Biology, Distribution, and Abundance of Peirson's Milkvetch and Other Special Status Plants of the Algodones Dunes, California

Final Report

Prepared for the American Sand Association

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A map of the Algodones Dunes is included at the end of this report showing the location of all sites and points, boundaries of temporary closures, location of fixed reference points, areas where plants were observed during the helicopter reconnaissance of the closures, negative survey areas, and detailed enlargements of areas with heavy concentrations of sites. This map was created by downloading GPS waypoint and track data from a Garmin GPSIII Plus© onto a Garmin MapSource™ CD-ROM topographical basemap of the vicinity. It was refined and edited using Microsoft PowerPoint™.

Photos by Arthur M. Phillips, III.

INTRODUCTION

The Algodones Dunes, managed by the Bureau of Land Management (BLM) as the Imperial Sand Dunes Recreation Area, are a complex of sand dunes located in Imperial County, California. The dune system extends from just south of the Mexican border northwestward for approximately 40 miles, and varies in width from 3-6 miles with individual dunes reaching a height of 200-300 feet. (Norris and Norris 1961). The dunes have been used for off-highway vehicle (OHV) recreation during the cooler months since at least the 1950s. They support a specialized, limited flora that has adapted to the severe conditions posed by an ever-changing habitat. Many of these species are endemic to sand dunes in the Lower Colorado Valley subdivision of the Sonoran Desert (Bowers 1986; Shreve 1951).

One of these plants, Peirson's milkvetch *(Astragalus magdalenae* var. *peirsonii)*, was listed as a Threatened species by the U.S. Fish & Wildlife Service (FWS) on October 6, 1998 (63 FR 53596). Pursuant to the listing, and pending Section 7 consultation between the BLM and FWS, major portions of the Algodones Dunes were subjected to a temporary closure to use by motorized vehicles in November 2000. This followed legal action filed by the Center for Biological Diversity (CBD), the Sierra Club, and the Public Employees for Environmental Responsibility.

In response to the closure, the American Sand Association (ASA) retained the services of the environmental consulting firm of Thomas Olsen Associates, Inc. (TOA) to provide an independent assessment of the abundance, distribution, and life history of Peirson's milkvetch. Additional distribution information was collected on several other Special Status plants, including:

Dune sunflower *(Helianthus niveus* var. *tephrodes)*
Wiggins' croton *(Croton wigginsii)*
Giant Spanish needles *(Palafoxia arida* var. *gigantea)*
Sand food *(Pholisma sonorae)*
Borrego milkvetch *(Astragalus lentiginosus* var. *borreganus)*

Peirson's milkvetch responded to wet conditions during the winter of 2000-01 with an explosive germination event. This presented a rare opportunity to examine its potential range and habitat preference in the spring of 2001. BLM protocol for monitoring Peirson's milkvetch in the dunes entails a stratified random sampling methodology, which includes the annual reading of permanent monitoring transects (described in more detail later in this report), which were read this year. This report describes comprehensive studies of the abundance, range, and habitat requirements of Peirson's milkvetch, and provides information on its biology and distribution, adding valuable insight for assessing the size and validity of the temporary closures.

Previous Studies

The initial survey of rare plants in the Algodones Dunes was carried out by WESTEC Services, Inc., under contract with the BLM in 1977. They surveyed for eight Special Status plants, of which seven were found, and originated the current method used by the BLM. WESTEC surveyed 66 west-east randomly selected parallel transects traversing the dunes, each segmented into cells 0.45 miles per side, to determine species abundance (WESTEC 1977). No further attempts to monitor special status plants in the dunes were made by the BLM until 1990, when ECOS, Inc. was contracted to perform a habitat characterization and sensitive species analysis, and design long-term monitoring plan (ECOS 1990). These studies did not count the total number of plants; instead, they analyzed population fitness by scoring a set of variables for each species.

