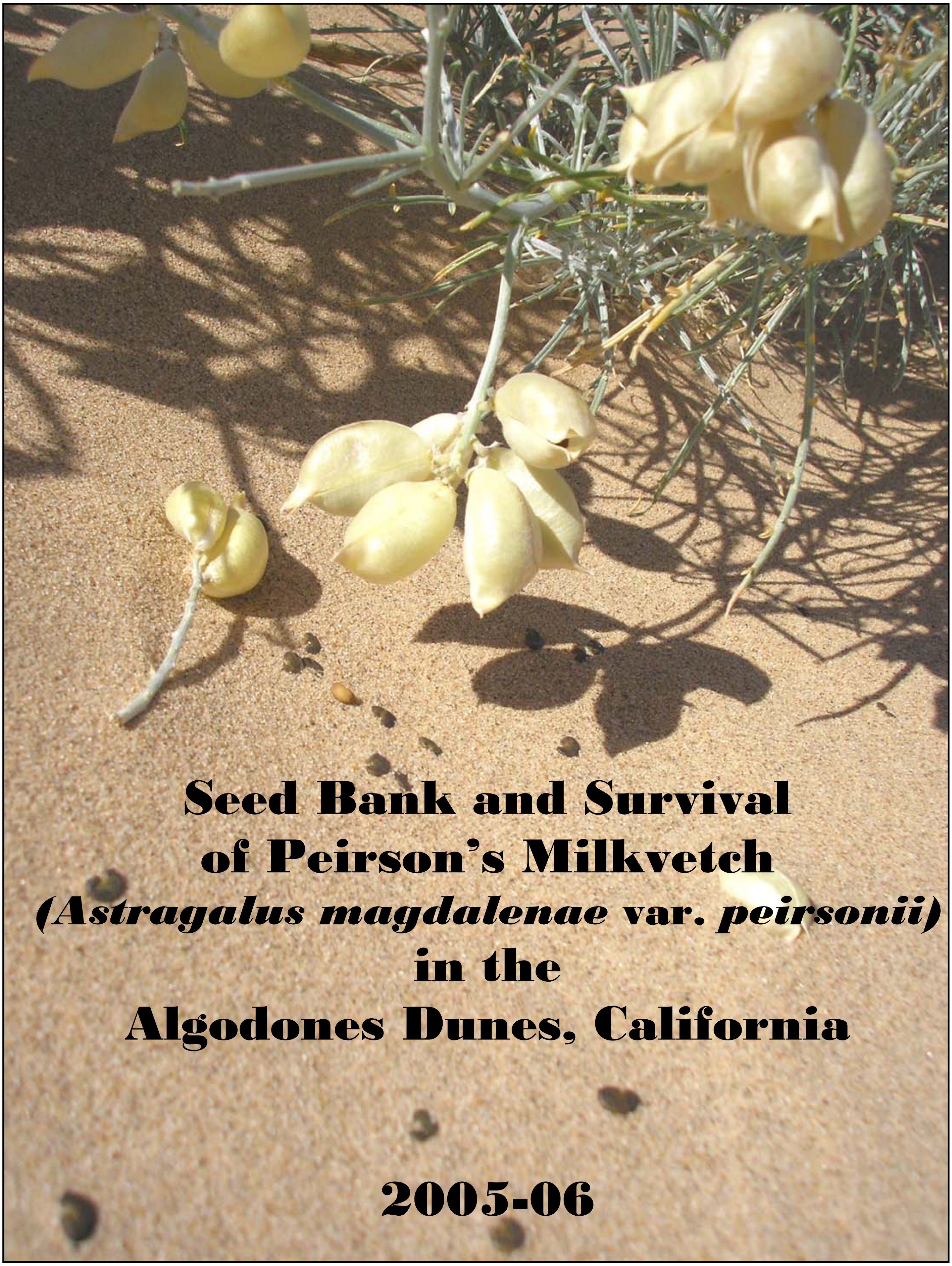


Seed Bank and Survival of Peirson's Milkvetch (*Astragalus magdalenae* var. *peirsonii*) in the Algodones Dunes, California

2005-06

SEED BANK AND SURVIVAL

of

PEIRSON'S MILKVETCH

(*Astragalus magdalenae* var. *peirsonii*)

in the

Algodones Dunes, California

2005-06

Final Report

Prepared for the
American Sand Association

Arthur M. Phillips, III, Ph.D.
Debra J. Kennedy

Botanical and Environmental Consulting
P.O. Box 73
Eckert, CO 81418

June 2006

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

ACKNOWLEDGMENTS

The authors would like to acknowledge the assistance of the members of the American Sand Association who provided transportation and support with their personal sand vehicles, shared their knowledge of the dunes, and helped sieve tons of sand under sometimes trying conditions. Otto and Vicki Privette helped us for the sixth straight year; we owe them a great debt of gratitude. We also relied heavily on our dedicated field assistant, Daniella Roth. Danke schoen! Vincent Brunasso shared many invaluable ideas about PMV biology and ecology. Dick Holliday assisted with transportation on multiple trips. Others to whom we are indebted for providing transportation include:

Holli Bechard
Ron Bechard
Larry Beck
Vincent Brunasso
Anthony Carnevale
Keith Carnevale
Andy Diamond
Bob Donahue
Becky Gauger
Chris Gauger
Mike Gertsen
Tim Giannelli
Rob Goodwin
Harold Gottschalk
Terry Guinn
Peter Haan
Ty Hollimon
Dick Holliday
Larry Holvey
Cory Hove
Jenny Hove
Don Johnson
Linda Lehman
Sam Lehman
Wendell Long
Mike Martin
Tony McKinney
Mike Openshaw
Steven Openshaw
John Peterson
Otto Privette
Richard Pruett
Chad Riccio
Terry Romine
Darrick Sandwick
Cass Sandwick
Joella Sartin
Bill Schueler
Jerry Seaver
Nanette Shallcross
Tom Townley
Brian Walker
Matthew Ware
Steven Ware
John Webber
Stan Weiler

Russ Borman, transportation chair for ASA, assisted with arranging transportation. Grant George, ASA president and Biology Committee chair, was responsible for the ASA oversight of the project. Bob Mason, Chairman of the ASA Board of Directors, provided encouragement and assistance whenever we called on him. Our deepest gratitude is expressed to all.

Dr. Barbara Phillips, Mar-Elise Hill, Dr. Frances Lazear, and Gregory Lazear assisted with the fieldwork. The Bureau of Land Management El Centro Resource Area, and U.S. Fish & Wildlife Service issued our research permits. This project was funded by the American Sand Association.

Photos by A. M. Phillips, III

INTRODUCTION

In stark contrast to the exceptionally wet conditions of the 2004-05 growing season, the 2005-06 season was the driest of our six-year study. There were two minor storms, one in mid-October and another in March, which left a season total of 0.26 inches at Cahuilla and 0.17 inches at Buttercup. In contrast, nearly five inches was recorded at both stations during the 2004-05 season.

This report summarizes findings from a sixth year of studies on the ecology, phenology, and demography of *Astragalus magdalenae* var. *peirsonii* (Peirson's milkvetch). Our field work during the 2005-06 season had two objectives: first, to study the survival and reproduction of plants from previous seasons and any seedlings that grew during the current season, and second, to analyze the seed bank of the species and compare the results with the seed bank study we conducted in 2002.

