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
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Cover photograph of Peirson’s milk-vetch
(*Astragalus magdalenae* var. *peirsonii*)
by Debbie Sebesta

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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 Allan 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: 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. Florencio Bravo, Neil Hamada, Jeff Hyrcko, and Bob Bower drove the dune buggy used in the survey of the southern portion of the dunes. Special thanks to Debbie Sebesta and Florencio Bravo, who braved the notorious summertime temperatures of the dunes to finish the monitoring, and to Neil Hamada, who made his personal dune buggy available for much of the monitoring.

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.

Executive Summary

A monitoring study of the special status plants of the Algodones Dunes, Imperial County, California, was conducted in spring and summer 1998. The study was designed to allow comparisons with an earlier study performed in 1977 by the consulting firm WESTEC, under contract to the Bureau of Land Management, as well as to monitor the status of the plants into the future.

The major management issue in the Algodones Dunes concerns the effects of off-highway vehicle (OHV) use on the 6 special status plants of the dunes, including Peirson's milk-vetch, listed as threatened by the U.S. Fish and Wildlife Service and as endangered by the State of California, and Algodones Dunes sunflower, listed as endangered by the State. 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 observers. Each transect consisted of contiguous cells 0.45 miles on a side. For each cell, observers placed each of the 6 species into one of 5 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).

Although there are some limitations inherent in the data collected both in this and the WESTEC study, the 1998 data indicate that all 6 special status plants are at least as abundant and widespread in the entire dune system as they were in 1977. Further, their distribution and abundance in the OHV open area appear to be at least as great as was the case in 1977, with the possible exception of sand food, which may have declined somewhat. It is possible, however, that this apparent decline is an artifact of the time of sampling: because of logistical problems, the southern, open area of the dunes was sampled about two months later than the northern, closed area of the dunes.

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 6 species appear to be at least as widespread and abundant in the entire open area in 1998 as they were in 1977, 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 trend would be expected to continue only if the current OHV use

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[1] As this goes to press it appears likely that a Federal District Court Judge will order the temporary closure of additional areas of the dunes until Endangered Species Act Section 7 consultation with the U.S. Fish and Wildlife Service is completed concerning the effects of the continued implementation of the California Desert Conservation Area Plan on Peirson's milk-vetch.

patterns in the dunes remain relatively unchanged. Monitoring to detect changes in OHV use patterns is being conducted through a separate study using aerial photography.

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). 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).

Vegetation and Special Status Plants

Five plant communities occur in and around the dune system (WESTEC 1977). The most extensive of these is desert psammophytic scrub, a community adapted to the mobile sand and deep water percolation characteristics of the dunes proper (WESTEC 1977). This community provides habitat for the following plant species, five of which are BLM special status plants:

Astragalus lentiginosus var. *borreganus* (Borrego milk-vetch)
Astraglaus 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)

Astraglaus 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.

OHV Use

Although residents of the Imperial Valley had begun to use automobiles with oversized tires as early as the 1950s, intensive OHV use of the dunes did not begin until the 1970s, with the design of specialized vehicles called dune buggies that were capable of climbing even the steepest dunes (WESTEC 1977). Recreational use of the dunes by OHV enthusiasts on major holiday weekends has increased from a level of about 15,000 people in 1977 to about 90,000 people in 1998 (WESTEC 1977; BLM records).

WESTEC 1977 Study

BLM closed much of the northern portion of the dunes (most of the area currently designated as wilderness) in 1972 to protect occurrences of the six special status plants. In 1977 the agency contracted a study to determine, among other things, the distribution and abundance of the six special status plants in the dunes. That study was undertaken by the consulting firm, WESTEC. The results are presented in a report submitted to BLM by WESTEC (1977). [2]

The methodology used by WESTEC was as follows. WESTEC superimposed a grid onto a map of the Algodones Dunes, corresponding to what WESTEC called the "California Coordinate System" (BLM's mapping experts have not heard of this system, nor have they been able to find reference to it). The vertical and horizontal lines of the grid run (at least approximately) true north-south and west-east, respectively (Map 3). The cells (called quadrants by WESTEC) formed by this grid are approximately 0.45 miles on a side. 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. It is unclear exactly how many cells WESTEC actually visited in the area closed to OHVs. The methodology used for the closed area is described by WESTEC (1977, page 47) as follows:

> Field surveys of areas closed to ORV use were made by helicopter and by two-man ground crews staged by the helicopter. Initial assessment of vegetation was made by helicopter, flying at a slow speed at approximately 50 feet above ground surface. Numerical ranking of densities of sensitive plant species and location of vegetation associations were recorded on printed strip topographic maps in the same manner as done by the vehicular survey in the open ORV areas. After completion of the aerial survey, two-man ground survey teams were placed by helicopter in areas requiring further analysis including possible habitats for *Ammobroma sonorae*. After completion of the ground survey in the ORV closed area, field crews were airlifted into other areas of the dunes requiring additional analysis.

Thus, it appears that WESTEC ranked cells for all species except *Ammobroma sonorae* from the air.

For all of the species except *Pholisma sonorae*, WESTEC used the following abundance (density) classes:

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[2] A seventh species, *Eriogonum deserticola*, was also included in WESTEC's survey. In 1977, this species was considered to be rare. No agency or organization currently treats this species as rare; consequently, it was not a target for the 1998 monitoring.

Density Class	Density 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.

Note that the density class values are relative, allowing comparison only of population sizes within species, not between species. Because of the underground attachment of the parasitic plant, *Pholisma sonorae*, a different set of density classes was used for this species:

Pholisma Density Class	Density 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.

The results of the WESTEC study are reported in WESTEC (1977). That report includes fold-out maps, each of which has the grid used to conduct the survey superimposed on it. Separate maps are provided for each species, with dots in the middle of each cell in which that species was encountered. Different sized dots are employed that correspond to the abundance estimated for each cell, with the smallest dot corresponding to abundance class 1 and increasingly larger dots corresponding to abundance classes 2, 3, and 4. Five of the six special status plants occurred both in the open and closed OHV areas of the dunes. *Astragalus lentiginosus* var. *borreganus* was found to occur only in a few cells in the southern, open part of the dunes. The dunes, however, account for only a small proportion of this species' total distribution, which ranges from the central and eastern Mojave desert to the eastern Colorado desert in California; it also occurs in Arizona and Sonora, Mexico (WESTEC 1977; Munz 1974).

Based on the results of the WESTEC study, BLM continued the management prescription in effect at the time of the 1977 study: to retain the closed and open OHV areas as designated. [3] Based on discussions with the authors of the California Desert Conservation Area Plan, which was finalized in 1981, this decision was based on the determination that the existing OHV activity was unlikely to jeopardize any of the species or result in the need to list them. The reasoning behind this determination was that all of the species (except for *Astragalus lentiginosus* var. *borreganus*) were well distributed in the northern, closed area of the dunes. These northern occurrences would be expected to remain viable. Additionally, even though the southern dunes are officially open to OHV use, many parts of the dunes within the open area are little used by OHVs because they are far away from OHV staging areas. Thus, BLM concluded that the species would remain viable even in much of the southern, open area of the dunes.

ECOS 1990 Study

Until 1990 no further attempts were made to directly monitor the special status plants of the dunes.[4] BLM personnel would make observations on the presence of the species and any apparent impacts to them from OHV use. These observations, however, were largely limited to the periphery of the dunes or near OHV staging areas. In 1990 BLM contracted with the consulting firm ECOS to design a monitoring study that could be used to regularly monitor the effects of OHVs on the special status plants in the dunes. The idea was for the contractor to design the study and collect the first year's data, which would then serve as a baseline. BLM personnel would then continue the monitoring in future years.

The contractor designed and implemented the monitoring study and presented BLM with a report (ECOS 1990). Unfortunately, the study design was flawed in several ways. As a result it was not continued. The most serious flaw involved the selection of study sites. Study sites were subjectively located near roads to make them readily accessible by observers. This does not allow inferences to be made to the entire dune system. The study also did not adequately sample the open area. Although the study purported to make inferences to the entire open area, the four study sites chosen for this purpose were all within 1 mile of potential OHV access sites. Because these areas are close to potential staging areas for OHVs, results from these sites will be biased toward relatively heavy OHV use (as opposed to the situation if at least some of the sites had been located in the more interior portions of the open area). Moreover, there was very poor interspersion of study sites throughout the open area: the entire southern and eastern portions of the open area were unsampled.

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[3] The closed area was increased by about 60 acres in 1994 with the closure of an area on the eastern portion of the dunes just north of State Highway 78 that had previously been open.

[4] A study of the ecology of the six species was conducted by Romspert and Burk (1979).

Another problem with the ECOS study was that it was conducted during a poor rainfall year. Precipitation at Gold Rock Ranch, just east of the southern half of the dunes (see Map 4), was 1.86 inches between July 1989 and June 1990, less than half of the average of 3.89 inches. Moreover, 1.3 inches of that total fell in July 1989; only 0.56 inches fell between August 1989 and June 1990. Six of the seven months between September 1989 and April 1990 were completely dry; only January, with 0.23 inches, had any effective precipitation (Figure 2). As a result, few of the target plant species were found. Although all of the special status plants are perennials, few to no above-ground parts of the plants will be found if there has been no rainfall.

Methods

In February 1998, BLM met with the California Department of Fish and Game and the California Native Plant Society to discuss monitoring at the Algodones Dunes. Southern California was benefitting from above-average rainfall resulting from an El Niño event, and the three agencies decided that they should take advantage of this by implementing monitoring in the dunes in spring 1998. Because of the problems associated with the ECOS study, the team determined that continuing that methodology would serve no useful purpose.

