor method of detecting PHSO, which is very cryptic. Thus, this species may have only been detected where it coexisted with one or more of the other target species.

The 1998 closed area values were considerably higher than in the entire dunes and even higher than in the open area. This same pattern repeats itself in the poor rainfall year 2000. It is unclear why 2000 would have been a good year for this species. This species is a root parasite, and most of the plant is buried in the sand. Only the flowering heads are visible above ground. It is parasitic on the roots of the shrubs, *Tiquilia plicata* and *Eriogonum deserticola* (Armstrong 1980) and possibly also on *Croton wigginsii* (WESTEC 1977). The stems of the plant can extend into the sand to a depth of 2 m or more (Armstrong 1999). Perhaps enough water is available at these depths to enable PHSO stems to grow and reach the surface. But, if so, why were so few plants found in 1999? Does stress on the host plants stimulate flowering of the parasite? Further study of the ecology of this species is necessary to adequately interpret the annual response patterns observed in this study.

Open area. PHSO abundance patterns for the open area are different from those for the entire dunes in terms of the order of abundance class values by year, but this difference may only be an artifact of sampling as indicated by the overlapping confidence intervals of all four years (Figure 17). Why 1998 and 2000 values in the open area should be so low compared to the values for the closed area is discussed below.

Comparison of closed and open areas. PHSO abundance class values are about the same in the open and closed area in 1999. In 1977 the closed area had a lower abundance class rating than the open areas. As discussed above this may be because of the method used to survey for PHSO in the closed area in 1977. In both 1998 and 2000 the values for the closed area were much higher than the values for the open area. Not surprisingly, given the pattern of response shown in Figure 22, the multivariate repeated-measures analysis of variance (Table 1) shows that the year x area interaction effect on transect abundance class totals is highly significant, leading to rejection of the null hypothesis that the response of the species over the years monitored was similar (parallel) in both the closed and open areas.

The large differences in PHSO between the closed and open areas in 1998 and 2000 may be due to one or more factors. The first is related to the cryptic nature of this species. Flowering heads blend in with the sand, particularly when not fully in bloom, making the species hard to see. Because transects in the southern open area were run using a dune buggy, plants may have been missed more frequently in the open area than in the closed area. Another potential reason for the disparity between the two areas relates to habitat for the host plants. The dunes in the northern area are not as high as the southern area, resulting in wider, interdune flats in the north which are more conducive to the growth of the host plants. It is also possible that OHV use may be contributing to the difference. OHVs certainly can directly impact the flowering parts of the species (Armstrong 1980, WESTEC 1977), and because of the plant's cryptic habit, it is unlikely that OHVs avoid the plant, simply because they cannot see it. OHV impacts to the host plants would also have a negative effect on PHSO. Absent additional study, however, it is not possible to determine which or what combination of these potential factors has been operating to create the disparity in abundance class responses in the two areas.

Study Limitations

It is important to understand the limitations of the monitoring data reported on here. Although the same cells were visited in 1998, 1999, and 2000 as in the 1977 WESTEC study, it is very unlikely that the same areas of each cell were surveyed in 1977 as in 1998, 1999, and 2000. Thus, the differences observed between 1977 transects and those in the other three years may result simply from the spatial variability within cells or may represent a combination of spatial variability and actual change. There is no means of testing this. The areas surveyed in 1998, 1999, and 2000 are more likely to be similar because survey teams used global positioning system (GPS) units in traversing transects. Teams were given the same transect latitudes to survey in each of the three years. The GPS units used currently have an accuracy of 10-20 meters (University of Colorado 2000), but prior to May 2, 2000, the Department of Defense (DOD) intentionally degraded signals from GPS satellites using a process known as Selective Availability (SA). These SA-degraded signals, along with other sources of error and bias, resulted in accuracies as poor as 100 m (Dana 1994). Thus, the transects actually traversed by observers may have been as much as 100 m apart (and possibly more as a result of human error), meaning that the same patches of target plants may not have been visited in each year. Transects monitored in 2001 and future years should be much more closely correlated following DOD's termination of SA on May 2, 2000.

Another limitation of the study method is that the results give only an index of abundance of the 6 species. While estimates of actual population size would certainly be better, the abundance class method was chosen for two reasons: (1) it allows for comparisons between recently collected data and the data collected by WESTEC in 1977; and (2) it enables monitoring of the entire dune system, something that would not have been possible if sampling to determine actual population size was conducted for all six target species. Beginning in 2001 BLM will implement a pilot sampling program to determine if it is practical to estimate actual population size for two of the target species: *Astragalus magdalenae* var. *peirsonii* and *Helianthus niveus* ssp. *tephrodes*.