Monitoring efforts were revived by the BLM in 1998. In consultation with the California Department of Fish and Game and the California Native Plant Society, a decision was made to resume monitoring plants in the Algodones Dunes, taking advantage of an above-average precipitation year to implement the program. Design flaws with the ECOS protocol caused it to be passed over in favor of the original 1977 survey by WESTEC. The dunes were divided into four geographic strata, 34 of the original 66 transects were randomly selected from those strata, divided into cells, and six special status plants (listed in the introduction of this report) were selected for monitoring. Numbers of plants found are then recorded within 10-50 m. of fixed parallel transects in each of the cells, and abundance classes are assigned for each species in each cell (BLM 2000). The BLM monitoring program was repeated in 2000 and 2001; results of the 2000 reading were presented in the BLM report for that year (BLM 2001). Results of the 2001 monitoring were not yet available at the time of this writing.

Survey Area

An overview of the geologic history and setting of the Algodones Dunes was provided by Norris and Norris (1961). The source of sand for the Algodones Dunes was Pleistocene Lake Cahuilla, a body of fresh water that occupied interior southern California from approximately Indio southward into Mexico, including the present-day Salton Sea and the Imperial Valley. The lake was full intermittently from late Pleistocene time to a few hundred years ago. The origin of sand for the dunes was apparently the shoreline of the lake as it evaporated, exposing beach sand that was transported by prevailing northwesterly winds. The dunes rise 200-300 feet above the desert floor and consist of a series of sand ridges along the western edge and a complex chain of overlapping barchan dunes. From north to south, the dune field morphology gradually changes; the highest slipfaces and best-developed dune-free depressions occur in the southern portion of the dune field.

METHODS

Purpose

The purpose of this investigation was to survey the Algodones Dunes to locate occurrences of Special Status plants, with particular emphasis on Peirson's milkvetch. When found, the areas were delimited, a census of the absolute number of milkvetch and other Special Status plants was conducted, and habitat notes were recorded. As many areas as possible were visited throughout the open areas of the dunes, and negative areas (of no plant occurrences) as well as those areas where the plants occurred were mapped using a geo-positioning systems (GPS) unit.

The investigation did not entail monitoring, and was a one-time census of plants which, while it can be easily replicated using the mapped geo-coordinates, was not intended to be repeated in future years. The study reported here is intended to stand on its own merits, not duplicate the efforts of the BLM. The BLM records plant occurrences within 10-50 m. of fixed parallel transects placed at randomly selected coordinates traversing the dunes. This investigation was designed to conduct and record a complete census of occurrences of Peirson's milkvetch and other Special Status plants. The methodology was not constrained by predetermined points or lines, allowing for the systematic inclusion of as much of the suitable habitat as possible.

Survey Design

A multi-stage non-probabilistic survey of the Algodones Dunes was conducted by TOA biologists on seven separate occasions between early March and mid-May 2001. Redman (1974) and Schiffer and House (1977) have argued that a multi-stage research design is most effective for resource management, and that "[w]ithout multi-stage capability, … studies cannot meet their research and management goals efficiently" (Schiffer and House 1977: 45). Sampling methodology was not included in this survey design, since the purpose of the investigation was to locate as many occurrences of the subject plants as possible, and to completely census every area in which they were discovered.

Peirson's milkvetch occurs in highly clustered, specialized habitats within the dunes, and a large portion of the Algodones Dunes does not contain habitat suitable for these plants. For the study of this type of population, many researchers (Redman 1974; Schiffer and House 1977; Schiffer et al. 1978; Plog et al. 1978; Wilson 1996) have determined that non-probabilistic research strategies are preferable to random or stratified random methods (which are generally more effective for the study of normally distributed populations). Schiffer et al. have argued that "[random] sampling techniques…do not facilitate… population estimation of rare or highly clustered elements" (Schiffer et al. 1977: 1).

Redman has suggested that non-probabilistic research methodologies can "be of considerable value," when seeking to determine the abundance and distribution of a

clustered population (Redman 1974: 5). Wilson has also recommended the use of a non-probabilistic survey strategy for clustered populations, stating that "the purpose is not to estimate the true proportions…but to cover the entire range of [occurrences]…"(Wilson 1996: 103). Non-probabilistic methodologies should not, however, be used to determine the statistical approximation of the distribution within a total survey area. Therefore, the extrapolation of the census data to the entire dunes or to other specific areas was not warranted for this survey.