Initially we had hoped to study seed bank depletion resulting from a germination event of Peirson's milkvetch. However no such event occurred in 2005-06. We proceeded with the study nonetheless, in order to provide comparative data with the first seed bank study utilizing a different method of sample site selection.

Peirson's milkvetch is a short-lived perennial in the Legume family (Fabaceae) that is widely distributed in clustered populations throughout the Algodones Dunes complex. It was listed as a Threatened species in 1998 (USFWS 1998, CNPS 2001, BLM 2000a) and has been the focal point of a number of legal and administrative actions since the fall of 2000. Despite the listing, little information was available on the plant's biology; thus, the American Sand Association has funded a multi-year research project in order to learn more about the ecology of this desert plant and its interactions with off-highway vehicles (OHVs**),** with which it shares the Algodones Dunes.

Off-highway vehicle (OHV) recreational use of the Algodones dunes complex has been occurring for several decades. Although there has been some speculation that increasing levels of OHV use within the dune system negatively affect the status of *A. m.* var. *peirsonii*, it is important to note that no scientific, empirical study supporting a negative impact of OHV use on Peirson's milkvetch (along with other plants and animals in the dune system) has yet been completed. There is, however, a growing body of scientific literature that indicates *there is virtually NO statistical correlation between OHV use and the germination or survival of Peirson's milkvetch in the Algodones dunes system* (BLM 2000a, 2005; Phillips et al. 2000; Phillips and Kennedy 2001, 2003, 2004, 2005).

Research Area

The Algodones Dunes are a complex of sand dunes located in southeastern Imperial County, California and extending a short distance into adjacent Baja California, Mexico. They support a specialized, limited biota that has adapted to the severe conditions posed by an ever-changing habitat with low, unpredictable rainfall, severe annual and diurnal temperature extremes and occasional severe abrading wind-carried sand. Many of the plant species found in the dunes are endemic to sand dunes in the

Lower Colorado Valley subdivision of the Sonoran Desert (Bowers 1986; Shreve 1964). Among these is Peirson's milkvetch.

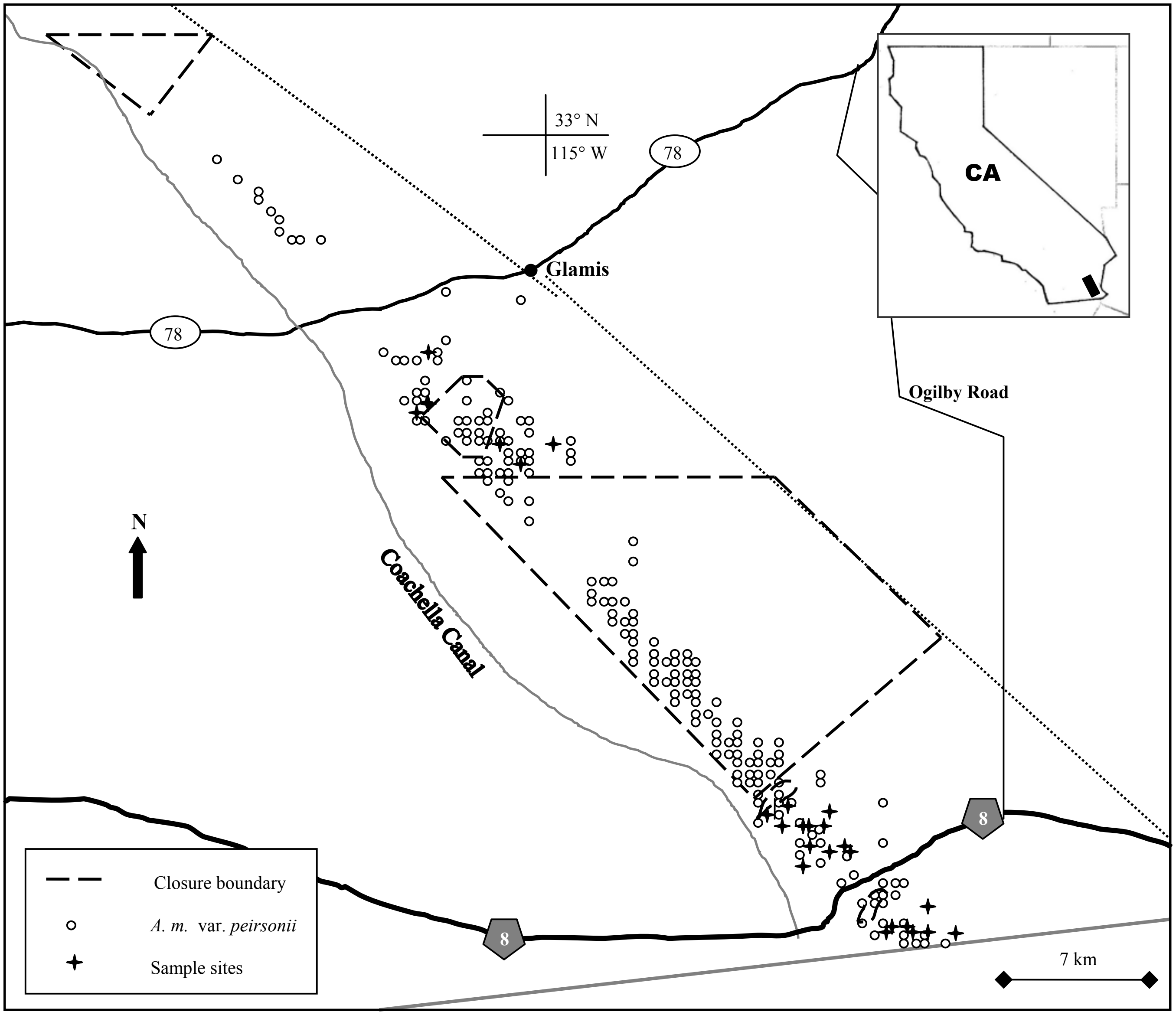


Figure 1. Distribution of *Astragalus magdalenae* var. *peirsonii* sites in the Algodones Dune system initially surveyed in spring 2001, sampled in winter 2001-02, and re-sampled in all subsequent studies[1]

An overview of the geologic history and setting of the Algodones Dunes is provided by Norris and Norris (1961). The system consists of a complex chain of overlapping barchan dunes, with the higher dunes rise 60-90 m (200-300 feet) above the desert floor. From west to east a series of sand ridges along the western edge gradually transition to the highest, most active dunes (generally the focal point of OHV recreation) in the eastern half of the system. Between the ridges and the high dunes are a series of

---

[1] Site locations are approximate; see Phillips et al. (2001) Appendix A for exact geo-coordinates. Locations within the closure areas were mapped by helicopter survey.

lower bowls and ridges, which support the highest levels of vegetation density, including Peirson's milkvetch.