It is also important to understand that this study was designed as a monitoring study, not as research to determine whether OHV use is reducing the numbers of any of these six target plants. A monitoring study can track changes in plant abundance over time that may correlate with OHV use, but such a correlation can only suggest OHV use as a possible cause of any differences observed. Research in the form of a controlled experiment is required to confidently attribute any observed decline to OHV use. Such an experiment requires random assignment of treatments (i.e., OHV use and no OHV use) to similar areas and replication of treatments, neither of which was performed as part of this study. Only one replication is available (one closed and one open area), the treatment was not randomly assigned to the two areas, and the two areas are not similar in terms of terrain and possibly rainfall. Thus, target plant responses that differ between the open and closed areas may be correlated with OHV use, but the study cannot determine if OHV use is the cause of these differences. Differences observed *may* be the result of OHV use, but may also be the result of habitat differences, precipitation, position in the dunes, or other unknown factors.[7] This limitation is not at all unusual for a monitoring study. As McDonald and others (1998) point out:

> We believe there is a need for research in monitoring programs, but we are critical of research disguised as long term monitoring. The two, monitoring and research, just need to be carefully defined and separated. Monitoring can determine correlations over time or space at best, and correlations over space if sample sites are collocated. Research can establish cause and effect, test hypotheses, and build useful models. A research component is needed to study rare resources, endangered species, important management issues, study cause and effect relationships suggested by monitoring data, establish simpler, more economical procedures, and build models for prediction into the future or the unsampled area. Monitoring data must be based on sound science and be able to stand on their own merits for the long term, say at least 50 years, but they rarely answer questions on ecological processes and uncertainties.

The need for research in conjunction with this monitoring project is discussed below.

Conclusions and Recommendations

WESTEC (1977) concluded:

> It should be noted that despite the observed impacts of ORV use in the Algodones Dunes, healthy reproducing populations of all seven species surveyed occurred within the dunes. The areas away from major ORV activities, notably in the central dune area between Highway 78 and Interstate 8, appeared relatively undisturbed.

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[7] The multivariate repeated-measures analysis of variance used here to determine if plant responses differ between the closed and open areas (i.e., testing to determine if the abundance class totals of the two areas are parallel over the period of study) offers some control over habitat differences. The test does not depend on the two areas ever having the same abundance class totals (something that would be likely only if the habitat of the two areas was similar), only that the differences between closed and open area abundances are similar over the four years studied. This approach also controls for precipitation differences between the open and closed areas, but *only* if those differences remained relatively constant over the four years.

It would appear from the current study that this situation has not changed much if at all since 1977. Healthy populations of all six species remain in the open area, though the above-ground expression of populations of some of these species fluctuates dramatically with precipitation. As noted in Willoughby (2000), all six species were at least as abundant and widespread in 1998 as they were in 1977. Following is a species-by-species summary of monitoring findings.

Astragalus lentiginosus var. *borreganus*, an annual species, occurs only in the southern, open area of the dunes. It was slightly more abundant in 1998 than in 1977, but this difference is not significant. The plant was not found at all in 1999 and 2000, probably the result of insufficient precipitation for germination and establishment.

The response of *Astragalus magdalenae* var. *peirsonii*, a short-lived perennial, is closely tied to precipitation. It was most abundant in 1998, the highest rainfall year, and least abundant in 2000, the lowest rainfall year. Responses of this species were similar in both the closed and open areas across all four years of monitoring.

The abundance of *Croton wigginsii*, a relatively long-lived shrub or sub-shrub, does not fluctuate much from year-to-year in response to annual rainfall. Once established, it appears to be able to maintain its population over at least two low-rainfall years. The species was significantly more abundant in 1998 than in 1977, mostly as a result of increases in the open area. This could be the result of OHV disturbance in the open area (unlike the other species, this species responds well to moderate levels of disturbance), but is probably more likely the result of differential rainfall amounts between the northern and southern dunes during periods of establishment or of other unknown factors. Except for 1977 the responses of the species in the open and closed areas were parallel.

Abundance of *Helianthus niveus* ssp. *tephrodes*, a shrubby perennial, is similar in pattern to *Croton wigginsii*, in that it appears to maintain itself after establishment through years of below-normal precipitation. Its abundance was higher in 1998 than in 1977, and it maintained the 1998 level of abundance in 1999 and 2000. The higher abundance in 1998 was entirely the result of increases in the open area. The species declined in abundance in the closed area between 1977 and 1998; like the rest of the dunes the 1998 closed area values were maintained into 1999 and 2000. The disparate response of this species in the closed and open areas may be due to differential rainfall amounts in the northern and southern dune areas or to other unknown factors. Except for 1977 the responses in the open and closed areas were parallel.

The abundance of *Palafoxia arida* var. *gigantea*, an annual species, was anomalously high in the poor rainfall year, 2000, almost entirely as a result of high numbers in the closed area. Numbers in the open area tracked precipitation patterns extremely well and, except for 2000, abundance in the closed area correlated well with rainfall. It is unclear why abundance of this species was high in the closed area in 2000. There is some indication that habitat in the northern part of the dunes is more favorable for this species than that in the southern part. Except for 2000, responses of this species in the open and closed areas parallel one another.