Survey Methodology

The Peirson's milkvetch survey was initially designed to include three stages of investigation. First, interviews were conducted with informants[1] familiar with the Algodones Dunes and the Imperial Dunes Recreation Area to determine any known occurrences of Peirson's milkvetch. Second, with the aid of transportation support provided by ASA members, a general reconnaissance of virtually all portions of the dunes outside of the administrative closures and wilderness area was performed. Third, using the data collected from both the informants and the general reconnaissance, along with the biologists' knowledge of habitat requirements, specific survey areas were selected and intensively searched for occurrences. At the time of the spring, 2001 surveys, Peirson's milkvetch was discovered to be both abundant and habitat specific. Most of the occurrences and all of the dense population areas were found within similar dune morphology. Most occurrences, and all dense patches, were found in shallow, west-facing blowouts east of steep, unstable slipfaces of the dunes. Moreover, these were also the sites of primary occurrence of other dune-adapted plants, including several Special Status species.

When plants were discovered, a site number was assigned to the area and a team of 2-3 biologists conducted a complete census of plants at the site, including all of the Special Status plants present. Under the direction of a team leader, ASA members frequently aided in the census of larger sites. The team leader completed a data form at each site, recording information on general habitat characteristics, associated species, condition of plants present, and total counts for each special status species. Each of the sites was photographed, and the geo-coordinates were entered (in the position format hdd°mm.mmm, map datum WGS 84) into a GPS unit, which was also used by a biologist to circumscribe the boundaries of the site. Upon completion of the survey of each site, the team advanced to the next survey area, checking adjacent suitable habitat features. Areas that were too small to circumscribe, and that contained a smaller number of Peirson's milkvetch, were designated "Points," at which milkvetch plants were counted and a geo-coordinate was entered, but a data sheet was not completed. Both site and point data were later topographically mapped and entered into a master database (Appendix A).

Applications for a permit to survey within the closure areas by motorized vehicle were repeatedly denied by the BLM (on file with TOA). However, in order to obtain

[1] The informants included a number of people who regularly use the dunes for recreational purposes, such as ASA members and other OHV users, along with BLM personnel and Border Patrol officers.

comprehensive distribution information, a fourth and final stage was added to the survey design in which TOA biologists conducted an aerial survey of the closures by helicopter.

Three TOA biologists, assisted by an ASA member pilot, carried out the aerial survey of the temporary closure areas. Parallel transects or concentric circles of decreasing diameter were flown within each of the closure area boundaries south of Highway 78, and a portion of the wilderness area north of the highway. Geo-coordinates for the closure boundaries (obtained from the BLM El Centro Field Office website) had been pre-entered into a GPS unit by the pilot. At an altitude of approximately 40-50 ft. and an air speed of 10-20 knots, numerous occurrences of subject plants were observed within all of the temporary closure areas south of Highway 78. The altitude of about 40-50 ft. was maintained in order to prevent disturbance of the dunes surface through downwash from the helicopter blades, yet was low enough to easily identify Peirson's milkvetch from the air. The helicopter did not land in any of the closure areas. All of the milkvetch occurrences were marked as points in a GPS unit, topographically mapped and entered into the master database (Appendix A). Additionally, the helicopter routes taken during the survey were tracked and recorded (Appendix B), and any routes in which no plants were observed were marked as negative areas on the final survey map (Appendix C). No complete censuses of the positive areas were possible from the air.

Table 1 (below) lists the dates during which fieldwork was performed at each of the main areas of the dunes and the number of sites recorded per trip.