The Algodones Dunes are about 65 km (40 miles) in length, trending from northwest to southeast, and from 5 to 10 km (3 to 6 miles) wide (see Figure 1 below). The total area of the dune system includes approximately 60,705 ha (150,000 acres), of which 10,730 ha (26,500 acres) were designated as a wilderness area in 1972 (BLM 2000b). Temporary administrative closures of an additional 20,000 ha (49,000 acres) were imposed in November 2000 as a lawsuit settlement over protection of Peirson's milkvetch.

METHODS

The 2005-06 growing season marked the sixth year of study of the *A. m.* var. *peirsonii* population, distribution and ecology in the Algodones Dune system. This report provides another year of cumulative scientific data, compiled through 13 individual studies conducted over a six-year period (2001-2006), on the ecology and life history of this important desert plant. Our initial study, conducted in 2001, included the mapping and documenting of known Peirson's milkvetch distribution and population throughout the entire dune system (see Phillips et al. 2001). Subsequent research, including that conducted in 2005-06, has focused on a 40% sample of sites identified in the initial 2001 survey as areas of known plant occurrence, randomly selected and stratified by location in the dunes complex (Phillips and Kennedy 2002).

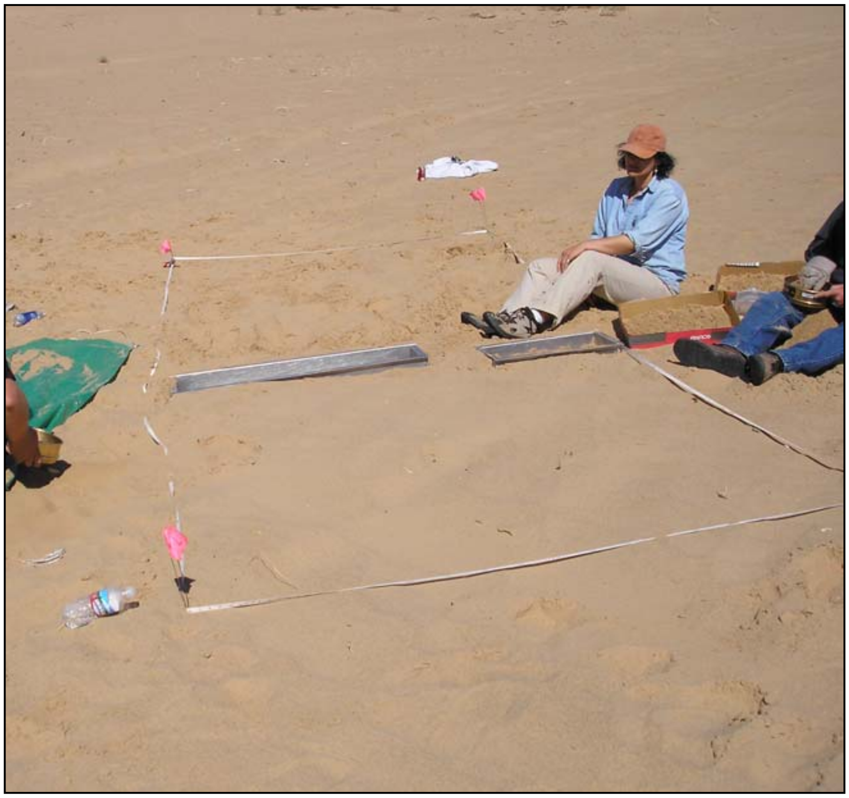
Over the course of this project, various methods have been adopted to address unresolved questions concerning the status of the *A. m.* var. *peirsonii* population. Study methods and protocols included in this research agenda evolved from prior findings; thus enabling us to establish a valid scientific framework from which we base our conclusions. A brief overview of methods utilized in the past five field seasons can be found in Phillips and Kennedy (2005: 7-9).

Year six of the study was conducted from November 2005 to April 2006 during which data on the *A. m.* var. *peirsonii* cohort survival rates and the seed bank were collected, documented and analyzed. The purpose of the soil seed bank study was to provide an estimate of the number of seeds in the seed bank in order to assess the potential status of the population, and to further test the validity of a prior seed bank study (see Phillips and Kennedy 2002) with current data. The purpose of the cohort survival census was to determine the viability and reproductive capability of Pierson's milkvetch from one growing season to another (given summer temperature extremes).

In a previous seed bank survey (Phillips and Kennedy 2002), we based our analysis of seed production on the purposive sampling of clusters of plants within previously identified sites of known plant occurrence. For the current study, however, we modified this approach to randomly select plots within sample sites for analysis, without regard to plant distribution within the site. Although purposive sampling (in 2001-02) allowed us to reach several valid conclusions regarding plant distribution and the perpetuation of plant clusters, along with gaining important data on the status of the

Peirson's milkvetch seed bank, random sampling allows us to extrapolate our findings to a larger portion of the plant's potential habitat – giving us a richer picture of the status of this important desert species.

The outline and size of each of 25 randomly selected sites was determined during the 2001 seed bank study. These parameters have been used in subsequent years, and were used as the basis of the 2005-06 study. On each sample site map, we interposed a virtual grid, with perpendicular N-S and E-W lines intersecting at the center of the site (thus creating *x* and *y* axes). Using a random number table, we selected four *xy* coordinates per site. These points were placed on the virtual site grid maps, and GPS coordinates were determined for each point. Using the GPS coordinates (and a WAAS-enabled GPS unit) the points were then located on the ground. Each point determined the northwest corner of a seed bank sample plot 5 x 2 meters in size. Three such plots were sampled at each site. Coordinates for a fourth plot were determined in case it was necessary to eliminate one of the plots due to location on a slipface, or in case plots overlapped.



Layout of seed bank sample plot used in 2005-06 survey

Metal plot frames 1 m x 0.25 m and 0.5 m x 0.25 m and 15 cm high were sunk in the sand at 10 systematic locations within the 5 x 2 m plot, for a total of 4.5 m^2 in each plot and 13.5 m^2 at each site. Large plot frames were placed with the long side of the frame perpendicular to the long side of the plot starting in the upper right corner, and placed systematically along the plot, skipping every other 1 m x 0.25 m space. The frames were sunk 10 cm into the sand, and the enclosed sand was removed using a plastic scoop and sifted through a No. 10 soil sieve 8 inches in diameter. Any seeds on the surface were counted and removed prior to sieving; seeds captured in the sieve were counted for each plot. After all sand was removed to the 10 cm depth, the sand and seeds were replaced. Smaller frames were placed in a similar manner along the other long side of the plot.

The initial work was conducted at six stratified randomly selected sites, a 24% sample of the 25-site set, from December 17-20, 2005. Two sites were selected in the Buttercup area, three were analyzed at Patton Valley, and one at Glamis.

The same selection method was utilized for a second seed bank survey trip in March 2006. Spring rains, however, rendered the sand too wet to sift efficiently, resulting in a smaller sample. Thus, two additional sites each at Patton Valley and Glamis were surveyed. These data were then added to the December 2005 data, bringing the 2005-06 sample to ten sites, comprising 29 sample plots (3 plots at nine of the sites and 2 plots at one site). Finally, in addition to the seed bank survey, survivorship surveys were conducted at all 25 sample sites in December 2005 and April 2006, consistent with previous years' work (see Phillips and Kennedy 2002, 2003, 2004, 2005).