Abundance of *Pholisma sonorae*, a root parasite, was highest in the worst rainfall year, 2000, and second highest in the best rainfall year, 1998; values for 1999 were very close to 1998. There is very poor correlation between annual rainfall and abundance. It is unclear why 2000 was a good year for the species. The high values in 2000 were the result of high values in the closed area. There were large differences in abundance between the closed and open areas in 1998 and 2000, with the closed area abundances much higher than those in the open area. The reason for these differences are unclear, but may be related to one or more factors, including differential detection rates in the two areas resulting from the plant's cryptic nature, possible OHV impacts in the open area, and better habitat in the northern part of the dunes.

As with the study reported in Willoughby (2000), comparing abundances between 1998 and 1977, the monitoring reported on here should not be interpreted to mean that OHV use is somehow "good" or even benign for the 6 species studied. The design of this study allows inferences to be made only to the entire dunes and to the large areas of the dunes within the open and closed areas. Although all six species, with the possible exceptions of *Palafoxia arida* var. *gigantea* and *Pholisma sonorae*, appear to be responding similarly in both the closed and open areas, this likely results from the fact that OHV use in the open area does not encroach–at least very intensively–on much of the habitat of the plants in relatively large portions of the open area away from OHV staging areas. This is illustrated by Map 24 in Willoughby (2000), which shows the frequency of vehicle tracks along 16 aerial photo transects in the dunes taken on Saturday, April 11, 1998, during a period of relatively high OHV use in the dunes (Easter weekend). Similar aerial photo transects were taken during Easter weekends in 1999 and 2000. These are in the process of being analyzed; results will be reported elsewhere.

Additional research into the life histories, habitat preferences, and response to OHV impacts is needed to supplement this monitoring and allow better interpretation of the monitoring data. An experiment similar to that used by Bruce Pavlik in the Eureka Dunes (Pavlik 1979) would help describe the nature of vehicle impacts to the species. Demographic studies similar to those conducted by Pavlik and Barbour on the rare plants of the Eureka Dunes (Pavlik 1979; Pavlik and Barbour 1985, 1986, and 1988) would help in developing ecological models for each of the plant species, including time and frequency of germination and establishment, optimum habitat, and mode of dispersal.

Literature Cited

Armstrong, W.P. 1980. Sand food: a strange plant of the Algodones Dunes. Fremontia 7(4):3-9.

Armstrong, W.P. 1999. Sand dunes: a phenomenon of wind. The bizarre sand food and sand plant. Wayne's Word Volume 7 (Number 4) Winter 1999. On the web at http://daphne.palomar.edu/wayne/ww0704.htm#Life

CNPS - California Native Plant Society, in press. Inventory of rare and endangered vascular plants of California, 6th edition. California Native Plant Society, Sacramento, CA.

Dana, P.H. 1994. Global positioning system overview. Available at the University of Colorado website: http://www.colorado.Edu/geography/gcraft/notes/gps/gps_f.html

ESRI (Environmental Systems Research Institute). 1998. ArcInfo Version 7.2.1. Redlands, CA.

McDonald, L., T. McDonald, and D. Robertson. 1998. Review of the Denali National Park and Preserve (DENA) Long-Term Ecological Monitoring Program (LTEM). Report to Alaska Biological Science Center, Biological Resources Division, USGS, Anchorage, AK. WEST Technical Report 98-7, Cheyenne, WY. This document can be downloaded from the following web page: http://www1.nature.nps.gov/im/monitor/index.htm#HowToPubs

Pavlik, B.M. 1979. The biology of endemic psammophytes, Eureka Valley, California, and its relation to off-road vehicle impact. U.S. Bureau of Land Management, California Desert Planning Staff, Riverside, CA. On file at Bureau of Land Management, California State Office.

Pavlik, B.M., and M.G. Barbour. 1985. Demography of endemic psammophytes, Eureka Valley, California. I. Seed production, dispersal and herbivory. California Department of Fish and Game, Endangered Plant Program, Sacramento, CA.

Pavlik, B.M., and M.G. Barbour. 1986. Demography of endemic psammophytes, Eureka Valley, California. II. Survivorship, seed bank dynamics and frequency of establishment. California Department of Fish and Game, Endangered Plant Program, Sacramento, CA.

Pavlik, B.M., and M.G. Barbour. 1988. Demographic monitoring of endemic sand dune plants, Eureka Valley, California. Biological. Conservation 46: 217-242.

Romspert, A.P., and J.H. Burk. 1979. Algodones Dunes sensitive plant project 1978-1979. Prepared for the Bureau of Land Management. On file at the BLM California State Office, Sacramento, CA.

Scheiner, S.M. 1993. MANOVA: Multiple response variables and multispecies interactions. Pp. 94-112 in: S.M. Scheiner and J. Gurevitch, eds. Design and Analysis of Ecological Experiments. Chapman & Hall, New York and London.

Skinner, M.W., and B.M. Pavlik. 1994. Inventory of rare and endangered vascular plants of California. Special Publication No. 1, 5th edition. California Native Plant Society, Sacramento, CA.

SPSS, Inc. 2000. SYSTAT 10.0. Chicago, IL.

Stehman, S.V., and D.W. Salzer. 2000. Estimating density from surveys employing unequal-area belt transects. Wetlands 20:512-519.