The team decided to use the basic methodology implemented by WESTEC in 1977 for two reasons: (1) it covered the entire dune system, and (2) the 1998 data could be compared to the 1977 data. The grid used by WESTEC was duplicated using the Geographical Information System (GIS), ArcInfo (ESRI 1998). Although the only maps available were those produced in the 1997 WESTEC report, BLM Mapping Sciences was able to duplicate the grid with what appears to be a remarkable degree of accuracy (the cartographer who mapped the original WESTEC grid apparently paid considerable attention to detail). Once this grid was created, the GIS was used to list the coordinates corresponding to the latitudes of transects run through the middle of each west-east row of cells (i.e., equidistant from the northern and southern boundary of each row) and the longitudes of the sides of each cell encountered along each west-east transect.

The null hypothesis to be tested was that there was no change in the abundance of the 6 species as determined in 1977 by WESTEC and in 1998 from the current study in the dunes as a whole, in the closed area, and in the open area.

Adequate resources were not available to run transects over the total of 66 west-east rows used in the WESTEC study. Consequently, a sample of rows was selected within which transects would be run. The 66 rows formed the population of rows that would be sampled. Each transect would sample every cell it traversed. For sampling purposes, the dunes were stratified into the following four strata: (1) the north open area (the area at the far north of the dunes that is designated open to OHV use; (2) the closed (wilderness) area (the area north of State Highway 78 and south of the north open area), (3) the northern half of the south open area, and (4) the southern half of the south open area (because of its size, the south open area was divided into two strata to ensure good interspersion of sampled rows throughout the area). Before selecting samples from each of these four strata, several rows were eliminated from the target population for logistical reasons. These included 4 rows near State Highway 78 that straddled both the closed and open areas (eliminated because of potential confounding effects), 1 row at the extreme northern end of the dunes because it straddled private orange groves and public lands, and 6 rows in the extreme southern part of the dunes because of the logistical problems in sampling these rows because of Interstate 8 and the All American Canal.

Thirty-one randomly selected rows were allocated among the four strata, as follows:

Northern, open area (dunes north of the North Algodones Dunes Wilderness): 4 transects
Closed area (North Algodones Dunes Wilderness): 10 transects
Northern part of southern open area: 8 transects
Southern part of southern open area: 9 transects

After this sample of 31 rows was selected, management requested that the 6 rows near the south end of the dunes be added back to the target population because of concerns that the proposed Herman Schneider Bridge might result in changes in OHV use patterns in that area of the dunes. It was decided to sample every other one of these 6 rows, which added 3 more rows to the sample, for a total of 34. Map 5 shows the positioning of these transects.

Thirty-four transects were run through the centers of each row of cells. 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 abundance class rankings used in the study are described below.

The closed area was sampled by teams of two observers who traversed each transect on foot. The open areas were 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.

Abundance Class Values

The 1998 study used abundance class values different from those used in the WESTEC study. Although at first it may seem unwise to change the definition of the abundance classes between studies, with the result that the 1998 data may not be directly comparable to the 1977 data, this was done for two reasons. First, it was felt that the WESTEC abundance classes were far too subjective, with the probable result that different observers would place sites that are the same in terms of density in different abundance classes. This introduces a large amount of non-sampling error into the study, and there is no means of determining the magnitude of this error. Since we intend to repeat the 1998 study in the future, it was necessary to derive a more objective set of abundance classes. Second, we believed that the definitions of some of the WESTEC abundance classes were not practical, in particular the class requiring the observer to estimate the abundance of the species up to 1/4 mile away and the class that requires the observer to make a determination as to how the abundance of a particular cell compares to the abundances of other cells in the dunes (how can an observer know how cells rated early in the study compare with cells that have not yet been observed?).

For all plants except *Pholisma sonorae* the following abundance classes were used:

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

For *Pholisma sonorae* the following abundance class codes were used:

Pholisma Density Class	Density 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.

Growing Season Precipitation

Precipitation data was collected from the Western Regional Climate Center for the following weather stations: Blythe CAA Airport, 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 closet 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. Because it is more than 50 miles from the dunes, the Blythe weather data were not used in the analysis. Yuma WSO AP weather data were also excluded from the analysis because no data for 1997-1998 were available and Yuma Citrus Station data for 1976-1977 were similar to those from Yuma WSO AP.

Precipitation data was collected for the following growing seasons: 1976-1977, immediately preceding the WESTEC study; 1989-1990, immediately preceding the ECOS study; and 1997-1998, immediately preceding the current study. Both Gold Rock Ranch and Yuma WSP AP stopped collecting weather data in 1996. Thus, while precipitation records from these station are available for the 1976-1977 growing season immediately preceding the WESTEC study, they are unavailable for the 1997-1998 growing season preceding the current study. This is unfortunate, particularly in the case of Gold Rock Ranch, because it does not allow for a direct comparison of weather data between the two monitoring periods. This is important because there can be large differences between the amount of precipitation recorded during the same month at different stations. This is illustrated by Figures 1-3, which shows the monthly variability between the 8 weather stations in the 1976-1977, 1989-1990, and 1997-1998 growing seasons, respectively.

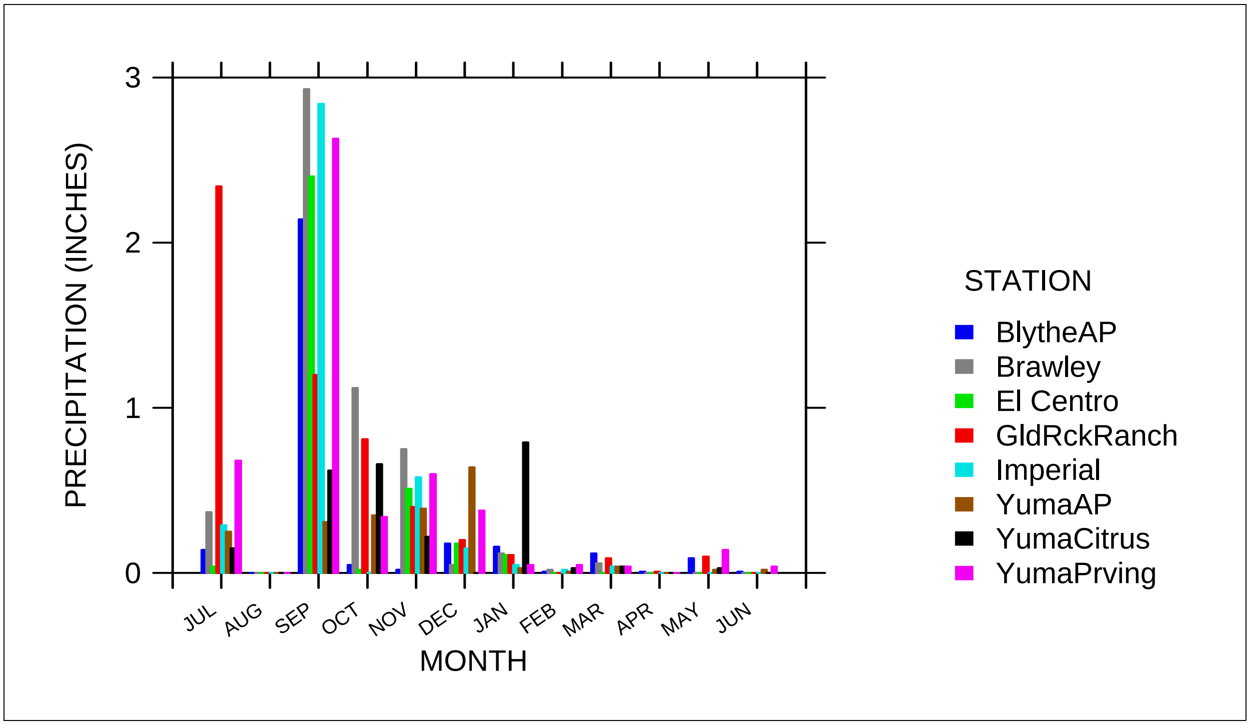

Figure 1. Monthly growing season precipitation for 1976-1977 at 8 weather stations in the vicinity of the Algodones Dunes.

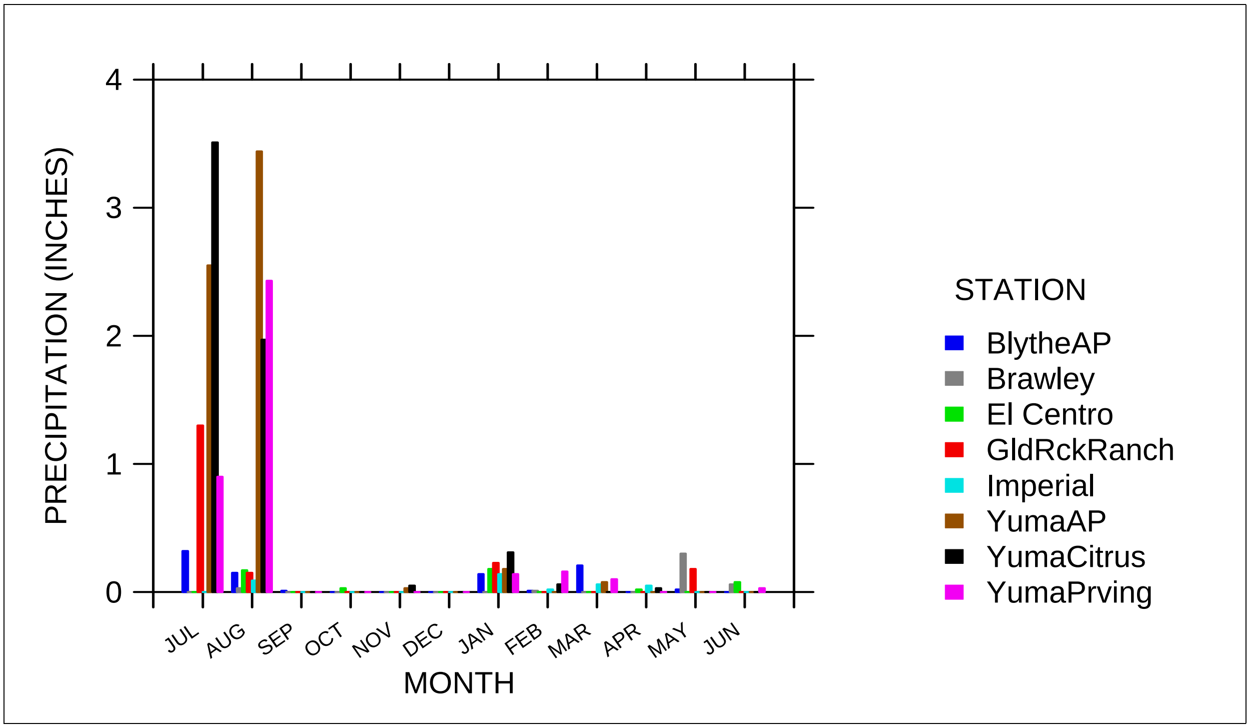

Figure 2. Monthly growing season precipitation for 1989-1990 at 8 weather stations in the vicinity of the Algodones Dunes.