Dates	Areas Surveyed	# Sites Recorded
3/03/01 – 3/04/01	south border	(initial reconnaissance)
3/22/01 – 3/23/01	south border	8
3/24/01 – 3/25/01	Gecko Rd.	12
4/03/01	south border	9
4/13/01 – 4/15/01	Patton Valley	29
4/25/01	closures (helicopter)	--
5/19/01 – 5/20/01	Gecko Rd.	3

Table 1. Summary of 2001 Surveys

RESULTS

A total of 61 Sites and 67 Points positive for one or more Special Status plants were surveyed during the investigation of the open areas of the dunes. Notable concentrations of sites were found in several areas, which included 1) the southern part of the dunes near the international border and west of Buttercup Valley, 2) the area near Patton Valley south of the large closure and west of the dune peaks, 3) between the small central closure and the large central closure, and 4) on the east side of the small central closure.

The results of this project are detailed in Appendix A, a spreadsheet summarizing all of the survey data from the project. Included for each Site and Point are the geo-coordinates, distance and direction from the nearest fixed reference point, and the counts of each Special Status plant. The second part of the database lists the 186 points where plants were noted during the helicopter survey in the closure areas; no exact counts were available within those areas.

Special Status Plants

The following discussion is a detailed account of the results of the survey for each of the Special Status plants investigated.

Peirson's Milkvetch

A grand total of 71,926 Peirson's milkvetch individuals were recorded during the surveys. Occurrences were clustered in general areas, and large portions of the dunes had no milkvetch. Generally, they were found west of the "high dunes," and were associated with the western line of intermediate active dunes.

Appendix A is a spreadsheet detailing the most populous sites, and the greatest concentration of sites, were found between I-8 and the international border, west of Buttercup valley; and south of the large closure in the vicinity of Patton Valley. The greatest number of plants found at any single site was 3,994 in the south border area, and of the total 17 sites in that area, there were five with more than 2,000 plants. There vwere a total of 29 sites in the Patton Valley area, including five sites with more than 2,000 plants. Sites were much less populous in the Gecko Road area, with 15 sites counted, the largest of which had 444 plants. There were 51 points recorded in that area, reflecting the smaller numbers of plants at many occurrences. The difference in plant numbers per site in the south and north was apparently the combined result of rainfall patterns and less favorable habitat in the highway 78-Gecko Road area. Precipitation in the Gecko Road area was apparently much less during the October 2000 storms that prompted germination, and the slipface-basin morphology that is favorable for milkvetch occurrence is not as well developed in the north.

From the helicopter survey it was possible to see the probable rainfall pattern. Occurrences noted were strongly concentrated in the southern part of the large closure, and there was a narrow transition to fewer occurrences in the northern part of the closure. There may have been additional places in the northern part of the closure with just a few plants that were not seen from the helicopter, but large patches were notably lacking.

The area with dense occurrences in the large central closure was perhaps twice the size of the area with sites south of the closure and north of I-8. Although no counts were possible from the helicopter, many sites with large numbers of plants were observed within the closure.

In addition to the Algodones Dunes, Peirson's milkvetch has also been reported from the Yuma Dunes in Arizona and the Gran Desierto dunes of northwestern Sonora, Mexico. Three areas in the Yuma Dunes were searched, including a specific locality in which it had been reported, and two areas in the Mohawk Dunes (Arizona) and no Peirson's milkvetch were found. An examination of the Yuma Dunes specimen housed at the University of Arizona herbarium by A. Phillips revealed that it appears to be a mis-identification. The habitat at that site was also different from where it occurs on the Algodones Dunes. Thus, the presence of Peirson's milkvetch in Arizona is unverified. Although it was not possible to visit the Gran Desierto, a specimen from there at the University of Arizona herbarium was verified by A. Phillips to be Peirson's milkvetch.

Dune Sunflower

Dune sunflower is an herbaceous perennial and is listed as endangered by the State of California (California Native Plant Society 1994). It was found at 31 of 61 sites for a total count of 1,289. The largest site had 431 individuals. This may represent a count of stems rather than discrete individuals; the plant tends to be clumped making it difficult to discern individual plants without excavating them.