Tabachnick, B.G., and L.S. Fidell. 2001. Using multivariate statistics, 4th edition. Allyn and Bacon, Boston, MA.

University of Colorado. 2000. Frequently Asked Questions About SA Termination. University of Colorado, Boulder. Available at the following web address: http://www.colorado.Edu/geography/gcraft/notes/gps/gps_f.html

von Ende, C.N. 1993. Repeated-measures analysis: growth and other time-dependent measures. Pp. 113-137 in: S.M. Scheiner and J. Gurevitch, eds. Design and Analysis of Ecological Experiments. Chapman & Hall, New York and London.

WESTEC Services Inc. 1977. Survey of sensitive plants of the Algodones Dunes. Prepared for Bureau of Land Management, California Desert District. On file at the BLM California State Office, Sacramento, CA.

Willoughby, J.W. 2000. Monitoring of special status plants in the Algodones Dunes, Imperial County, California: Results of 1998 monitoring and comparison with the data from WESTEC's 1977 monitoring study. Bureau of Land Management, California State Office.

Appendix 1

This appendix contains three tables with summary information from the study. Table 3 shows the number of cells surveyed for each of the 34 transects, along with the number of those cells that were considered to be potential habitat for at least one of the target species. A cell was rated as having potential habitat based on the WESTEC map of vegetation associations (WESTEC 1977, Figure 3-1). Cells with greater than 5 percent cover of Desert Psammophytic Scrub or Open Dunes were considered to have potential habitat for at least one of the six target plant species.

Table 4 details each year's survey results for each transect and for each species. Number of cells occupied, total abundance class values, and number of plants tallied along each of the 34 transects are given, along with total cells occupied, total abundance class values, and total number of plants tallied for the entire dunes, the closed area (transects 5-14), the northern open area (transects 1-4), the southern open area (transects 15-34) and all of the open area.

Table 5 shows the number of individual plants tallied while reading the 34 transects in 1998, 1999, and 2000. No such tallies are available for 1977. These values should not be viewed as or used for population estimates because the tallies were not made in quadrats of a specified size. Observers were instructed to tally plants in an area of approximately 50 m on either side of the center line of each transect (resulting in belt transects about 100 m wide), but no measuring devices were used to ensure this, and visibility along some transects did not extend to 50 m on both sides of the center line (e.g., where high dunes restricted visibility in one direction). Also, when numbers of plants were too many to accurately count, observers were directed to abandon counting and simply give an abundance class rating. From the data sheets it appears that counting may have been a problem only for *Palafoxia arida* var. *gigantea*.

The reader should also remember that 10 of the 34 transects were in the closed area, with the remaining 24 falling in the open area. For this reason, the absolute counts shown below are usually greater in the open area.

Table 3. Number of cells surveyed along each transect and the number of those cells with potential habitat. A cell was rated as having potential habitat based on the WESTEC map of vegetation associations (WESTEC 1977, Figure 3-1). Cells with greater than 5 percent cover of Desert Psammophytic Scrub or Open Dunes were considered to have potential habitat for at least one of the six target plant species.

Transect Number	Number of Cells	Number of Cells with Potential Habitat	Transect Number	Number of Cells	Number of Cells with Potential Habitat
1	8	7	18	23	21
2	8	7	19	22	19
3	8	7	20	20	20
4	8	8	21	20	19
5	11	10	22	20	19
6	11	10	23	16	13
7	11	11	24	13	12
8	12	12	25	13	12
9	13	12	26	21	19
10	14	13	27	20	15
11	14	13	28	17	15
12	14	12	29	18	16
13	16	14	30	17	17
14	16	15	31	15	15
15	19	18	32	20	20
16	21	19	33	21	21
17	20	19	34	22	20
			Total cells surveyed	542	500
			Total cells surveyed closed area	132	122
			Total cells surveyed north open area	32	29
			Total cells surveyed south open area	378	349
			Total cells surveyed all open area	410	378

Table 4. Transect details showing numbers of cells occupied, total abundance class values, and number of plants tallied along each of the 34 transects for each species in 1977, 1998, 1999, and 2000. Also given are total cells occupied, total abundance class values, and total number of plants tallied for the entire dunes, the closed area (transects 5-14), the northern open area (transects 1-4), the southern open area (transects 15-34) and all of the open area. Abbreviations are: ASLEB = *Astragalus lentiginosus* var. *borreganus*; ASMAP = *Astragalus magdalenae* var. *peirsonii*; CRWI2 = *Croton wigginsii*; HENIT = *Helianthus niveus* ssp. *tephrodes*; PAARG = *Palafoxia arida* var. *gigantea*; PHSO = *Pholisma sonorae*.