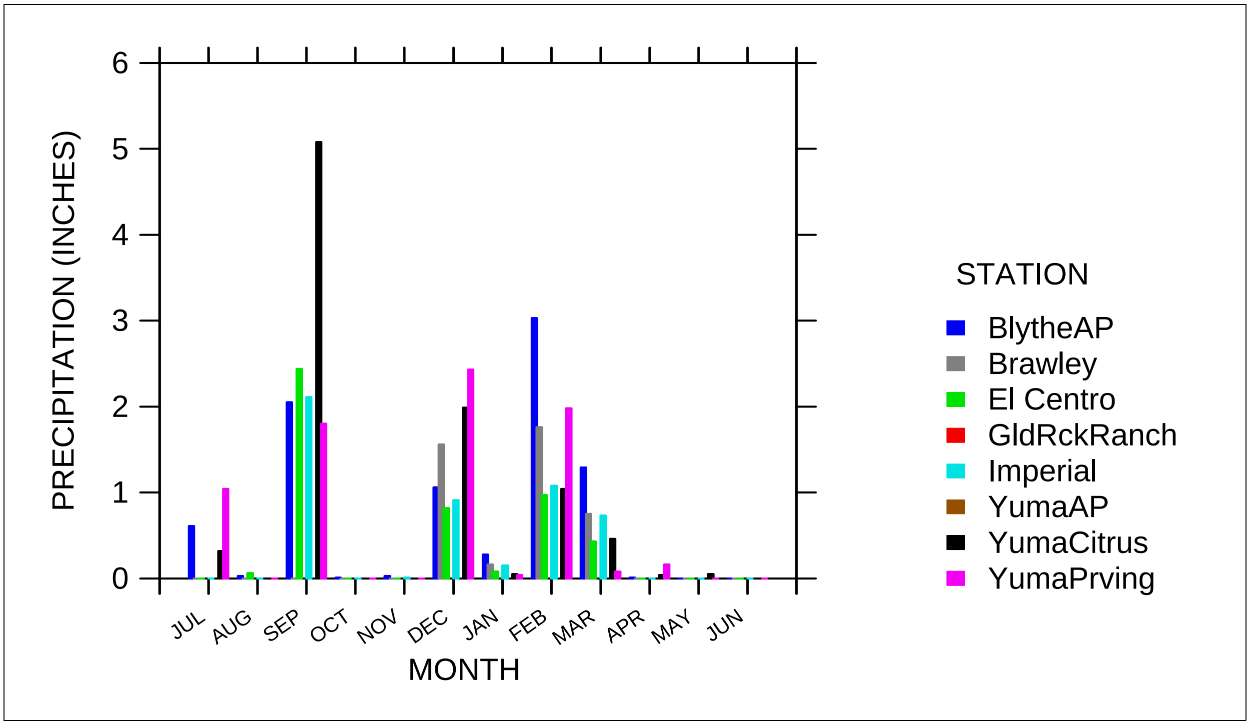

Figure 3. Monthly growing season precipitation for 1997-1998 at 8 weather stations in the vicinity of the Algodones Dunes.

Results and Analysis

Monitoring took place between 9 April and 29 August 1998. The following table shows the dates the transects were surveyed.

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		

Transects 19-34 were surveyed later than planned because of mechanical problems encountered with the dune buggy used. A new dune buggy was purchased to complete the study. The 6 target plant species, with the possible exception of *Pholisma sonorae* (discussed in more detail below), were still identifiable during the August surveys.

A total of 542 cells were surveyed along the 34 transects. Abundance class values were assigned to the adult and seedling classes of each target species. Actual tallies of the numbers of adult plants encountered during the survey were also made. Some teams also tallied seedlings of each species, though the study design did not call for this. Because WESTEC did not distinguish between adults and seedlings, the higher of the two abundance class values–adult and seedling–was used in the following analysis (i.e., if the abundance class value for adult plants of one of the species was 2 and the seedling abundance class was 3, the value 3 was used in the analysis).

Changes in Occupied Cells and Cell Abundance Class Values

Abundance class maps. Abundance class maps similar to those developed by WESTEC were developed for each species, but only for the cells along the transects run in 1998. For each species there are 3 such maps, one showing the cell abundance classes determined by WESTEC in 1977, one showing the abundance classes of the cells encountered during the 1998 study, and one showing the differences between the abundance classes recorded between the two periods.

Maps 6-8 show *Astragalus lentiginosus* var. *borreganus*, Maps 9-11 show *Astraglaus magdalenae* var. *peirsonii*, Maps 12-14 show *Croton wigginsii*, Maps 15-17 show *Helianthus niveus* ssp. *tephrodes*, Maps 18-20 show *Palafoxia arida* var. *gigantea*, and Maps 21-23 show *Pholisma sonorae*.

Tables summarizing cell changes. The following tables show the numbers of cells occupied by each species out of the total of 542 cells surveyed in 1998, compared to the numbers obtained by WESTEC in 1977. Numbers are given for the entire dunes (542 cells), the closed area only (132 cells), and the open area only (410 cells). The tables also show how the species abundance class values for the cells surveyed changed between 1977 and 1998. Shown, again for the entire dunes, the closed area only, and the open area only, are the number of cells that increased, decreased, or stayed the same between 1977 and 1998, along with the magnitude of any increase or decrease. These data were used to prepare the abundance class maps.

As the tables show, the number of cells occupied increased in the entire dunes for all 6 species between 1977 and 1998. The same trend occurred in the open area for every species but *Pholisma sonorae*, which showed a decrease in the number of cells occupied. This difference may be an artifact of the later sampling of the southern, open part of the dunes, and not a result of any actual change between the two time periods. This is discussed in more detail under the transect analysis section below.

In the closed area, the number of cells occupied increased between 1977 and 1998 for all species except *Astragalus lentiginosus* var. *borreganus*, which apparently does not occur in the closed area and *Helianthus niveus* ssp. *tephrodes*, which showed a decline in the number of cells occupied. Possible reasons for this are discussed in the transect analysis section below.

The changes in abundance class values between 1977 and 1998 show almost the same trend as the changes in occupied cells. For the entire dunes, abundance class values increased for all 6 species (i.e., more cells showed increases than showed decreases–this is summarized in the three rows at the bottom of the tables). In the closed area, abundance class values increased for *Croton wigginsii*, *Palafoxia arida* var. *gigantea*, and *Pholisma sonorae*. Since *Astragalus lentiginosus* var. *borreganus* does not occur in the closed area, there was no change in the abundance class values for that species. *Helianthus niveus* ssp. *tephrodes* and *Astraglaus magdalenae* var. *peirsonii* both showed decreases. For *Helianthus*, this mirrors the change in occupied cells, but the decrease in abundance class values for *Astraglaus magdalenae* var. *peirsonii* differs from the response observed when looking at the change in occupied cells: while this species occupied 3 more cells in 1998 than in 1977, three more cells decreased in abundance class values than increased.

In the open area, all species except *Pholisma sonorae* increased in abundance class values. Abundance class values for *Pholisma sonorae* decreased in more cells than they increased. As noted above and discussed in detail in the section titled “Analysis of Changes Observed Along Transects,” below, this apparent decrease may be an artifact of sampling.

Astragalus lentiginosus* var. *borreganus

	Entire Dunes (542 Total Cells)	Closed Area (132 Total Cells)	Open Area (410 Total Cells)
No. cells occupied			
1998	27	0	27
1977	16	0	16
Difference 1998-1977	+11	0	+11
Abundance class differences between 1977 and 1998			
No. cells increased by 4 units	0	0	0
No. cells increased by 3 units	1	0	1
No. cells increased by 2 units	8	0	8
No. cells increased by 1 unit	15	0	15
No. cells unchanged	504	132	372
No. cells decreased by 1 unit	4	0	4
No. cells decreased by 2 units	8	0	8
No. cells decreased by 3 units	2	0	2
No. cells decreased by 4 units	0	0	0
Summary of abundance class differences 1977 - 1998			
Total cells increased	24	0	24
Total cells decreased	14	0	14
Increased - Decreased	+10	0	+10

Astragalus magdalenae* var. *peirsonii

	Entire Dunes (542 Total Cells)	Closed Area (132 Total Cells)	Open Area (410 Total Cells)
No. cells occupied			
1998	122	31	91
1977	90	28	62
Difference 1998-1977	+32	+3	+29
Abundance class differences			
No. cells increased by 4 units	0	0	0
No. cells increased by 3 units	7	0	7
No. cells increased by 2 units	43	8	35
No. cells increased by 1 unit	39	6	33
No. cells unchanged	399	101	298
No. cells decreased by 1 unit	31	9	22
No. cells decreased by 2 units	22	7	15
No. cells decreased by 3 units	1	1	0
No. cells decreased by 4 units	0	0	0
Summary of abundance class differences 1977 - 1998			
Total cells increased	89	14	75
Total cells decreased	54	17	37
Increased - Decreased	+35	-3	+38