The habitat for dune sunflower is somewhat different from the other Sensitive Species. It tends to grow in areas with more active sand movement, such as on the lower portion of slipfaces. Apparently it can withstand burial by sand better than the other species by growing quickly through accumulating sand. On the other hand, dune sunflower was not seen in areas where sand deflation had occurred, so it is apparently less able than other species to tolerate exposure of its roots. While dune sunflower was a frequent associate in the swales where concentrations of other plants were found, there were also numerous areas observed with a few sunflowers and no other vegetation on actively moving sand; these were not tallied during this project.

On a survey conducted in May 1992, A. Phillips noted abundant dune sunflowers in sand fields at the western portion of the Barry Goldwater Range, Marine Corps Air Station, southeast of Yuma, Arizona.

Wiggins' Croton

Wiggins' croton is a woody shrub that was found at 52 sites for a total count of 3,614. They were quite evenly distributed throughout the four areas. Like Peirson's milkvetch, it grows on the gently sloping sides of basins across from slipfaces. It most often grows on south or southeast slopes of basins, and sometimes grows farther toward the floor of the basin than milkvetch. Otherwise, the habitats for the two species are very similar.

Although a few plants were seen partially buried by sand, most had been subjected to moderate to severe deflation, on the order of 1-1.5 m, sometimes resulting in death of the plant when its root could no longer hold up its crown. Some sites had quantities of dead wood scattered around the basin slopes from dead croton and desert

buckwheat *(Eriogonum deserticola)*. Wiggins' croton is dioecious (male and female flowers on separate plants), and many were flowering at the time of the survey. Some sites had large numbers of croton seedlings of undetermined age.

Giant Spanish Needles

Giant Spanish needles is an annual or short-lived perennial that frequently occurs in sites with milkvetch and croton. It was found at 47 sites with a total count of 4,191 individuals. Most of its occurrences were south of the large enclosure and south of I-8; it was rare in the Gecko Road area. The plants were beginning to flower during the field surveys for this project.

Its habitat differs slightly from milkvetch in that it prefers the floor of basins just beyond the slipface. It appears to tolerate partial burial by sand fairly well. Giant Spanish needles is a vigorous and robust plant and is able to grow rapidly to keep ahead of accumulating sand. It is closely related to typical Spanish needles *(Palafoxia arida* var. *arida),* a smaller cousin that is an abundant spring ephemeral in sandy low desert areas of Arizona, California, and northern Mexico (Felger 2000).

Sand Food

Sand food is one of the most unusual plants in the flora of the Sonoran Desert. It lacks chlorophyll and is parasitic on the roots of desert buckwheat, pleated coldenia *(Tiquilia plicata),* and several other desert shrubs. The point of connection may be a meter or more below the surface. A flowering stem is sent to the surface in spring producing a disk-shaped inflorescense with hundreds of tiny pink flowers. Sand food stems are succulent and store copious amounts of water, and during times of drought apparently provide moisture to the host plant. Indigenous tribes formerly collected the stems as a source of food and moisture (Bowers 1986; Felger 2000).

Sand food was found at scattered locations during the survey, most commonly in the Gecko Road area and the area just south of the large closure. It was generally in somewhat flat areas, but its appearance was difficult to predict, as there were many sites with its hosts but without sand food. Sixty-five plants were found at nine sites and points. The plants were flowering at the time of our fieldwork. A few had been subjected to sand deflation since their stems had reached the surface, and were pedestaled to a height of about 20 cm. This did not seem to affect their flowering.

Borrego Milkvetch

Borrego milkvetch occurs on the east side of the dunes in small depressions that may hold water for a period of time following heavy precipitation (ECOS 1990). Its habitat is quite different from the other species; in fact, it is not truly a dune plant.

The preferred habitat for Borrego milkvetch was not often surveyed during the course of this project. Only one site with 15 Borrego milkvetch plants, two giant Spanish needles, and no other Sensitive species was located on the eastern edge of the dunes.