ASLEB

Transect Number	1977			1998			1999			2000		
	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
1	0	0	N/A	0	0	0	0	0	0	0	0	0
2	0	0	N/A	0	0	0	0	0	0	0	0	0
3	0	0	N/A	0	0	0	0	0	0	0	0	0
4	0	0	N/A	0	0	0	0	0	0	0	0	0
5	0	0	N/A	0	0	0	0	0	0	0	0	0
6	0	0	N/A	0	0	0	0	0	0	0	0	0
7	0	0	N/A	0	0	0	0	0	0	0	0	0
8	0	0	N/A	0	0	0	0	0	0	0	0	0
9	0	0	N/A	0	0	0	0	0	0	0	0	0
10	0	0	N/A	0	0	0	0	0	0	0	0	0
11	0	0	N/A	0	0	0	0	0	0	0	0	0
12	0	0	N/A	0	0	0	0	0	0	0	0	0
13	0	0	N/A	0	0	0	0	0	0	0	0	0
14	0	0	N/A	0	0	0	0	0	0	0	0	0

Year	Transect Number	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1977	Number Cells Occupied	0	0	0	1	0	1	0	0	0	0	0	0	4	1	0
	Sum of Abun. Class Values	0	0	0	3	0	2	0	0	0	0	0	0	10	2	0
	Number Plants Tallied	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1998	Number Cells Occupied	2	4	2	0	1	0	4	3	1	0	0	3	4	1	2
	Sum of Abun. Class Values	2	4	2	0	1	0	8	6	2	0	0	5	8	1	2
	Number Plants Tallied	6	12	4	0	8	0	118	155	11	0	0	61	211	3	5
1999	Number Cells Occupied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sum of Abun. Class Values	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Number Plants Tallied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2000	Number Cells Occupied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sum of Abun. Class Values	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Number Plants Tallied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Transect Number	1977			1998			1999			2000		
	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
30	5	7	N/A	0	0	0	0	0	0	0	0	0
31	0	0	N/A	0	0	0	0	0	0	0	0	0
32	3	7	N/A	0	0	0	0	0	0	0	0	0
33	0	0	N/A	0	0	0	0	0	0	0	0	0
34	1	2	N/A	0	0	0	0	0	0	0	0	0
Total All	16	33	N/A	27	41	594	0	0	0	0	0	0
Total Closed (5-14)	0	0	N/A	0	0	0	0	0	0	0	0	0
Total No. Open (1-4)	0	0	N/A	0	0	0	0	0	0	0	0	0
Total So. Open (15-34)	16	33	N/A	27	41	594	0	0	0	0	0	0
Total All Open	16	33	N/A	27	41	594	0	0	0	0	0	0

ASMAP

Transect Number	1977			1998			1999			2000		
	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
1	0	0	N/A	1	1	11	1	1	9	0	0	0
2	1	1	N/A	2	3	29	2	3	16	1	1	4
3	0	0	N/A	2	4	108	2	2	10	0	0	0
4	1	1	N/A	2	4	418	2	2	11	1	1	1
5	3	5	N/A	3	4	38	2	2	2	1	1	2
6	0	0	N/A	2	4	83	1	2	11	1	1	1
7	3	5	N/A	3	6	49	1	1	4	0	0	0
8	3	6	N/A	2	4	33	1	1	5	1	1	1
9	3	6	N/A	3	4	22	2	2	5	0	0	0
10	3	8	N/A	3	5	313	1	1	1	1	1	1
11	0	0	N/A	4	6	60	2	2	11	2	2	2
12	4	6	N/A	3	4	10	3	3	10	0	0	0
13	6	11	N/A	3	5	41	3	4	21	3	3	6
14	3	6	N/A	5	7	45	5	6	60	3	3	7

Transect Number	1977			1998			1999			2000		
	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
15	6	8	N/A	5	8	88	3	3	4	0	0	0
16	6	9	N/A	6	12	222	5	5	14	0	0	0
17	9	17	N/A	9	21	857	3	3	10	8	8	20
18	8	15	N/A	5	10	171	3	5	59	3	3	4
19	4	7	N/A	7	13	191	4	4	20	0	0	0
20	3	5	N/A	5	9	83	1	1	3	0	0	0
21	3	3	N/A	5	7	79	2	3	12	0	0	0
22	2	3	N/A	4	6	98	2	4	80	0	0	0
23	2	3	N/A	4	7	221	3	4	44	0	0	0
24	0	0	N/A	6	9	103	2	4	58	1	1	1
25	0	0	N/A	7	10	69	2	3	21	0	0	0
26	1	1	N/A	3	6	131	3	5	31	2	2	7
27	0	0	N/A	4	10	672	2	3	26	0	0	0
28	1	1	N/A	4	8	203	2	3	25	1	1	2
29	2	2	N/A	4	8	272	3	4	20	1	1	2

Transect Number	1977			1998			1999			2000		
	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
30	4	5	N/A	0	0	0	2	5	197	2	2	9
31	1	2	N/A	2	2	8	1	2	39	1	2	11
32	0	0	N/A	3	7	335	3	5	103	2	2	5
33	4	4	N/A	1	1	1	0	0	0	0	0	0
34	4	7	N/A	0	0	0	0	0	0	0	0	0
Total All	90	147	N/A	123	215	5,064	74	98	942	35	36	86
Total Closed (5-14)	28	53	N/A	32	49	694	21	24	130	12	12	20
Total No. Open (1-4)	2	2	N/A	7	12	566	7	8	46	2	2	5
Total So. Open (15-34)	60	92	N/A	84	154	3,804	46	66	766	21	22	61
Total All Open	62	94	N/A	91	166	4,370	53	74	812	23	24	66