Croton wigginsii

	Entire Dunes (542 Total Cells)	Closed Area (132 Total Cells)	Open Area (410 Total Cells)
No. cells occupied			
1998	163	32	131
1977	90	25	65
Difference 1998-1977	+73	+7	+66
Abundance class differences			
No. cells increased by 4 units	2	0	2
No. cells increased by 3 units	34	3	31
No. cells increased by 2 units	58	14	44
No. cells increased by 1 unit	33	6	27
No. cells unchanged	374	96	278
No. cells decreased by 1 unit	25	7	18
No. cells decreased by 2 units	13	5	8
No. cells decreased by 3 units	3	1	2
No. cells decreased by 4 units	0	0	0
Summary of abundance class differences 1977 - 1998			
Total cells increased	127	23	104
Total cells decreased	41	13	28
Increased - Decreased	+86	+10	+76

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

	Entire Dunes (542 Total Cells)	Closed Area (132 Total Cells)	Open Area (410 Total Cells)
No. cells occupied			
1998	168	25	143
1977	129	43	86
Difference 1998-1977	+39	-18	+57
Abundance class differences			
No. cells increased by 4 units	3	0	3
No. cells increased by 3 units	43	3	40
No. cells increased by 2 units	60	4	56
No. cells increased by 1 unit	35	9	26
No. cells unchanged	326	80	246
No. cells decreased by 1 unit	35	15	20
No. cells decreased by 2 units	35	17	18
No. cells decreased by 3 units	5	4	1
No. cells decreased by 4 units	0	0	0
Summary of abundance class differences 1977 - 1998			
Total cells increased	141	16	125
Total cells decreased	75	36	39
Increased - Decreased	+66	-20	+86

Palafoxia arida* var. *gigantea

	Entire Dunes (542 Total Cells)	Closed Area (132 Total Cells)	Open Area (410 Total Cells)
No. cells occupied			
1998	350	92	258
1977	144	44	100
Difference 1998-1977	+206	+48	+158
Abundance class differences			
No. cells increased by 4 units	3	3	0
No. cells increased by 3 units	28	12	16
No. cells increased by 2 units	146	36	110
No. cells increased by 1 unit	116	27	89
No. cells unchanged	202	46	156
No. cells decreased by 1 unit	42	8	34
No. cells decreased by 2 units	5	0	5
No. cells decreased by 3 units	0	0	0
No. cells decreased by 4 units	0	0	0
Summary of abundance class differences 1977 - 1998			
Total cells increased	293	78	215
Total cells decreased	47	8	39
Increased - Decreased	+246	+70	+176

Pholisma sonorae

	Entire Dunes (542 Total Cells)	Closed Area (132 Total Cells)	Open Area (410 Total Cells)
No. cells occupied			
1998	54	33	21
1977	39	6	33
Difference 1998-1977	+15	+27	-12
Abundance class differences			
No. cells increased by 4 units	2	1	1
No. cells increased by 3 units	3	2	1
No. cells increased by 2 units	19	16	3
No. cells increased by 1 unit	28	13	15
No. cells unchanged	453	95	358
No. cells decreased by 1 unit	26	4	22
No. cells decreased by 2 units	6	1	5
No. cells decreased by 3 units	3	0	3
No. cells decreased by 4 units	2	0	2
Summary of abundance class differences 1977 - 1998			
Total cells increased	52	32	20
Total cells decreased	37	5	32
Increased - Decreased	+15	+27	-12

Bar Graphs of Mean Transect Abundance Classes and Frequencies

Although the above information on changes in the numbers of occupied cells and cell abundance class values between 1977 and 1998 gives insight into the status of the 6 species between the two time periods, statistical analysis is not appropriately applied to the cell values. That is because the transects, not the cells along them, were randomly selected. It is therefore appropriate to analyze the transects as the sampling units.

Figures 4-37 are bar graphs showing mean transect abundance class values and mean transect frequencies for each of the 6 species. Except for *Astragalus lentiginosus* var. *borreganus,* which was not found in either year in the closed area, there are 6 bar graphs for each species, three showing mean abundance class values for the entire dunes, the closed area, and the open area, and three showing mean transect frequencies for the entire dunes, the closed area and the open area.

The graphs were generated using the program SYSTAT (SPSS 1998). Each graph compares mean values for the transects run in 1998 with the values for the same transects run by WESTEC in 1977 (i.e., the cell values observed by WESTEC for the cells comprising the 1998 transects were used to compute 1977 transect values). The graphs on the left of each page compare mean transect abundance class values for each species (in the entire dunes, closed area, and open area) between the two time periods. Abundance class values for each cell along a transect were added together and divided by the total number of cells for that transect to compute an abundance class value for the transect. The mean of all the transect values 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. Abundance classes for 1977 are those used by WESTEC. Abundance classes for 1998 are the higher of the adult and seedling abundance classes, which were recorded separately. The higher abundance class was used because WESTEC did not record seedlings and adults separately.

Because the abundance classes were defined somewhat differently between the two time periods (for reasons previously discussed), comparisons have also been made between mean transect frequencies in 1977 and 1998. These results, given for each species on the right side of each page, ignore abundance class values and focus only on whether the species was observed in a particular cell. Frequency values for each transect were calculated by dividing the number of cells along the transect in which the species was observed by the total number of cells along the transect. Mean frequency transect values and 95% confidence intervals were then computed for each area compared.

As the graphs show, the basic trend was the same for each species regardless of whether mean abundance class values or frequencies were used. The graphs are shown here primarily to illustrate this fact. If the transects had been independently selected in each year, inspection of the graphs to determine if the 95% confidence intervals overlap would be a crude way to visually determine if observed differences were statistically significant (at the $P < 0.05$ level). Because, however, the transects are paired between the two time periods (i.e., the transects that were randomly selected in 1998 are the same ones used for the 1977 data), analysis is appropriately carried out by means of paired significance tests. Results of this analysis are given in the next section.

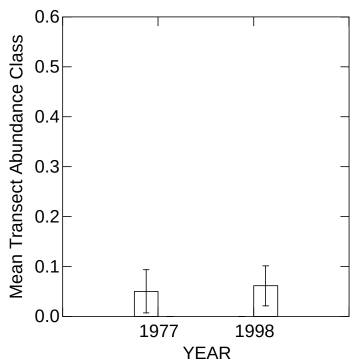

Figure 4. *Astragalus lentiginosus* var. *borreganus* mean transect abundance class values for entire dunes. Error bars are 95% confidence intervals.

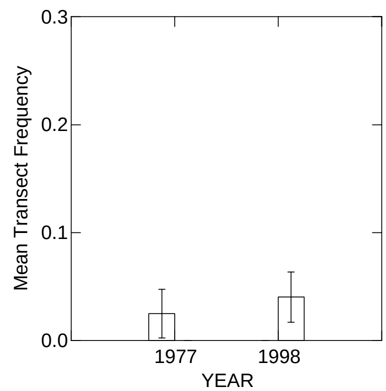

Figure 6. *Astragalus lentiginosus* var. *borreganus* mean frequencies for entire dunes. Error bars are 95% confidence intervals.

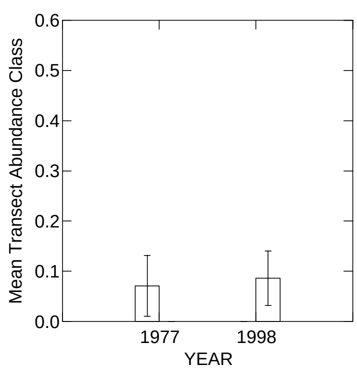

Figure 5. *Astragalus lentiginosus* var. *borreganus* mean transect abundance class values for open area. Error bars are 95% confidence intervals.

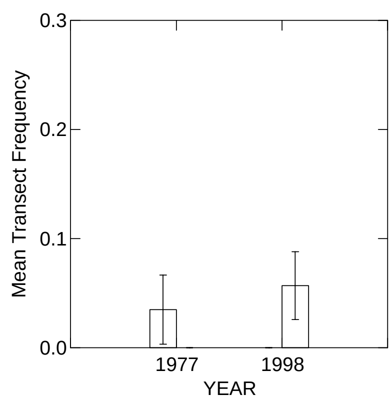

Figure 7. *Astragalus lentiginosus* var. *borreganus* mean transect frequencies for open area. Error bars are 95% confidence intervals.

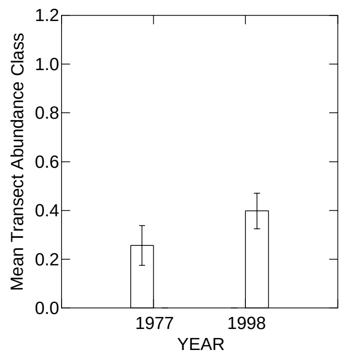

Figure 8. *Astragalus magdalenae* var. *peirsonii* mean transect abundance class values for entire dunes. Error bars are 95% confidence intervals.

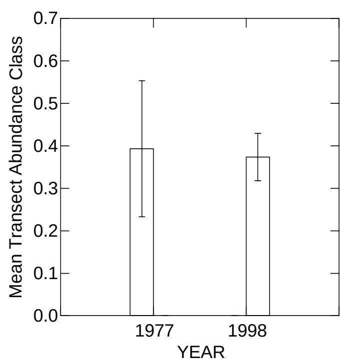

Figure 9. *Astragalus magdalenae* var. *peirsonii* mean transect abundance class values for closed area. Error bars are 95% confidence intervals.