Growing Season Precipitation

Examination of climatic data from stations near the dunes, obtained from the Western Regional Climate Center, corroborates the climatic correlation with Peirson's milkvetch growth during the 2000-2001 season. Although data from the dunes are unavailable prior to November 2000, when weather stations were installed at Buttercup and Cahuilla Ranger Station (BLM 2001), the effects can be deduced from nearby stations. Climatic data were collected for Brawley 2SW, Yuma Citrus, and Yuma Quartermaster weather observation stations. The Brawley station is the closest station to the northern end of the dunes, about 20 miles west (BLM 2000). Yuma Citrus, at about 10 miles, is the closest station to the southern end of the dunes (BLM 2001); this station was not used because of incomplete data in September and October 2000 and March 2001. The Yuma Quartermaster station, located about 15 miles east of the Buttercup Valley area in the Yuma Crossing State Historic Park on the Colorado River, had complete data and was used for analysis.

The data from these stations show a sharp contrast between the 1999-2000 and 2000-2001 growing seasons (September-March) at both stations, and a large differential between Brawley and Yuma during October 2001, the probable germination period for the 2001 cohort of Peirson's milkvetch plants (Table 2).

Month/Year	Precipitation (in.)		No. of Days		Greatest Amount/Date	
	Brawley	Yuma	Brawley	Yuma	Brawley	Yuma
Sep. '99	0.38	0	1	0	0.38 23rd	0
Oct. '99	0	0	0	0	0	0
Nov. '99	0	0	0	0	0	0
Dec. '99	0	0	0	0	0	0
Jan. '00	0	0	0	0	0	0
Feb. '00	0	0	0	0	0	0
Mar. '00	0.08	0.17	2	2	0.05 6th	0.11 5th
Sep. '00	0	0	0	0	0	0
Oct. '00	0	1.58	0	2	0	0.83 22nd
Nov. '00	0	0	0	0	0	0
Dec. '00	0	0	0	0	0	0
Jan. '01	0	0.50	0	4	0	0.33 10th
Feb. '01	0.88	1.22	7	4	0.25 26th	0.62 28th
Mar. '01	0.47	1.38	3	1	0.35 7th	1.38 6th

Table 2. Growing season precipitation at Brawley 2SW and Yuma Quartermaster weather stations, 1999-2000 and 2000-2001

Precipitation in the fall of 1999, nil at Yuma and 0.38 inches at Brawley, was apparently insufficient for germination in either area. A two-day precipitation event in late October 2000, measuring over 1½ inches at Yuma, was probably responsible for the milkvetch germination event on the dunes. The reduced precipitation (none at Brawley;

some must have fallen in the Gecko Road area) is the likely cause of the less spectacular germination in the Gecko Road area. Continued good rainfall at Yuma during the winter (over 3 inches between early January and early March, with 2 inches falling between February 28 and March 7) probably sustained the plants that had germinated in October and resulted in additional germination that was noted in census figures in April. Brawley had about half as much precipitation during the February 27-March 7 period. April and May precipitation figures were not yet available as this report was written.

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DISCUSSION AND ANALYSIS

Peirson's Milkvetch Phenology and Life History

The vast majority Peirson's of milkvetch plants observed were of a uniform age and in their first year. Peirson's milkvetch is a short-lived perennial that explosively germinates when favorable moisture conditions occur (Barneby 1964; Bowers 1986), in this case an abundance of fall moisture in October 2000. Only five individuals were found that appeared to be older than the current growing season. It was apparently quite serendipitous that our survey was conducted during a year when abundant germination occurred; a year earlier Peirson's milkvetch might have appeared to be extremely rare (BLM 2001).

The most detailed discussion of Peirson's milkvetch ecology is found in Barneby.

> On the Algodones Dunes, where it is found in company with a shrubby *Eriogonum,* … the Peirson's milkvetch is abundant in favorable seasons. After a drought of several years' duration, only a few tattered veterans, some of them half smothered and others with a trunklike taproot exposed for a foot or more by the shifting sands, bear witness to a formerly flourishing colony. The plants are potentially perennial but mature rapidly, beginning to bear fruit some two months after germination of the seeds, and thus insure continuation of their sort. The taproot is extraordinarily long, as might be expected under dune conditions, and penetrates deeply before lateral rootlets are produced. In one young plant a simple whiplash root, broken off and incomplete, measured nearly six feet in length, five or six times that of the stem above ground (Barneby 1964: 862).