CRWI2

Transect Number	1977			1998			1999			2000		
	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
1	0	0	N/A	4	7	225	3	5	115	3	5	82
2	3	4	N/A	2	6	721	2	4	111	1	3	276
3	0	0	N/A	2	5	29	1	2	28	2	3	32
4	0	0	N/A	2	4	133	2	4	125	2	4	156
5	3	4	N/A	2	6	463	1	3	181	2	5	208
6	0	0	N/A	2	4	72	2	4	109	2	5	180
7	1	2	N/A	2	5	49	2	4	139	3	7	320
8	2	3	N/A	2	4	3	2	5	148	1	2	17
9	2	3	N/A	3	6	138	2	3	39	2	2	12
10	3	4	N/A	3	5	129	2	5	213	3	6	182
11	0	0	N/A	5	11	118	3	7	184	3	5	69
12	4	6	N/A	4	8	76	1	2	39	3	5	218
13	6	14	N/A	4	8	234	5	11	599	6	12	520
14	4	7	N/A	5	9	200	6	15	849	6	13	613

Transect Number	1977			1998			1999			2000		
	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
15	6	10	N/A	9	16	304	11	18	450	6	14	461
16	5	11	N/A	10	23	515	10	18	436	10	18	368
17	11	20	N/A	10	21	655	7	19	739	13	21	207
18	3	10	N/A	12	18	321	8	18	474	13	21	294
19	5	11	N/A	6	14	644	8	18	618	10	19	637
20	4	9	N/A	10	21	760	9	16	288	6	14	580
21	6	7	N/A	7	17	229	8	16	365	7	17	954
22	5	11	N/A	9	20	330	6	14	344	7	18	969
23	3	7	N/A	9	22	264	4	10	254	6	14	460
24	1	1	N/A	5	12	146	3	7	196	4	7	242
25	0	0	N/A	4	11	52	5	8	134	5	8	101
26	0	0	N/A	5	13	115	4	10	343	4	12	708
27	0	0	N/A	5	17	152	4	7	182	6	13	386
28	1	1	N/A	4	10	32	5	10	226	4	6	137
29	3	4	N/A	3	6	42	4	10	328	3	6	255

Transect Number	1977			1998			1999			2000		
	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
30	3	4	N/A	0	0	0	3	6	261	3	5	87
31	1	1	N/A	3	7	52	3	6	199	3	6	100
32	0	0	N/A	3	7	88	3	9	726	3	6	191
33	2	2	N/A	5	12	104	6	10	147	6	10	97
34	3	5	N/A	2	5	118	4	6	108	4	5	87
Total All	90	161	N/A	162	360	7,513	149	310	9,697	162	317	10,206
Total Closed (5-14)	25	43	N/A	32	66	1,482	26	59	2,500	31	62	2,339
Total No. Open (1-4)	3	4	N/A	9	22	1,108	8	15	379	8	15	546
Total So. Open (15-34)	62	114	N/A	121	272	4,923	115	236	6,818	123	240	7,321
Total All Open	65	118	N/A	130	294	6,031	123	251	7,197	131	255	7,867

HENIT

Transect Number	1977			1998			1999			2000		
	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
1	0	0	N/A	2	3	33	1	2	12	0	0	0
2	3	8	N/A	2	3	24	2	3	35	2	3	20
3	0	0	N/A	2	3	78	2	2	2	0	0	0
4	1	1	N/A	2	4	14	2	4	97	2	5	122
5	5	10	N/A	1	1	4	2	2	7	2	2	11
6	5	8	N/A	2	3	61	1	2	17	3	3	7
7	0	0	N/A	2	2	6	2	2	8	3	3	8
8	5	10	N/A	1	2	8	1	1	1	1	1	2
9	3	7	N/A	3	6	243	1	2	35	1	2	21
10	6	13	N/A	2	5	289	3	5	125	2	4	98
11	0	0	N/A	7	14	868	3	7	169	5	9	223
12	5	8	N/A	2	6	34	4	8	201	4	9	259
13	7	14	N/A	2	3	37	4	7	141	5	9	108
14	7	12	N/A	3	5	8	4	9	293	5	8	161

Transect Number	1977			1998			1999			2000		
	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
15	6	10	N/A	10	18	26	8	12	127	10	16	220
16	7	11	N/A	7	14	42	10	13	108	9	15	174
17	10	13	N/A	10	22	94	10	18	354	9	10	42
18	11	22	N/A	10	22	188	13	25	469	11	14	90
19	2	3	N/A	10	22	472	11	19	360	8	13	138
20	4	5	N/A	8	16	373	10	20	331	9	15	293
21	5	6	N/A	8	23	388	7	15	391	7	13	343
22	2	3	N/A	8	20	260	8	17	393	5	8	133
23	2	3	N/A	9	23	253	8	17	343	7	12	220
24	1	2	N/A	6	16	138	6	10	80	7	13	173
25	0	0	N/A	8	23	130	7	14	278	7	12	98
26	2	4	N/A	7	20	221	6	11	215	8	17	453
27	0	0	N/A	8	25	484	9	19	458	9	15	215
28	4	4	N/A	5	14	281	10	16	187	7	14	200
29	5	5	N/A	4	7	52	7	13	239	8	14	186