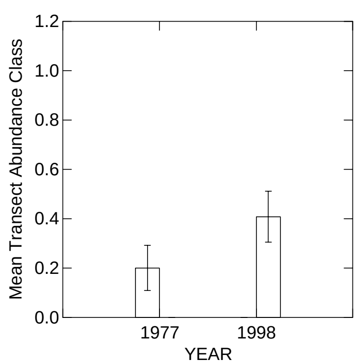

Figure 10. *Astragalus magdalenae* var. *peirsonii* mean transect abundance class values for open area. Error bars are 95% confidence intervals.

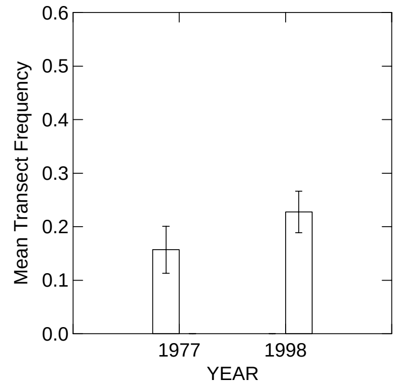

Figure 11. *Astragalus magdalenae* var. *peirsonii* mean transect frequencies for entire dunes. Error bars are 95% confidence intervals.

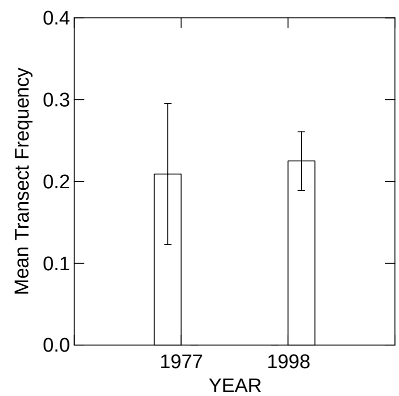

Figure 12. *Astragalus magdalenae* var. *peirsonii* mean transect frequencies for closed area. Error bars are 95% confidence intervals.

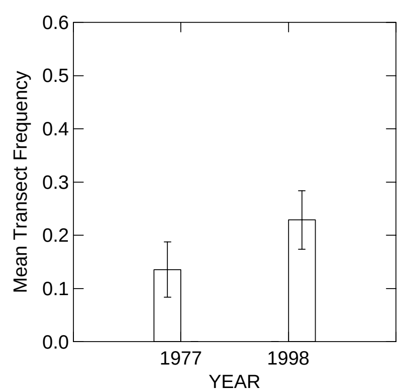

Figure 13. *Astragalus magdalenae* var. *peirsonii* mean transect frequencies for open area. Error bars are 95% confidence intervals.

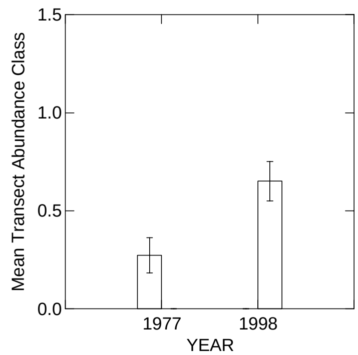

Figure 14. *Croton wigginsii* mean transect abundance class values for entire dunes. Error bars are 95% confidence intervals.

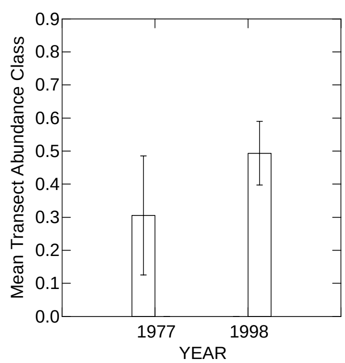

Figure 15. *Croton wigginsii* mean transect abundance class values for closed area. Error bars are 95% confidence intervals.

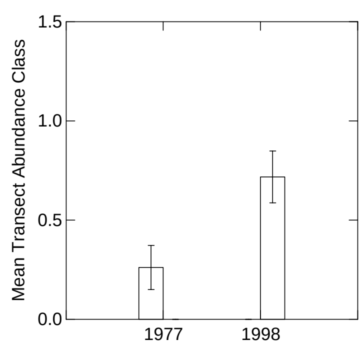

Figure 16. *Croton wigginsii* mean transect abundance class values for open area. Error bars are 95% confidence intervals.

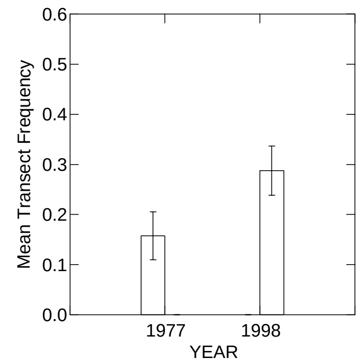

Figure 17. *Croton wigginsii* mean transect frequencies for entire dunes. Error bars are 95% confidence intervals.

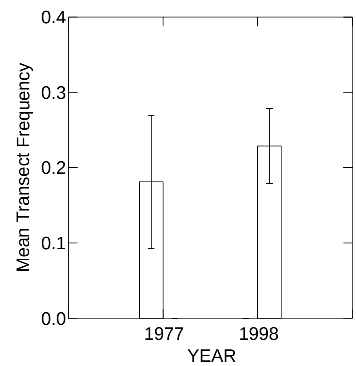

Figure 18. *Croton wigginsii* mean transect frequencies for closed area. Error bars are 95% confidence intervals.

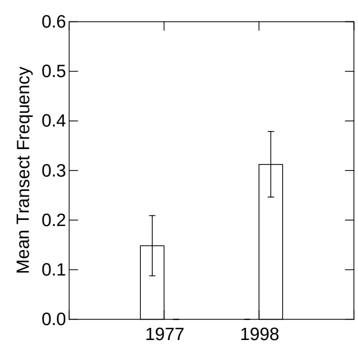

Figure 19. *Croton wigginsii* mean transect frequencies for open area. Error bars are 95% confidence intervals.

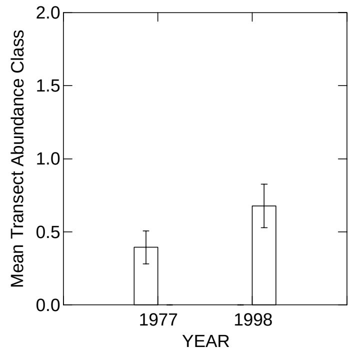

Figure 20. *Helianthus niveus* ssp. *tephrodes* mean transect abundance class values for entire dunes. Error bars are 95% confidence intervals.

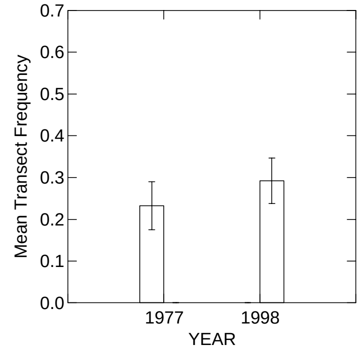

Figure 23. *Helianthus niveus* ssp. *tephrodes* mean transect frequencies for entire dunes. Error bars are 95% confidence intervals.

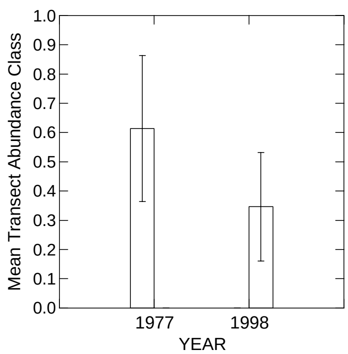

Figure 21. *Helianthus niveus* ssp. *tephrodes* mean transect abundance class values for closed area. Error bars are 95% confidence intervals.

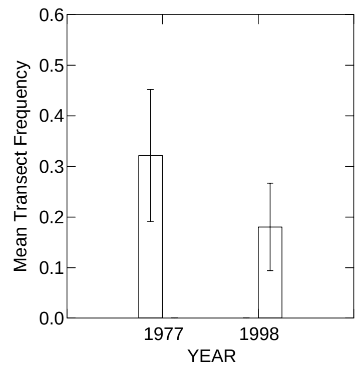

Figure 24. *Helianths* niveus ssp. *tephrodes* mean transect frequencies for closed area. Error bars are 95% confidence intervals.

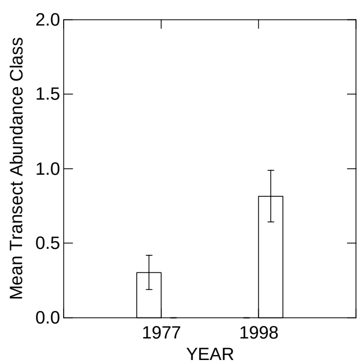

Figure 22. *Helianthus niveus* ssp. *tephrodes* mean transect abundance class values for open area. Error bars are 95% confidence intervals.

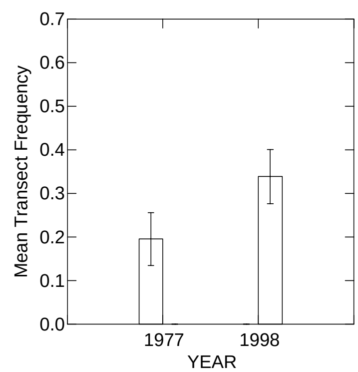

Figure 25. *Helianthus niveus* ssp. *tephrodes* mean transect frequencies for open area. Error bars are 95% confidence intervals.

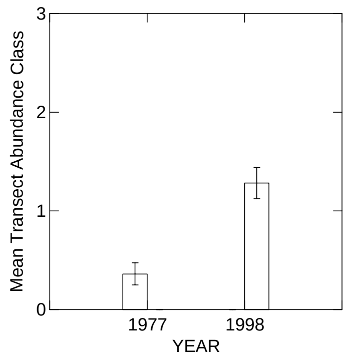

Figure 26. *Palafoxia arida* var. *gigantea* mean transect abundance class values for entire dunes. Error bars are 95% confidence intervals.