A. m. var. *peirsonii* seed population estimates are based on sample site values. Density values are calculated individually for each location and population estimates extrapolated only to those sites of known Peirson's milkvetch occurrence at each location. Thus, extrapolation of mean seed density (seeds per square meter) at the four Buttercup sites surveyed in 2005-06 is limited to the 17 Buttercup sites originally identified in 2001, the mean seed density at five sample sites at Patton Valley is extrapolated only to the 27 original Patton Valley sites, and so on. This method is consistent with natural resource sampling methodology, and was recently adopted for the 2004 BLM survey of special status plants in the Algodones Dunes complex (BLM 2005). Our population estimates, however, tend to be conservative, since we extrapolate seed density data only to *known and documented sites of plant distribution* – comprising an area of approximately 56 ha, or 0.9% of *A. m.* var. *peirsonii* potential habitat in the Algodones Dunes complex.

Upon completion of the 2005-06 fieldwork, data were analyzed using SPSS version 11.0 statistical software (SPSS 2001). Both seed bank and cohort survivor population estimates were made based on actual counts at each sample site per location, then extrapolated to all the sites of known plant occurrence (identified in 2001), stratified by location. Precipitation and survivorship graphs were produced with Microsoft Excel 2002; all other graphs and charts were created with SPSS.

RESULTS AND DISCUSSION

In contrast to the 2004-05 growing season, which saw the greatest amount of both rainfall and Peirson's milkvetch germination of the six years of our study, the 2005-06 season was the driest year, with essentially no germination. Only two rainfall events occurred during the 2005-06 season: a very minor event on October 17th and 18th, and a light rainfall on March 11th. The six months between these rains was completely dry.

Our first survey of the season was November 19-20, during which we developed sampling methodology to be used for the seed bank study. This was followed by survival assessments and seed bank studies December 16-20, 2005, seed bank work at additional sites March 10-13, 2006, and plant counts from April 14-17 to be used as a baseline for survival studies the following year. A summary of plant population data collected in the 2005-06 studies is in Appendix A of this report.

Population, Distribution and Survival

Although no significant germination event occurred during the 2005-06 growing season, the results of population studies conducted during the sixth year of this project show an actual count of 1,233 live *A.m.* var. *peirsonii* 2004-05 and older survivors documented at our 25 sample sites in December 2005, and 914 plants in April 2006. These values were subsequently analyzed with an SPSS statistical program to determine average plant density per location (number of plants per square meter) and extrapolated to the original 60 sample sites identified in 2001. The results are presented in Table 1.

Spring 2005 PMV Population Estimates and Survivorship to December 2005 and April 2006

	Mar. 2005	**Apr. 2005**	**December 2005**					**April 2006**				
	Population Estimate*	**Population Estimate***	Population (actual count)	Density (μ PMV/m^2)	Range	Std. Dev.	**Population Estimate**	Population (actual count)	Density (μ PMV/m^2)	Range	Std. Dev.	**Population Estimate**
Buttercup	**94,166**	**75,184**	550	0.0091	0.023	0.0077	**1,095**	311	0.0051	0.013	0.0045	**616**
Patton Vly.	**76,483**	**80,270**	661	0.0032	0.012	0.0620	**1,317**	625	0.0031	0.009	0.0028	**1376**
Glamis	**10,748**	**9,594**	22	0.0027	0.015	0.0061	**76**	15	0.0015	0.008	0.0032	**43**
Totals	**181,397**	**165,048**	1,233				**2,488**	921				**2,035**

*2005 Population Estimates from Phillips and Kennedy 2005.
Population estimates based on extrapolation of mean plant density per location to all sample sites identified in 2001

Table 1. Population estimates of Spring 2005 cohorts surviving to December 2005 and April 2006

Based on the results of the 2005-06 population studies, the estimated population of *A.m.* var. *peirsonii* 2004-05 survivors present within 56 ha of the plant's potential habitat in the Algodones Dunes in December 2005 was approximately 2,488 plants, and 2,035 in April 2006. Clearly, this is a dramatic decline in plant population estimates from those of spring 2005. Nevertheless, further investigation and analysis shows that the 2005-06 decline in population is neither exceptional nor, as is later argued, threatening to the status of *A.m.* var. *peirsonii.*

The decline of 2004-05 cohorts to December 2005 is nearly 80 percent. Clearly first-year plants, with shallow, less-developed roots systems, were less capable of surviving through the period of drought that lasted from mid-March to mid-August; thus they had a mortality rate of 98.8 percent by April 2006. As discussed further in this report, however, perennial survivors, with approximately 171 seedpods per plant, greatly contribute to the soil seed bank – thus are critical to the continuing integrity of this important desert species.

A graph showing survivorship curves for the 2000, 2003, 2004, and 2004-05 cohorts is shown in Figure 2. This log-base 10 chart shows the sharp reduction in plant numbers during the summer, notably for the 2000 cohort in which the reduction (79%) was tempered by summer rains, and for the 2003 cohort (reduced by 99.7%), which germinated in February and did not have any rainfall during the ensuing summer. The 2003-04 cohorts (November and February) also had rainfall in late summer 2004, but there were also losses in the November-germinating plants due to drought conditions in mid-winter. The difference in mortality rates between perennials and the 2004-05 cohort can be seen by the contrast in the steepness of the curves.

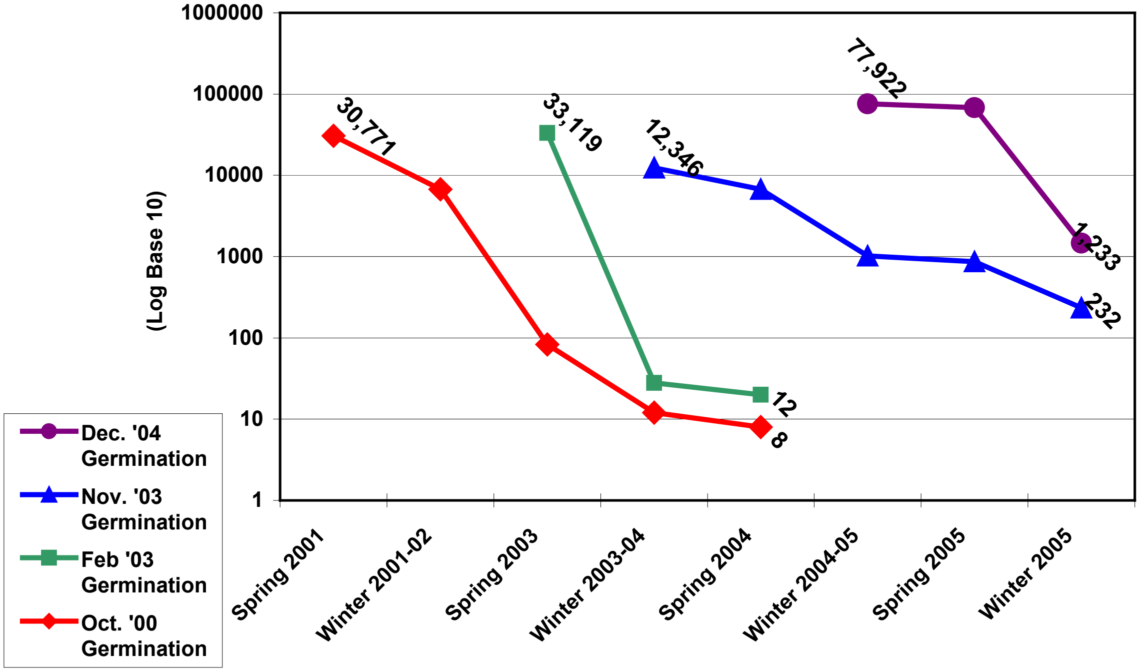


Figure 2. Survival of 2000, 2003 and 2004 germinants to spring 2006 at 25 sample sites

By the fall of 2005 we were unable to reliably distinguish plants that had germinated in 2003-04 from older plants, of which few if any presumably remained. Thus our counts in 2005-06 consisted of “2004-05 plants” and “perennials” (plants age 2 yrs. and older). Table 2 shows the number of perennials counted in December 2004 and 2005, and the number of first-year plants counted in March 2005, along with their survival rates through the spring of 2006.