Transect Number	1977			1998			1999			2000		
	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
30	5	9	N/A	3	8	124	8	17	693	8	15	180
31	3	4	N/A	6	16	234	6	14	666	6	13	285
32	3	4	N/A	4	9	191	8	15	553	9	14	151
33	5	6	N/A	2	6	139	3	5	54	4	6	32
34	5	7	N/A	2	4	54	7	11	103	8	9	68
Total All	129	212	N/A	167	388	5,851	194	357	7,545	191	316	4,734
Total Closed (5-14)	43	82	N/A	25	47	1,558	25	45	997	31	50	898
Total No. Open (1-4)	4	9	N/A	8	13	149	7	11	146	4	8	142
Total So. Open (15-34)	82	121	N/A	134	328	4,144	162	301	6,402	156	258	3,694
Total All Open	86	130	N/A	142	341	4,293	169	312	6,548	160	266	3,836

PAARG

Transect Number	1977			1998			1999			2000		
	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
1	0	0	N/A	7	17	843	0	0	0	2	3	16
2	0	0	N/A	7	19	1,427	0	0	0	5	11	498
3	0	0	N/A	5	9	192	1	1	1	4	8	194
4	1	1	N/A	3	8	764	1	1	6	5	10	497
5	2	2	N/A	10	19	808	2	2	2	6	13	264
6	0	0	N/A	9	17	1,495	0	0	0	7	11	170
7	7	10	N/A	7	15	499	2	2	4	8	13	155
8	7	13	N/A	7	20	2,823	2	2	5	5	12	547
9	5	7	N/A	8	16	481	0	0	0	8	15	580
10	5	7	N/A	10	22	1,222	0	0	0	9	21	1,566
11	0	0	N/A	8	15	363	4	4	8	10	25	2,131
12	9	15	N/A	11	30	4,534	8	8	16	12	27	2,800
13	7	11	N/A	11	24	1,741	6	6	16	11	26	1,939
14	2	2	N/A	11	28	10,709	7	7	31	15	36	1,851

Transect Number	1977			1998			1999			2000		
	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
15	6	11	N/A	14	24	563	2	2	2	6	6	13
16	6	9	N/A	14	25	448	6	6	10	6	7	35
17	10	10	N/A	16	27	531	4	5	21	6	7	32
18	12	22	N/A	16	31	974	2	2	4	8	10	113
19	5	8	N/A	16	29	570	4	4	7	8	14	420
20	4	5	N/A	15	27	333	5	5	6	2	3	78
21	1	1	N/A	11	17	279	2	2	4	1	2	11
22	4	4	N/A	15	25	524	1	1	1	0	0	0
23	4	5	N/A	13	23	274	4	4	6	4	4	5
24	5	7	N/A	11	17	238	1	1	1	0	0	0
25	0	0	N/A	9	15	154	0	0	0	0	0	0
26	2	3	N/A	13	22	242	0	0	0	1	1	2
27	0	0	N/A	12	23	341	0	0	0	1	1	1
28	5	6	N/A	10	16	235	1	1	1	0	0	0
29	4	4	N/A	11	18	211	1	1	2	0	0	0

Transect Number	1977			1998			1999			2000		
	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
30	6	11	N/A	9	14	183	0	0	0	0	0	0
31	2	2	N/A	13	21	366	2	7	1,300	2	3	15
32	5	7	N/A	2	4	38	1	1	1	0	0	0
33	8	10	N/A	11	16	217	1	1	3	0	0	0
34	10	13	N/A	5	5	27	0	0	0	0	0	0
Total All	144	206	N/A	350	658	34,649	70	76	1,458	152	289	13,933
Total Closed (5-14)	44	67	N/A	92	206	24,675	31	31	82	91	199	12,003
Total No. Open (1-4)	1	1	N/A	22	53	3,226	2	2	7	16	32	1,205
Total So. Open (15-34)	99	138	N/A	236	399	6,748	37	43	1,369	45	58	725
Total All Open	100	139	N/A	258	452	9,947	39	45	1,376	61	90	1,930

PHSO

Transect Number	1977			1998			1999			2000		
	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
1	0	0	N/A	2	3	31	1	2	15	2	2	5
2	0	0	N/A	3	3	7	1	1	4	3	5	31
3	0	0	N/A	4	9	91	3	6	89	3	8	114
4	1	1	N/A	3	4	14	2	3	13	5	13	213
5	1	1	N/A	3	5	30	1	1	1	2	8	242
6	0	0	N/A	4	5	18	3	3	8	4	6	32
7	1	2	N/A	5	10	82	0	0	0	4	10	188
8	0	0	N/A	4	6	20	3	3	6	3	4	15
9	0	0	N/A	2	4	38	3	3	5	2	2	2
10	1	1	N/A	2	2	7	1	1	4	2	6	67
11	0	0	N/A	5	9	33	1	1	7	4	9	82
12	0	0	N/A	0	0	0	1	1	5	3	7	109
13	3	3	N/A	4	6	31	1	1	1	5	18	396
14	0	0	N/A	4	9	53	3	5	20	5	11	72