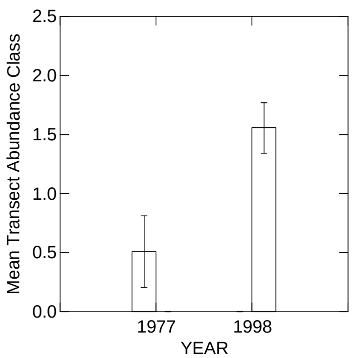

Figure 27. *Palafoxia arida* var. *gigantea* mean transect abundance class values for closed area. Error bars are 95% confidence intervals.

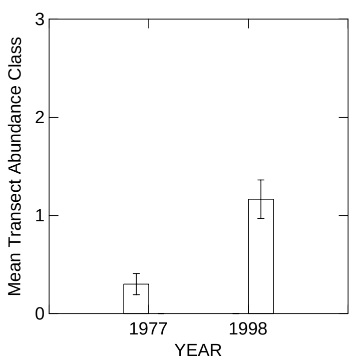

Figure 28. *Palafoxia arida* var. *gigantea* mean transect abundance class values for open area. Error bars are 95% confidence intervals

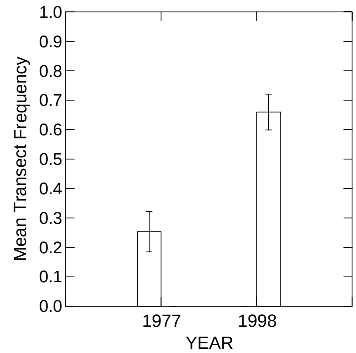

Figure 29. *Palafoxia arida* var. *gigantea* mean transect frequencies for entire dunes. Error bars are 95% confidence intervals.

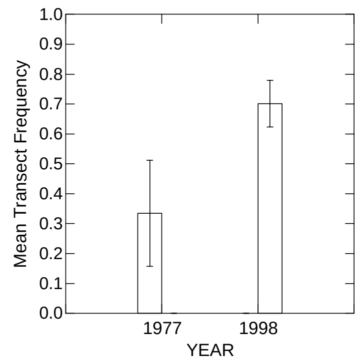

Figure 30. *Palafoxia arida* var. *gigantea* mean transect frequencies for closed area. Error bars are 95% confidence intervals.

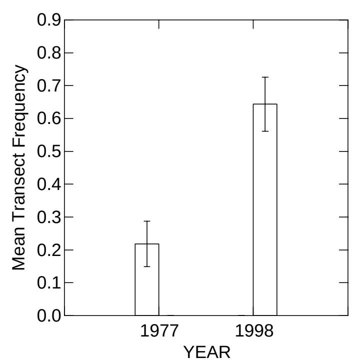

Figure 31. *Palafoxia arida* var. *gigantea* mean transect frequencies for open area. Error bars are 95% confidence intervals.

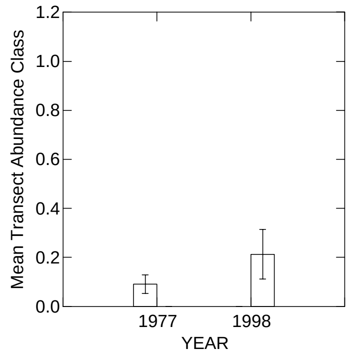

Figure 32. *Pholisma sonorae* mean transect abundance class values for entire dunes. Error bars are 95% confidence intervals.

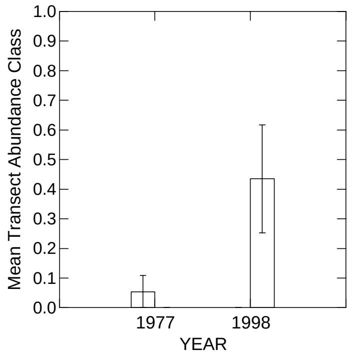

Figure 33. *Pholisma sonorae* mean transect abundance class values for closed area. Error bars are 95% confidence intervals.

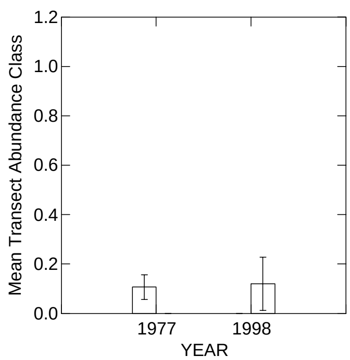

Figure 34. *Pholisma sonorae* mean transect abundance class values for open area. Error bars are 95% confidence intervals.

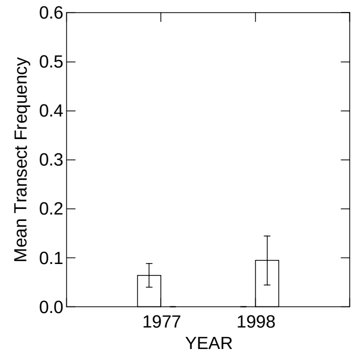

Figure 35. *Pholisma sonorae* mean transect frequencies for entire dunes. Error bars are 95% confidence intervals.

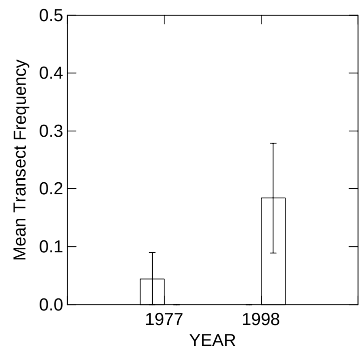

Figure 36. *Pholisma sonorae* mean transect frequencies for closed area. Error bars are 95% confidence intervals.

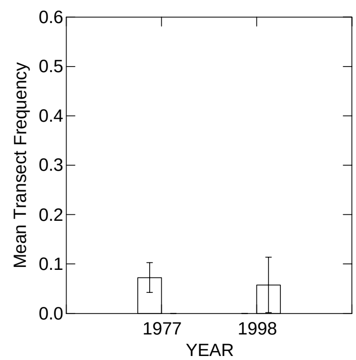

Figure 37. *Pholisma sonorae* mean transect frequencies for open area. Error bars are 95% confidence intervals.

Analysis of Changes Observed Along Transects

The tables below compare mean values for the transects run in 1998 with the values for the same transects run by WESTEC in 1977. The first table under each species compares mean transect abundance class values between the two time periods. Because the abundance classes were defined somewhat differently between the two time periods (for reasons previously discussed), comparisons have also been made between mean transect frequencies in 1977 and 1998. These results, given in the second table under each species, ignore abundance class values and focus only on whether the species was observed in a particular cell.

Both mean transect abundance class values and mean frequencies were compared by means of paired *t* tests, the results of which are shown in the tables below. The program SYSTAT (SPSS 1998) was used to conduct the tests. Actual *P* values are shown, along with asterisks corresponding to critical levels of significance. Single, double, and triple asterisks correspond to significance at $P < 0.05$, $P < 0.01$, and $P < 0.001$, respectively. No Bonferroni adjustment was applied to the threshold *P* values, despite the fact that the comparisons for the closed and open areas involve subsamples of the data set for the entire dunes, because these comparisons were planned prior to the study (Sheskin 2000:528).

The distribution of the differences between the 1998 and 1977 transect values are fairly well behaved, approximating a normal distribution to the extent that *t* tests would be expected to perform well. As a precaution, however, particularly since there is a sample size of only 10 transects in the closed area, paired-sample randomization tests were run on the data sets using the program RT (Manly 1997a). This procedure, described in detail by Manly (1997b:91-97), resamples the original data set many times. The test does not depend on any assumptions of normality and is apparently just as powerful as a parametric test even when all of the assumptions for the latter test are satisfied. The randomization *P* values for all of the tests shown below very closely correspond to the values obtained using *t* tests. The randomization *P* values are not given here, but are available from the author.

Astragalus lentiginosus* var. *borreganus

Area	Mean Transect Abundance Class Value		Sample Size (No. of transects)	*t* value (from paired *t* test)	*P*
	1977	1998			
Entire Dunes	0.050	0.061	34	0.430	0.670
Closed Area	0	0	10	#	#
Open Area	0.071	0.086	24	0.428	0.673

Insufficient data for test (plant apparently does not occur in closed area–all transect values were zero in 1977 and 1998).

Area	Mean Transect Frequency		Sample Size (No. of transects)	*t* value (from paired *t* test)	*P*
	1977	1998			
Entire Dunes	0.025	.040	34	1.002	0.324
Closed Area	0	0	10	#	#
Open Area	0.035	0.057	24	1.002	0.327

Insufficient data for test (plant apparently does not occur in closed area–all transect values were zero in 1977 and 1998).

Astragalus magdalenae* var. *peirsonii

Area	Mean Transect Abundance Class Value		Sample Size (No. of transects)	*t* value (from paired *t* test)	*P*
	1977	1998			
Entire Dunes	0.257	0.398	34	2.859	0.007 **
Closed Area	0.393	0.374	10	-0.244	0.812
Open Area	0.200	0.408	24	3.672	0.001 **

Area	Mean Transect Frequency		Sample Size (No. of transects)	*t* value (from paired *t* test)	*P*
	1977	1998			
Entire Dunes	0.157	0.228	34	2.440	0.020 *
Closed Area	0.209	0.225	10	0.353	0.732
Open Area	0.135	0.229	24	2.596	0.016 *

Croton wigginsii

Area	Mean Transect Abundance Class Value		Sample Size (No. of transects)	*t* value (from paired *t* test)	*P*
	1977	1998			
Entire Dunes	0.274	0.651	34	6.879	0.000 ***
Closed Area	0.305	0.494	10	2.069	0.068
Open Area	0.261	0.717	24	7.353	0.000 ***

Area	Mean Transect Frequency		Sample Size (No. of transects)	*t* value (from paired *t* test)	*P*
	1977	1998			
Entire Dunes	0.158	0.288	34	4.558	0.000 ***
Closed Area	0.181	0.229	10	1.084	0.307
Open Area	0.148	0.312	24	4.815	0.000 ***