	#Perennial Survivors Dec. 04	*#2004-05 Germinants Mar. 05*	*#Perennial Survivors Dec. 05*	*#2004-05 Survivors Dec. 05*	*#2004-05 Survivors Apr. 06*
Buttercup	188	41,626	12	550	311
Patton Valley	933	34,284	33	661	625
Glamis	47	2,012	1	22	15
Total ***Percent***	**1,168**	**77,922**	**46** ***19.9%***	**1,233** ***1.6%***	**921** ***1.2%***

Table 2. Survival of 2004-05 cohort plants and older perennials through Spring 2006.

2006 Seed Bank

The primary purpose of the 2005-06 seed bank study was to compile additional comparable data to 1) test the validity of our 2001-02 seed bank survey results and 2) test the consistency of the *A. m.* var. *peirsonii* soil seed bank in the Algodones Dunes. Thus, our research hypothesis for this portion of the study is H_o: $\mu_{2002} = \mu_{2005}$, in which μ = mean number of seeds per square meter at 25 sample sites, stratified by location. Table 3 shows a comparison of results of the 2001-02 and 2005-06 seed bank surveys, including the range of population estimates at each location in the two studies.

PMV Seed Population Estimates Per Location -- 2001-02 and 2005-06												
	2001-02						**2005-06**					
	Seed Population (actual count)	Density (μ seeds/m^2)	Range	Std. Dev.	**Population Estimate$_1$**	**Population Estimate$_2$**	Seed Population (actual count)	Density (μ seeds/m^2)	Range	Std. Dev.	**Population Estimate$_1$**	**Population Estimate$_2$**
Buttercup	753	7.9700	22.15	7.900	**358,905**	**955,037**	235	7.3700	16.67	5.920	**331,886**	**883,604**
Patton	911	5.6210	12.14	3.840	**1,947,873**	**2,313,823**	243	3.5999	23.78	5.665	**1,557,328**	**1,849,906**
Glamis	47	0.5800	0.97	0.354	**11,131**	**16,527**	114	5.0666	21.11	9.1265	**153,445**	**227,932**
Totals	**1,711**				**2,317,909**	**3,285,387**	**592**				**2,042,659**	**2,961,442**

Population Estimate$_1$ based on extrapolation of mean seed density to 25 sample sites
Population Estimate$_2$ based on extrapolation of mean seed density to 60 sample sites

Table 3. Seed counts, density and population estimates per survey location, 2001-02 and 2005-06

As the above table illustrates, despite the use of diverse sampling methods, variation in germination and survival rates, and varying precipitation levels between 2001-2006, the seed population estimates from the two surveys are strikingly similar. Indeed, as the results of paired sample-*t* tests show (Table 4, below), the mean seed density, surveyed at two distinct periods of time, is statistically equal at all three locations. Thus, our research hypothesis ($\mu_{2002} = \mu_{2005}$) is accepted.

Location	***t***	***Sig.***
Buttercup	-.106	.920**
Patton Valley	-.800	.441*
Glamis	1.061	.349*

*$p > 0.1$; **$p > 0.9$

Table 4. Results of paired sample-*t* tests, comparing mean seed density at three locations surveyed in 2001-02 and 2005-06, with a 95% CI.

The significance of this finding cannot be overstated. The results of these tests are clearly indicative of the remarkable consistency of the *A. m.* var. *peirsonii* soil seed bank over a five-year period – and the continuing viability of the species. Although the number of seedlings in a given year has varied from essentially zero (2002 and 2006) to nearly 78,000 (2005) at our 25 sites, and the number of perennial plants has varied from five (2001) to 6,400 (2002), the seed bank was at statistically identical levels in both 2002 and 2006, with population estimates within 56 ha of Peirson's milkvetch potential habitat in the dunes system of between 2 and 3 million seeds.

The relative contribution to the seed bank by plants of various ages of plants has also been a topic of some debate and confusion. The answer is that it varies from year to year depending on the age structure of the reproductive population. Table 5 presents an estimate of relative seed bank contribution (in number of pods) over the six-year period of this study.

The total number of fertile plants (perennial and 2004-05 cohort) counted at 25 sites in April 2006 was 850. Using the previously established convention of an average of 171 pods per plant, pod production in 2006 at those 25 sites is estimated at 145,350.

	2001	*2002*	*2003*	*2004*	*2005*	*2006*
First-year plants	69,615	0	0	30	99,725	0
Perennial plants	0	1,096,452	14,193	3,420	199,728	145,350

Table 5. Seedpod production by first-year reproductive plants and perennials at 25 sample sites, 2001-2006.[2]

Similarly, seedpod production data from the 2005-06 study can be compared with that of 2001-02, a year that followed a large germination event with a high percentage of first-year plants producing seed. Table 5 shows that pod production in 2006 was only about 13% of the 2002 figure, likely due to disparate plant survival rates (21% of first-year plants in 2002 compared to 1.6% in 2006). As is argued further in this report, however, early July rains apparently account for the higher survival rates in 2002, while

---

[2] Assumes production of 5 pods per plant by first-year plants and 171 pods per plant by perennials, and that 100% of perennials are reproductive.

in 2005, summer rain did not occur until mid-August, after a five-month drought (see Table 6 below).

Considering, however, that each Peirson's milkvetch seedpod produces 11-16 seeds (Phillips et al. 2001; Phillips and Kennedy 2002; also Barneby 1964: 862), a conservative estimate of the number of seeds added to the existing seed bank by a population of "only" 850 surviving plants is 1,598,850 seeds.

These 2006 seed counts and estimates directly support our seed bank study results of 2001-02. Additionally, they lend support to our argument that it is *the status of the seed bank rather than counts of live plants that is most indicative of the health and continuing viability of this important desert plant.* Indeed, in spite of excessively dry conditions during the winter of 2005-06, and the resultant minimal germination and survival rate, there was a *substantial contribution of seeds to the soil seed bank* in 2005-06.