Although Peirson's milkvetch is potentially a perennial, most plants that germinated in October 2000 were flowering in March 2001 and setting fruit by May. This means that they contributed to the replenishment and enhancement of the seed bank during their initial growing season; many may not survive if dry conditions occur during the following winter, but their survival is not necessary for the preservation of the species since they have already reproduced. There appeared to be a secondary germination event associated with rains in March 2001; many of these plants had not flowered by late May, and it is likely that they will succumb to summer heat and drought before reproducing. Their reproduction is not essential for the species since so many of the plants that germinated in the fall produced seeds.

The pods produced by Peirson's milkvetch are strongly inflated, and can blow across the surface of the dunes until they lodge against a shrub or in a swale with reduced wind velocity (Bowers 1986). Thus they can be transported from one favorable site to another, or remain near the parent plant, depending on winds. Because the plants are usually in the open, not growing under shrubs, and clustered, it would appear that many pods break open and shed their seeds near the parent plant, replenishing the seed bank where the parent plant grew.

The pods contain 11-16 seeds each 4.5-5.5 mm long, the largest of any North American species of *Astragalus* (Barneby 1964). The large size insures that the seeds, once shed from the pods, remain in place in the sand. It also provides the seeds with stored energy for the seedlings to penetrate the sand and reach the surface if they are deeply buried in sand (Bowers 1986).

The potential for a desert annual or short-lived perennial rests not in the plants that are actively growing at any particular time but in the seed bank, the dormant seeds resting in the soil awaiting the return of brief, favorable conditions for their germination (Pavlik and Barbour 1988; Venable and Pake 1999). Dormant seeds in the soil allow plants to survive long periods of unfavorable growing conditions, both seasonal and annual. The contribution of the 2000-2001 cohort of Peirson's milkvetch to replenishing the seed bank is impressive. The largest site censused in March 2001, before the secondary germination event, contained 3,738 plants, 90% of which were noted as reproductive. If each plant produced 5 pods, and each pod contained 14 seeds, the contribution to the seed bank at that site alone would be more than 235,000 seeds. The largest site counted was 3,994 plants in early April. The proportion of plants estimated to be reproductive when this site was censused was only 20%, reflecting the March germination event. Making the same assumptions as above, the 2001 seed bank contribution of this site would be nearly 56,000 seeds. By the time of our April trip, many plants had shed their pods, and seeds were plainly visible on the sand surface. The large, flat black seeds contrast strongly with the light-colored sand, and at several sites observers noted that seeds were "all over the place." In these cases the pods had not been dispersed far before they broke open and shed their seeds.

Data on the longevity of dormant seeds in the seed bank are scanty. Shreve (1951) observed that an exceptional year brings forth large crops of species that have been dormant for the preceding 10-15 years. Pavlik and Barbour (1988) tested seeds of *Astragalus lentiginosus* var. *micans* from the Eureka Dunes and found a 76% germination rate for seeds 8 years old. A discussion of "bet-hedging" is found in Venable and Pake (1999). This is the concept that seeds of a particular species have different germination requirements so that not all germinate at once even during the most favorable conditions, preventing catastrophic loss in the event of weather events that result in mass mortality of seedlings.

Annual Population Variation

The annual variation in population of living plants of Peirson's milkvetch is strikingly shown by reviewing data from the BLM monitoring reports (BLM 2001). The number of plants tallied on 34 BLM transects in 1998, 1999, and 2000 was 4,370, 812, and 66 respectively. BLM data for the 2001 monitoring efforts was not available as of this writing. The total number of plants older than October 2001 noted during this project was 5, contrasted to nearly 72,000 plants less than one year old. From this, it is apparent that it is impossible to ascertain the status of such plants and the health of their populations without either studying them during a rare germination event, or by analyzing the seed bank.

A discussion of precipitation timing, amount, and temporal distribution and the effects on winter annual germination is provided by Venable and Pake (1999).