Helianthus niveus* ssp. *tephrodes

Area	Mean Transect Abundance Class Value		Sample Size (No. of transects)	*t* value (from paired *t* test)	*P*
	1977	1998			
Entire Dunes	0.394	0.677	34	2.585	0.014 *
Closed Area	0.613	0.346	10	-1.557	0.154
Open Area	0.303	0.815	24	4.722	0.000 ***

Area	Mean Transect Frequency		Sample Size (No. of transects)	*t* value (from paired *t* test)	*P*
	1977	1998			
Entire Dunes	0.233	0.292	34	1.329	0.193
Closed Area	0.322	0.180	10	-1.575	0.150
Open Area	0.195	0.339	24	3.440	0.002 **

Palafoxia arida* var. *gigantea

Area	Mean Transect Abundance Class Value		Sample Size (No. of transects)	*t* value (from paired *t* test)	*P*
	1977	1998			
Entire Dunes	0.362	1.281	34	9.757	0.000 ***
Closed Area	0.510	1.557	10	7.905	0.000 ***
Open Area	0.301	1.166	24	7.127	0.000 ***

Area	Mean Transect Frequency		Sample Size (No. of transects)	*t* value (from paired *t* test)	*P*
	1977	1998			
Entire Dunes	0.253	0.660	34	8.582	0.000 ***
Closed Area	0.335	0.701	10	3.969	0.003 **
Open Area	0.218	0.643	24	7.565	0.000 ***

Pholisma sonorae

Area	Mean Transect Abundance Class Value		Sample Size (No. of transects)	*t* value (from paired *t* test)	*P*
	1977	1998			
Entire Dunes	0.091	0.213	34	2.125	0.041 *
Closed Area	0.053	0.435	10	4.998	0.001 **
Open Area	0.107	0.120	24	0.213	0.833

Area	Mean Transect Frequency		Sample Size (No. of transects)	*t* value (from paired *t* test)	*P*
	1977	1998			
Entire Dunes	0.064	0.095	34	1.034	0.309
Closed Area	0.044	0.184	10	2.906	0.017 *
Open Area	0.073	0.058	24	-0.460	0.650

Transect Abundance Class Comparisons. Changes in transect abundance class values are summarized below for the entire dunes, the closed area, and the open area.

Entire dunes. Sample mean transect abundance class values increased between 1977 and 1998 for every species. All of these increases, except the one observed for *Astragalus lentiginosus* var. *borreganus,* were statistically significant.

Closed area. Mean transect abundance class values increased significantly between 1977 and 1998 for *Croton wigginsii*, *Palafoxia arida* var. *gigantea*, and *Pholisma sonorae*. *Astragalus lentiginosus* var. *borreganus* is apparently confined to the southern part of the dunes, and was therefore not encountered in the closed area in either year. Sample means for *Astragalus magdelanae* var. *peirsonii* declined slightly in the closed area, but the decline was not close to being statistically significant ($P = 0.812$). Sample means for *Helianthus niveus* ssp. *tephrodes* also declined in the closed area; this difference was also not statistically significant at $P < 0.05$, but approached significance ($P = 0.154$).

Open area. Mean transect abundance class values increased significantly between 1977 and 1998 for *Astragalus magdelanae* var. *peirsonii*, *Croton wigginsii*, *Helianthus niveus* ssp. *tephrodes*, and *Palafoxia arida* var. *gigantea*. Sample mean values also increased for *Astragalus lentiginosus* var. *borreganus* and *Pholisma sonorae*, but these changes were not statistically significant.

Frequency Comparisons. Changes in transect frequencies are summarized below for the entire dunes, the closed area, and the open area.

Entire dunes. Mean transect frequency increased significantly between 1977 and 1998 for *Astragalus magdelanae* var. *peirsonii*, *Croton wigginsii*, *Helianthus niveus* ssp. *tephrodes*, and *Palafoxia arida* var. *gigantea*. It also increased for *Astragalus lentiginosus* var. *borreganus* and *Pholisma sonorae*, but these increases were not statistically significant.

Closed area. Mean transect frequency increased significantly in the closed area for *Palafoxia arida* var. *gigantea* and *Pholisma sonorae*. It also increased for *Astragalus magdelanae* var. *peirsonii* and *Croton wigginsii*, but these changes were not statistically significant (*Croton wigginsii* approached significance at $P = 0.068$). Note the difference between the mean transect frequency for *Astragalus magdelanae* var. *peirsonii*, which increased, and its mean transect abundance class values, which decreased. Just like the situation with the abundance class values, however, the increase in frequency was not close to being significant ($P = 0.732$). The sample mean transect frequency declined for *Helianthus niveus* ssp. *tephrodes*, but this decline was not statistically significant (though it approached significance at $P = 0.150$). *Astragalus lentiginosus* var. *borreganus* was not encountered in the closed area in either year.

Open area. Mean transect frequency increased significantly in the open area between 1977 and 1998 for *Astragalus magdelanae* var. *peirsonii*, *Croton wigginsii*, *Helianthus niveus* ssp. *tephrodes*, and *Palafoxia arida* var. *gigantea*. Frequency also increased for *Astragalus lentiginosus* var. *borreganus*, but the increase was not statistically significant. Frequency decreased for *Pholisma sonorae*, but the decrease was not close to being statistically significant ($P = 0.650$). Note the contrast between *Pholisma*'s decrease in frequency and the increase in mean transect abundance class; like the case for frequency, the change in mean transect abundance class was also not close to significance ($P = 0.833$).

Growing Season Precipitation

Figures 38 through 42 show monthly precipitation for the growing seasons immediately preceding the 1977 WESTEC study and the 1998 study for the following weather stations: Gold Rock Ranch (data available for the 1976-1977 growing season only), Brawley 2 SW, Imperial, El Centro, and Yuma Citrus Station. Locations of these stations in relationship to the Algodones Dunes are shown in Map 4. In general, the growing season precipitation preceding the 1998 monitoring study was higher than that preceding the 1977 study, but the magnitude of the difference varies by weather station. The biggest difference is shown at the Yuma Citrus Station, where 2.54 inches of rain were recorded in 1976-1977 as opposed to 9.03 inches in 1997-1998 (the 2.54 inches for 1976-1977 is low compared to the 5.26 inches recorded at Gold Rock Ranch during the same time period, but more than 2 inches of Gold Rock Ranch's total came from July, which may have had minimal effect on the germination and growth of plants observed the following spring). Two stations west of the dunes, however, showed much smaller differences in total growing season precipitation between 1976-1977 and 1997-1998: 3.26 inches compared to 4.83 inches for El Centro and 3.97 inches compared to 4.99 inches for Imperial. Brawley showed more total precipitation for 1976-1977, 5.42 inches, than for 1997-1998, 4.23 inches, but there is some indication this may be the result of a failure to record rainfall in September 1997. Both the Imperial and El Centro stations recorded September 1997 rainfall greater than 2 inches; it seems improbable that no trace of this rainfall would have reached Brawley.

Except for Yuma Citrus Station, where 1976-1977 growing season precipitation was 95 percent of the long-term mean, both the 1976-1977 and 1997-1998 growing season precipitation were above normal, as shown in the table below.

	Percent of Long-Term Mean Precipitation by Growing Season	
Weather Station	1976-1977	1997-1998
Gold Rock Ranch	132%	No data
Yuma Citrus Station	95%	339%
Brawley 2 SW	198%	154%
El Centro	119%	176%
Imperial	149%	188%

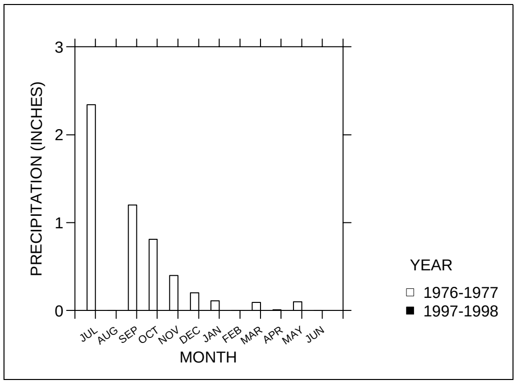

Figure 38. Monthly growing season precipitation at Gold Rock Ranch (data available for 1976-1977 only). Total growing season precipitation: 5.26 in. Long-term mean 4.00 in.

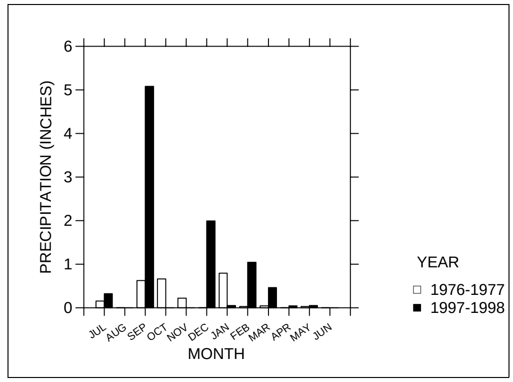

Figure 39. Monthly growing season precipitation at Yuma Citrus Station. Total growing season precipitation: 1976-1977: 2.54 in.; 1997-1998: 9.03 in. Long-term mean 2.66 in.

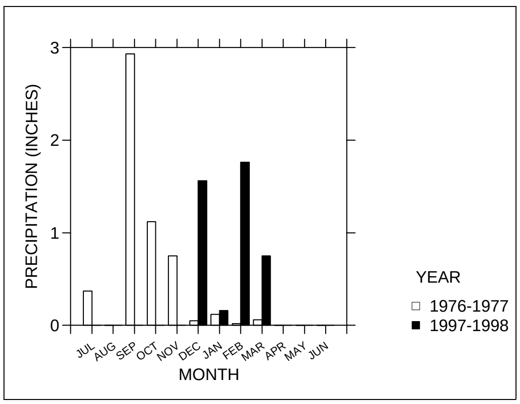

Figure 40. Monthly growing season precipitation at Brawley 2 SW. Total growing season precipitation: 1976-1977: 5.42 in.; 1997-1998: 4.23 in. Long-term mean 2.74 in.