Seedpod production among perennial plants, documented in 2005-06

Climate and Survival

The link between climatic events and germination, reproduction, and survival of Peirson's milkvetch has been a primary area of investigation since the start of this project in the spring of 2001. The climatic link between the germination event in the fall of 2000 and rainfall was examined by Phillips et al. (2001). During the first year of our study, it was necessary to utilize remote weather records to correlate germination with precipitation. Installation of two Remote Automated Weather Stations (RAWS) in November 2001 at Buttercup and Cahuilla Ranger Station has allowed a much more accurate estimate of rainfall within the dune system. Monthly rainfall records from August 2004 through May 2006 are shown in Table 6. Records from September 2002 through May 2005 may be found in Phillips and Kennedy (2005).

Date	*Precipitation (in.)*		*#Days*	*Max (in.)*	*Date*	*#Days*	*Max (in.)*	*Date*
-	Buttercup	Cahuilla	Buttercup			Cahuilla		
Aug. 04	0.85	0.47	1	0.85	14th	1	0.47	14th
Sep. 04	0	0.36	0			1	0.36	19th
Oct. 04	1.30	0.88	3	0.84	21st	4	0.51	21st
Nov. 04	0.20	0.52	3	0.11	22nd	2	0.41	21st
Dec. 04	0.83	0.85	3	0.73	6th	4	0.80	6th
Jan. 05	0.77	0.80	5	0.35	4, 26	5	0.44	4th
Feb. 05	1.06	1.46	5	0.71	17th	5	1.17	17th
Mar. 05	0.47	0.35	1	0.47	5th	1	0.35	5th
Apr. 05	0.05	0	1	0.05	24th	0		
May 05	0	0	0			0		
Jun. 05	0	0	0			0		
Jul. 05	0	0.52	0			2	0.50	30th
Aug. 05	0.84	3.82	3	0.53	9th	3	3.58	9th
Sep. 05	0	0	0			0		
Oct. 05	0.02	0.02	1	0.02	18th	2	0.01	17 &18
Nov. 05	0	0	0			0		
Dec. 05	0	0	0			0		
Jan. 06	0	0	0			0		
Feb. 06	0	0	0			0		
Mar. 06	0.15	0.24	1	0.15	11th	1	0.24	11th
Apr. 06	0	0	0			0		
May 06	0	0	0			0		

Source: California Dept. of Water Resources, 2004-06.

Table 6. Precipitation records at two RAWS stations in the Algodones Dunes, August 2004-May 2006. Shaded areas indicate growing season.

The total precipitation at the Buttercup RAWS during the 2005-06 growing season was 0.17 inches, while the Cahuilla RAWS station recorded 0.26 inches. This contrasts with 2004-05 when Buttercup received 4.68 inches and Cahuilla recorded 4.86 inches. Thus, 2005-06 was the driest of the six years of the study, and there was a 2700% difference in precipitation between 2004-05 and 2005-06. Before 2005-06, the driest season in the study was 2001-02, when 0.66 inches were recorded at Buttercup and 0.26 inches fell at Cahuilla (Phillips and Kennedy 2002).

A major rainfall event occurred on August 9, 2005, dropping 3.58 inches of rainfall at Cahuilla. The downpour caused severe flooding and road damage along highway 78 and in the Gecko Road area. It apparently had little effect on Peirson's milkvetch survival, however, as the survival rate in December 2005 was only 1.6% of 2004-05 plants and 19.9% of older plants (from December 2004-05 to December 2005-06). It appears that the hot, dry conditions from April through the end of July had caused heavy mortality prior to the late summer storm.

The same storm that hit Glamis also produced precipitation at Buttercup, although much less. A total of 0.68 inches was recorded over a two-day period, on August 8-9. As in the north dunes, the dry months of April through July apparently caused high plant mortality prior to the August rains.

Our first trip to the dunes in the fall of 2005 was in November, a month after a minimal rainfall event of 0.02 inches on October 17-18. Apparently the amount of rain falling during the October storm was not sufficient to cause germination, and the July storm was not during a season when germination occurs. Both of these corroborate assumptions that have been made previously regarding timing and amount of rainfall as causative factors for germination (Phillips and Kennedy 2002, 2005).

The link between rainfall and germination is shown in Figures 3 and 4 (below). The shaded precipitation fields are cumulative precipitation at the Buttercup and Cahuilla RAWS weather stations. For the purposes of this study, we have defined the growing season as October through April, and the dormant summer season as May through September.

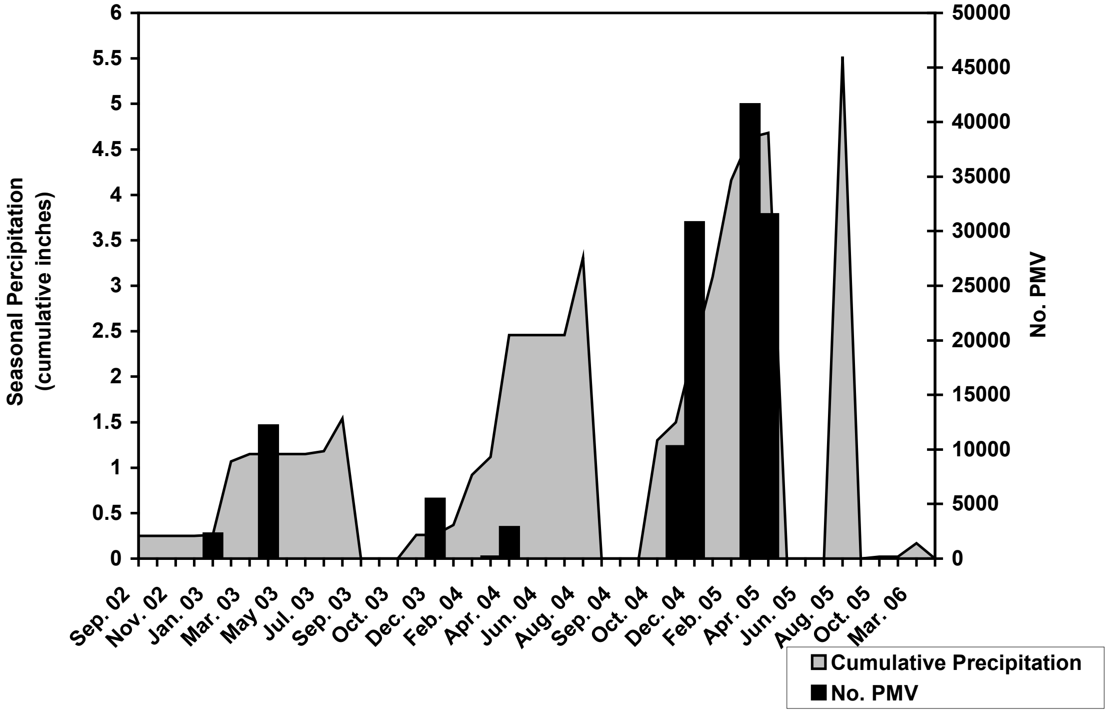


Figure 3. Seasonal precipitation v. seedling counts at 7 Buttercup sample sites 2002-06