Transect Number	1977 Number Cells Occupied	1977 Sum of Abun. Class Values	1977 Number Plants Tallied	1998 Number Cells Occupied	1998 Sum of Abun. Class Values	1998 Number Plants Tallied	1999 Number Cells Occupied	1999 Sum of Abun. Class Values	1999 Number Plants Tallied	2000 Number Cells Occupied	2000 Sum of Abun. Class Values	2000 Number Plants Tallied
15	0	0	N/A	0	0	0	1	2	7	0	0	0
16	1	1	N/A	1	1	4	1	1	2	0	0	0
17	1	2	N/A	0	0	0	0	0	0	0	0	0
18	3	6	N/A	3	4	18	0	0	0	0	0	0
19	1	1	N/A	1	1	5	1	1	1	0	0	0
20	3	3	N/A	0	0	0	0	0	0	0	0	0
21	3	4	N/A	0	0	0	2	2	3	0	0	0
22	1	4	N/A	0	0	0	2	2	2	0	0	0
23	1	2	N/A	0	0	0	1	1	5	0	0	0
24	2	2	N/A	0	0	0	1	1	2	0	0	0
25	0	0	N/A	0	0	0	1	1	2	0	0	0
26	2	2	N/A	0	0	0	1	2	11	1	1	1
27	0	0	N/A	0	0	0	1	1	1	0	0	0
28	0	0	N/A	0	0	0	1	1	1	2	2	6
29	2	2	N/A	0	0	0	1	1	1	1	1	1

Transect Number	1977			1998			1999			2000		
	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
30	0	0	N/A	1	1	1	7	13	83	0	0	0
31	0	0	N/A	2	2	2	2	3	23	0	0	0
32	4	6	N/A	0	0	0	2	6	43	0	0	0
33	4	4	N/A	1	1	1	3	4	20	0	0	0
34	4	10	N/A	0	0	0	0	0	0	0	0	0
Total All	39	57	N/A	54	85	486	52	73	385	51	113	1,576
Total Closed (5-14)	6	7	N/A	33	56	312	17	19	57	34	81	1,205
Total No. Open (1-4)	1	1	N/A	12	19	143	7	12	121	13	28	363
Total So. Open (15-34)	32	49	N/A	9	10	31	28	42	207	4	4	8
Total All Open	33	50	N/A	21	29	174	35	54	328	17	32	371

Table 5. Total number of seedlings and adult plants tallied along transects in 1998, 1999, and 2000 for each species in the closed area, open area, and the entire dunes. Abundance class values for cells along transects were determined using the total of seedlings and adult plants, also shown below. Abbreviations are: ASLEB = *Astragalus lentiginosus* var. *borreganus*; ASMAP = *Astragalus magdalenae* var. *peirsonii*; CRWI2 = *Croton wigginsii*; HENIT = *Helianthus niveus* ssp. *tephrodes*; PAARG = *Palafoxia arida* var. *gigantea*; PHSO = *Pholisma sonorae*. There are 34 total transects, 10 in the closed area and 24 in the open area. For PHSO, numbers are for dried flower heads (listed under the heading "seedlings") and living flower heads (listed under the heading "adults").

		Closed Area			Open Area			Entire Dunes		
Species	Year	Seed-lings	Adults	Total	Seed-lings	Adults	Total	Seed-lings	Adults	Total
ASLEB	1998	0	0	0	0	594	594	0	594	594
	1999	0	0	0	0	0	0	0	0	0
	2000	0	0	0	0	0	0	0	0	0
ASMAP	1998	29	665	694	22	4,348	4,370	51	5,013	5,064
	1999	0	130	130	0	812	812	0	942	942
	2000	0	20	20	0	66	66	0	86	86
CRWI2	1998	756	726	1,482	875	5,156	6,031	1,631	5,882	7,513
	1999	0	2,500	2,500	26	7,171	7,197	26	9,671	9,697
	2000	2	2,337	2,339	8	7,859	7,867	10	10,196	10,206
HENIT	1998	758	800	1,558	90	4,203	4,293	848	5,003	5,851
	1999	1	996	997	289	6,259	6,548	290	7,255	7,545
	2000	2	896	898	7	3,829	3,836	9	4,725	4,734
PAARG	1998	142	24,533	24,675	2	9,972	9,974	144	34,505	34,649
	1999	1	81	82	1,300	76	1,376	157	1,301	1,458
	2000	0	12,003	12,003	0	1,930	1,930	0	13,933	13,933
PHSO	1998	144	168	312	27	147	174	171	315	486
	1999	52	5	57	106	222	328	158	227	385
	2000	48	1,157	1,205	26	345	371	74	1,502	1,576