Recreational Vehicle Considerations

At each site located and censused during this project, biologists kept a tally of all plants that had been affected by OHV activity. This included observing plants that were located in vehicle tracks, whether or not they showed any sign of damage. It also included plants that might have been previously damaged, even if tracks were no longer present.

The total number of plants that showed any evidence of having been affected by OHVs was 667, or 0.93% of all Peirson's milkvetch plants counted. It was apparent that nearly all plants that were run over were resilient, and popped back up with no damage to the stems or the flowers. As soon as wind obliterated the tracks there was no sign of any effect. The proportion of plants that had been affected by OHVs was small primarily because drivers avoid vegetated basins due to the potential for tire damage from woody stems of shrubs, and wood scattered on the ground from dead plants. Even though tire damage would not occur from running over a first-year milkvetch, they are protected by their location in general proximity with shrubs.

Vegetated sites sometimes had a route going through them, but drivers did not deviate from the route as they passed through vegetated sites. Every driver who transported us remarked that they do not drive in such places. The occurrence of dune plants and heavy use areas for vehicles is to a large extent mutually exclusive.

CONCLUSIONS

The shifting sands of dunes constitute a severe habitat for which plants must be adapted to cope with being both covered and exposed (Bowers, 1986). Our observations at the Algodones Dunes show that plant life within the dune system is consistently concentrated in areas where there is relative substrate stability, compared to areas where sand is more actively accumulating or being removed. In terms of dune morphology, these areas are generally located on the lee side of large dunes, in areas where the surface gradually slopes upward from deep or shallow basins at the base of steep slipfaces. The

slopes are generally west facing, and extend from the floor of the slipface basin upward to a ridgetop that rings the basin. Vegetation gradually decreases toward the rim, and the ridgetops are essentially free of vegetation. The vegetated slopes appear to be under gradual deflation, as evidenced by the pedestaled habit of most plants. It is in such places that the common shrubs, dune buckwheat and Wiggins' croton, occur. They are consistently pedestaled to a depth of a meter or more below the root crown, and eventually they topple over when the taproot is no longer able to support the weight of the stems. It is in such places that Peirson's milkvetch commonly occurs; plants are found from the floor of the basin to beyond the ridge, but the greatest concentrations of milkvetch are generally above the middle of the slope. Milkvetch plants are also frequently pedestaled, usually from 1-3 cm and always to the same height for all plants in a cluster. This can be considered evidence for their germination at the same time.

1. Peirson's milkvetch underwent an explosive germination event during the winter of 2000-01, with favorable conditions for germination occurring in October 2000. More than 70,000 plants were censused during field surveys for this study. Many of these plants flowered and set seed in spring 2001, replenishing the seed bank and demonstrating the potential abundance of the species. Such favorable conditions normally occur infrequently, and must be studied to assess the full potential of the species.

2. A helicopter survey of the closed areas revealed many occurrences, especially within the southern portion of the large central closure. These sites could not be censused, but they appeared to be similar in number and abundance of plants to adjacent open areas.

3. Most dune plant species are concentrated in areas that continuously lose sediment, located in shallow basins east of slipfaces of active dunes. Areas with active sand accumulation and movement are generally essentially free of plants. The areas that are likely to have the greatest concentrations of Peirson's milkvetch and its associated species are quite predictable from dune morphology.

4. The results of this study provide information in addition to that collected by BLM monitors, using different methodology. Our complete censuses of all sites located within portions of the dunes provide a good indication of the abundance, distribution, and ecological requirements of Peirson's milkvetch and its associated species.

5. Less than 1% of the plants located had been affected by OHVs. The vast majority of these showed no adverse effects, and continued to grow and flower. The stems of first-year Peirson's milkvetch are quite flexible, probably as an adaptation to withstand strong winds. Vegetated areas are generally avoided by OHV drivers due to the threat of tire damage from driving over sharp sticks. OHVs do not appear to be a threat to the health of the Algodones Dunes population of milkvetch, which flourished in 2001 in areas that were open as well as closed to OHV use.

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