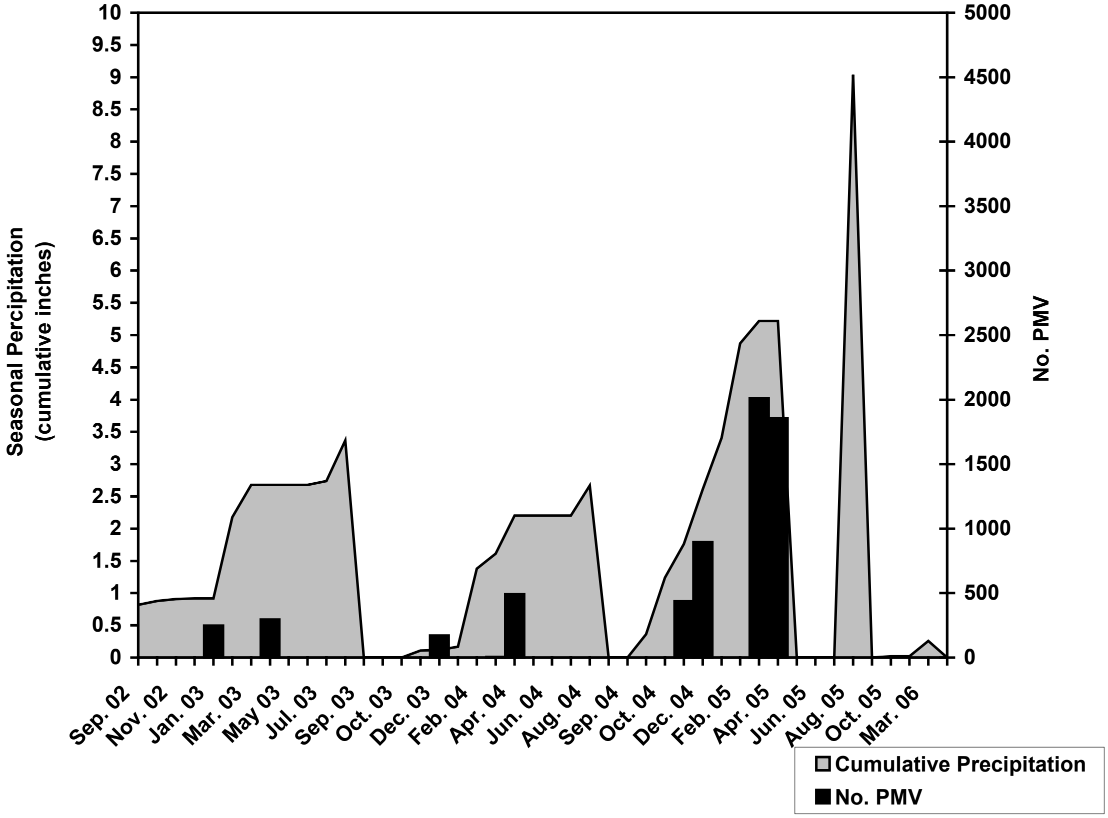


Figure 4. Seasonal precipitation v. seedling counts at 6 Glamis sample sites 2002-06

The cumulative precipitation totals are reset in our diagrams as of 1 October each year. (The actual cumulative figures from the RAWS stations are reset annually on November 16th.) The dark bars represent plant counts at each visit for seven study sites at Buttercup and six sites at Glamis (near the Cahuilla RAWS). Patton Valley site data is not included as there is no nearby weather station.

As the above figures clearly indicate, there is an obvious correlation between the amount and timing of seasonal precipitation in the dunes system and the germination and/or survival rates of Pierson's milkvetch.

We find that the limited (and perhaps too early) precipitation of 2005 resulted in minimal germination. The major rainfall event of August 8-9, 2005 is clearly shown on the graphs. These monsoon thunderstorms dropped large amounts of moisture in a short period of time, especially at Glamis, where flooding was reportedly widespread and runoff caused damage to roads. It was somewhat surprising to find that survival of plants that germinated in 2004-05 was only 1.6% over the summer of 2005. Apparently the rather early start to summer – the last rainfall of the season was on March 11th – resulted in heavy mortality of first-year plants during early summer, prior to the August storms. In December 2005 moist sand was noted 4-6 inches below the surface; this must have been residual moisture from August, and resulted in healthy-looking plants that had been able to withstand the drought conditions of early summer.

The first (and only) rains of fall occurred on October 17th and 18th, 2005, and left 0.02 inches at both Cahuilla and Buttercup. This did not result in any germination, as noted on the November and December 2005 visits. Although prior studies have shown that a moderate amount of rain at that time of year can result in germination, the small amount recorded in 2005 coupled with still-warm temperatures likely made the light fall rains ineffective.

The remainder of the 2005-06 winter was dry until March 11th, when rains totaling 0.15 inches at Buttercup and 0.24 inches at Cahuilla fell at the dunes. This made 2005-06 the driest winter season of the six years of this study. Minimal germination occurred after this storm, as a total of nine seedlings was counted in April.

Additionally, the first rain of the 2003-04 growing season may have occurred too late in the season (November 12th), when 0.26 in fell at Buttercup and 0.11 in was recorded at Cahuilla. The winter was quite dry until a storm in late February. Both of these storms resulted in some germination, however an early April rainfall comparable in magnitude to the February storm resulted in no additional germination. These combined observations provide important evidence that Peirson's milkvetch seeds do not germinate after late rains; most probably a temperature-driven response that prevents seeds from germinating so late in the season that they would have no chance to develop enough to survive the approaching summer.

In stark contrast to precipitation and subsequent lower germination rates in both the 2003-04 and 2005-06 growing seasons (shown in Figures 3 and 4), the magnitude of precipitation in 2004-05 and the explosive germination event it triggered is also clearly evident. Indeed, by mid-March nearly 78,000 first-year plants were counted, more than twice as many first-year plants as were counted in any previous census at the 25 sample sites, and at some sites many of the germinants were already in fruit. The smooth slope of the cumulative rainfall curve in the Figures shows that the season was not punctuated by dry spells (plateaus) as in the prior and latter seasons. The sand was continuously wet a couple of cm below the surface all winter, which apparently accounts for nearly continuous germination throughout the season. Significantly, the Figures also show that a six-week dry spell (with associated warm temperatures and high winds) resulted in a decrease in the number of first-year plants counted in April 2005. Indeed, these critical findings are further supported by additional independent precipitation trend studies:

> Pierson's milk-vetch abundance was closely tied to precipitation throughout the four years of monitoring. Species abundance was highest in 1998, second highest in 1977, third highest in 1999, and lowest in 2000. This mirrors the ranking of the four growing seasons in terms of average precipitation. … *Responses of this species were similar in both the closed and open recreation areas across all 4 years of monitoring*. [BLM 2003:120; emphasis added]

Nevertheless, despite the dry conditions throughout the 2005-06 growing season, surviving perennials and 2004-05 plants produced an abundance of seedpods (145,350 pods, resulting in over 1.5 million seeds among 25 sample sites) by the spring of 2006, making a significant contribution to the existing seed bank. Apparently, the deep, well-developed root systems of older plants allow them to tap moisture stored far beneath the sand's surface, ensuring the reproductive capacity of these perennial plants through significant periods of drought.

Germination, Survival and Recreational Dunes Use

According to the BLM, visitation rates in the Algodones Dunes have climbed steadily over the years and are anticipated to continue to trend upward over the next ten years (BLM 2003, 2004). Indeed, "many families use outdoor recreation as a way to form bonds and transfer important family values to children. A number of Americans feel recreation strengthens the family as a unit and the children as individuals. …Participation in outdoor activities can greatly increase family interaction and foster cohesion" (BLM 2003: 150). Thus, investigation of the impact of increased visitation on the status of *A.M.* var. *peirsonii* in the dunes system is of grave concern.