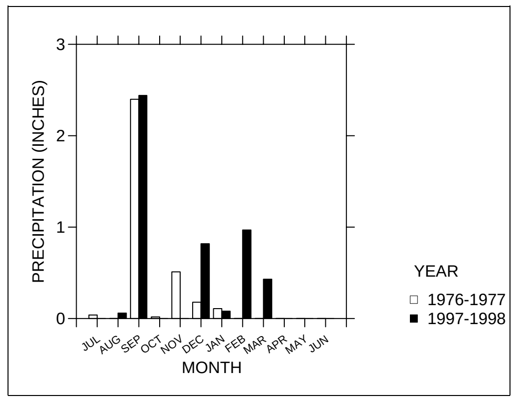

Figure 41. Monthly growing season precipitation at El Centro. Total growing season precipitation: 1976-1977: 3.26 in.; 1997-1998: 4.83 in. Long-term mean 2.75 in.

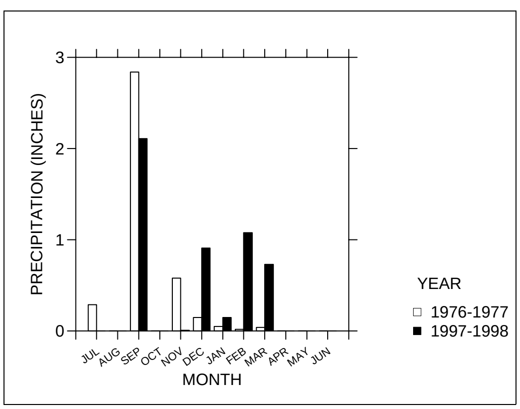

Figure 42. Monthly growing season precipitation at Imperial. Total growing season precipitation: 1976-1977: 3.97 in.; 1997-1998: 4.99 in. Long-term mean 2.66 in.

Conclusions and Recommendations

It is important to realize the limitations of these monitoring data. Because it is very unlikely that the same areas of each cell were surveyed in both 1977 and 1998, it is quite possible that the differences observed result from the spatial variability within cells instead of or in addition to any changes that may have occurred between the two time periods. Thus, increases observed in sample values between 1977 and 1998, even though statistically significant, cannot be used as "proof" that particular species were more abundant and/or widespread in 1998 than in 1977. Additionally, weather station data indicate that precipitation was more favorable during the 1997-1998 growing season than during the 1976-1977 growing season preceding the WESTEC study. Thus, differences between 1977 and 1998 may reflect the more favorable weather of the 1997-1998 growing season.

That said, the 1998 data do indicate that all six species are at least as abundant and widespread in the entire dune system as they were in 1977. Further, their distribution and abundance in the open area appear to be at least as great as was the case in 1977, with the possible exception of *Pholisma sonorae*. That species appeared to decline in frequency (but not in abundance class, when the transect means are considered) in the open area between 1977 and 1998, though this decline was not close to statistical significance. It is entirely possible, however, that this apparent decline is an artifact of the time of sampling. Most of the southern, open area of the dunes (transects 18-34) was sampled between 28 June and 29 August. Consequently, fewer individuals of *Pholisma sonorae* may have been encountered than would have been the case if the area had been sampled earlier. Two pieces of evidence support this conclusion. One is that many more *Pholisma* individuals (both living and dead) were found in the northern part of the dunes, including the open area at the north end of the dunes, than in the southern part of the dunes. The northern dunes were sampled between 9 April and 28 April. In the part of the dunes north of Highway 78, observers recorded *Pholisma* individuals in 37.5% of the cells in the open area and 25% of the cells in the closed area. In contrast, only 2.4% of the cells surveyed in the open area south of Highway 78 contained *Pholisma* individuals.

The other piece of evidence supporting the hypothesis that surveys in the open area south of Highway 78 were conducted too late to find *Pholisma sonorae* that might have been present is the difference between live *Pholisma* individuals found in dunes north versus south of Highway 78. In the portion of the dunes north of Highway 78, 31.3% and 17.4% of the cells surveyed in the open and closed areas, respectively, contained live *Pholisma* individuals, compared to only 0.8% of the cells surveyed in the open area south of Highway 78. In addition, while only one of the 14 transects in the dunes north of Highway 78 yielded a value of zero for live *Pholisma* individuals, all but one of the 20 transects in the dunes south of Highway 78 had values of zero. Not surprisingly, a randomization test of 10,000 samples conducted using the program RT (Manly 1997a), [5] comparing the transect mean abundance values for live *Pholisma* in the dunes

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[5] A randomization test, described earlier, was used in lieu of a *t* test because of the large number of zeros in the sample from the southern open area of the dunes.

north of Highway 78 to the values for live *Pholisma* in the dunes south of Highway 78, showed a highly significant difference ($P = 0.0001$).

While mean abundance class values for *Helianthus niveus* ssp. *tephrodes* increased significantly for the dunes taken as a whole, values for the closed area declined, though this decline was not significant. Mean transect frequency values for this species also increased in the entire dunes, but this increase was not significant. In the closed area, the frequency values mirrored the abundance class values in showing a decline, though this decline was not statistically significant. In the open area this species showed significant increases in both mean frequency and mean abundance class values.

It is unclear why the values for this species would increase in the open area but not in the closed area. There is some indication that the trend may be independent of any OHV effects since it appears to related to the location (and, therefore, possibly the timing) of the area sampled. One of the 4 transects in the northern open area declined in abundance class, in addition to 8 out of 10 of the transects in the closed area. In contrast, only one of the 20 transects in the southern open area showed a decrease. An analysis of variance was used to compare the 1998 mean transect abundance class values among three areas: (1) northern open dunes (4 transects); (2) northern closed dunes (10 transects); and (3) southern open dunes (20 transects). The ANOVA showed a highly significant difference between the three areas ($P < 0.001$). Three posthoc tests were run, including the Bonferonni *t*, Scheffe's test, and Tukey's LSD. All showed a significant ($P < 0.05$) difference between the northern open and the southern open areas, a highly significant difference ($P < 0.01$) between the northern closed and the southern open areas, and no significant difference between the northern open and northern closed areas. This indicates that the difference is related to position in the dunes rather than anything to do with OHV use.

There are at least two possible explanations for this outcome. One is that the abundance and distribution of *Helianthus niveus* ssp. *tephrodes* north of Highway 78 has for some reason not kept pace with its distribution and abundance in the dunes south of Highway 78. The other possibility is that the timing of the survey in the northern dunes, which was much earlier than for the southern dunes, somehow resulted in individuals being overlooked.

This study should not be interpreted to mean that OHV use is somehow "good" 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 6 species appear to be at least as widespread and abundant in the entire open area in 1998 as they were in 1977, 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, 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). Photographs were true color, taken at a scale of 1:7200. The frequency of vehicle tracks in a 100 cell mylar grid placed on each photograph frame was determined by counting the number of cells containing one or more vehicle tracks. Percent frequency for a particular frame was then calculated by dividing the number of cells occupied by tracks by the total number of cells and multiplying by 100. Thus, a frame with tracks in 37 cells would have a percent frequency of 37%. As Map 24 shows, many of the photo frames in the interior portions of the southern open area showed no or a low frequency of vehicle tracks.

Significant impacts from OHV use on all 6 species have been observed at and near staging areas (WESTEC 1977; ECOS 1990; current study); of the 6 species only *Croton wigginsii* appears to be adapted to the moderate OHV impacts that occur near but not on staging areas (Romspert and Burk 1979). Significant impacts to both vegetation and wildlife from OHVs near staging areas in the dunes have been documented by Luckenbach and Bury (1983).

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.

It would appear from the current study that this situation has not changed much if at all since 1977. It is possible, however, given advancing technology in the capabilities of dune vehicles and the advent of cellular phones (making it less dangerous to be stranded by vehicle failure in the interior areas of the dunes), that this pattern of use may change. Such a change could result in more intensive use in the habitat of the 6 species that until now has remained relatively undisturbed. In order to detect any such changes in OHV use patterns, BLM initiated a study in 1998 to monitor this. The study involves aerial photo transects across the dunes on Easter weekend (a heavy use period) to monitor vehicle tracks in the dunes. These aerial photo transects were initiated in 1998 (from which Map 24 was generated) and will be reflown periodically to detect any significant changes in OHV use patterns. To date, aerial photo transects have been flown on Easter weekend 1998, 1999, and 2000. Results of this monitoring effort will be reported elsewhere.

One of the limitations of both the WESTEC study and the current study is that the results give only an index of abundance of the 6 species. Monitoring that results in estimates of actual population size would be better. Given current funding and personnel capabilities, however, the WESTEC methodology of using abundance classes was chosen for the current study because it allows more complete coverage of the dunes than would be possible if actual density estimation was attempted. This is particularly true if information on all 6 species is to be collected. Another advantage of continuing the WESTEC methodology is that it allows the comparison of the 1998 information with WESTEC's 1977 information. Based on experience from the 1998 study, it appears possible to derive actual population estimates for two of the most important species, *Astragalus magdelanae* var. *peirsonii* and *Helianthus niveus* ssp. *tephrodes*. A pilot study testing the use of distance sampling techniques (Buckland et al. 1993) to estimate the population size of *Astragalus magdelanae* var. *peirsonii* will be undertaken in Spring 2001 [6] in the southwestern part of the dunes near a proposed OHV crossing (the Herman Schneider Bridge) over Interstate 8. This will be used to monitor site-specific impacts associated with the construction of this bridge, as well as to determine if the methodology might be used in the dunes as a whole.

The methodology used in 1998 was repeated in 1999 and 2000. Results from the 1999 and 2000 monitoring will be reported elsewhere.

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[6] We had planned to conduct this pilot study in spring 2000, but–because of very low rainfall–too few plants of this species were visible to allow this.

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