Figure 5 shows BLM visitation data at the Algodones Dunes 2001 - 2004 and projected visitation estimates of the 2005-06 recreation season. According to the BLM " a 'visit' occurs when one person visits BLM lands to engage in any recreation activity, whether for a few minutes, full day, or more" (BLM 2003: 237). 2005-06 projected visitation estimates are derived from BLM analyses, based on an average 5 percent growth rate from a 2000 baseline season.

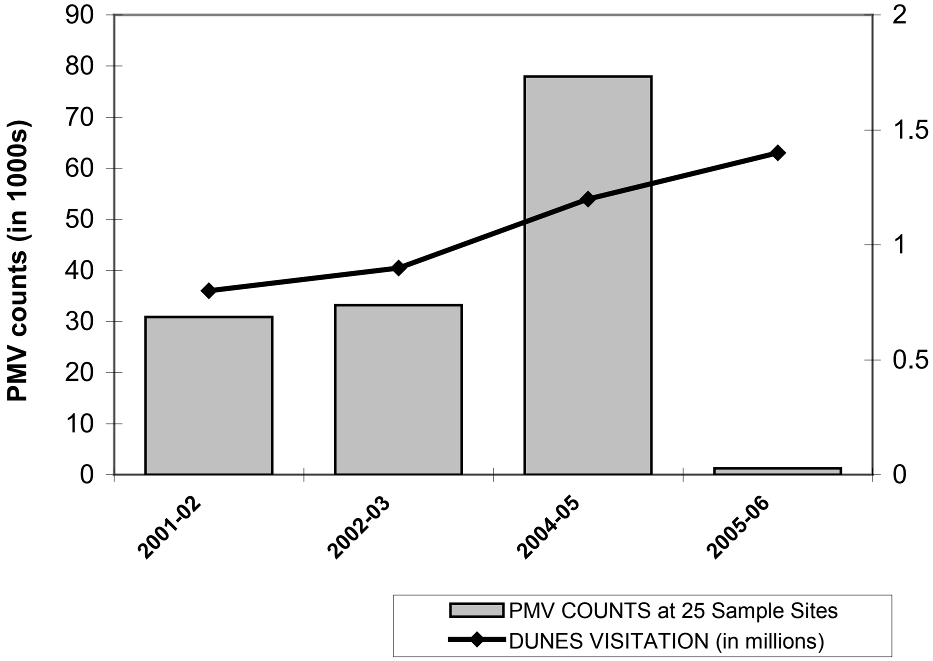


Figure 5. Seasonal Algodones Dunes visitation and Peirson's milkvetch population 2001-2006

As this Figure shows, there is little correlation between recreational use rates and the occurrence of Peirson's milkvetch in the Algodones Dunes. Indeed, if such a correlation did exist, we would expect to see a plant population decline in correspondence with a visitation increase. Not only is this inverse relationship not readily apparent, these data clearly show the opposite effect -- an *increase* in plant population during a period of increased dunes visitation (2001-2005). In fact, the only population decrease that occurred over the entire period of study was during the 2005-06 season, which was (coincidentally) the driest of the growing seasons we have yet encountered. Furthermore, Figure 5 shows a dramatic increase in Peirson's milkvetch population in 2004-05, despite a rise in recreational dunes use. As Table 6 and Figures 3 and 4 (above) show however, 2004-05 was also the wettest growing season we have documented since 2000. Indeed, through direct comparison of Figures 3, 4 and 5, it is clear that the precipitation data essentially mirror fluctuations in plant populations, whereas recreational use data show no correlation with population variance whatever.

CONCLUSIONS

This report summarizes four significant findings from our 2005-06 study of the status of *A. m.* var. *peirsonii* in the Algodones Dunes system.

1) Despite dry conditions, minimal germination and low survival rates, a small number of mature *A. m.* var. *peirsonii* can substantially contribute to the soil seed bank, thus ensuring proliferation of the species.
2) Despite diverse weather conditions, and variations in germination and survival rates, the soil seed bank is remarkably stable over time.
3) Increases in recreational use have little or no impact on annual fluctuations in Peirson's milkvetch population in the Algodones Dunes.
4) The timing and duration of precipitation, along with other climatic factors, is the likely cause of annual variation in plant germination and survival rates.

The contrast between the 2004-05 and 2005-06 growing seasons for Peirson's milkvetch was the greatest of any two consecutive seasons in the course of this study: the former was the wettest documented, producing the highest number of plants, and the latter was the driest, with the fewest plants. Nonetheless, the surviving plants from 2004-05 and previous years did well, with a combination of favorable temperatures and residual soil moisture producing vigorous vegetative growth and abundant reproduction in the spring.

The 2005-06 seed bank study included analysis of the nature of the seed bank, and gathering data that could be used to corroborate conclusions we drew from our initial seed bank study in 2001-02. From the beginning of the study our assumption has been that the status of the population, and the health and well-being of the species, cannot be determined from analysis of the number of living plants alone. The seed bank must be considered as the primary source of information in assessing whether an ephemeral, short-lived species such as Peirson's milkvetch is healthy or imperiled, increasing or decreasing, and in need of intervention or protection to ensure its survival. The similarity of the status of the seed bank in 2002 and 2006 (statistically identical at the 95% confidence level) shows unequivocally that this is the best method of determining whether the species is increasing, decreasing, or stable.

In contrast to the stability of the seed bank, the number of living plants, especially seedlings, is strongly tied to the amount and timing of rainfall. The winter seasons of 2004-05 and 2005-06 had the greatest extremes of rainfall amount of the six years of our studies, and the contrast in numbers of living plants, especially seedlings, followed this pattern precisely.

Comparison of dunes visitation data and the occurrence of Peirson's milkvetch, however, show no correlation between increased recreation and plant occurrences, adding further support to our contention that it is *natural, rather than human, factors that account for annual variance in plant populations.*

Finally, we conclude that the population of *A.* m var. *peirsonii* in the Algodones Dunes is vibrant, healthy, and responsive to climatic events that promote germination more than any other factor, natural or man-caused. It is able to remain dormant by means of a healthy seed bank when conditions are unfavorable, and to germinate explosively when rainfall conditions and temperature are favorable. It is well-adapted to survive and thrive extreme conditions of rainfall, drought, heat, cold, and abrading winds which move large amounts of substrate in a short time. The adaptability of the plants, and their distribution in the dunes with respect to patterns of OHV use, make natural factors under which it has evolved much more important than man-caused factors, including recreation, in determining its health, vigor, and status in the Algodones Dunes.

REFERENCES CITED

Barneby, R. C. 1964. *Atlas of North American Astragalus*. Memoirs of the New York Botanical Garden 13: 858-863.

BLM. 2000a. Monitoring 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. Report prepared by Bureau of Land Management, California State Office, Sacramento, CA, Nov. 2000.

BLM. 2000b. Map of Imperial Sand Dunes Recreation Area. Prepared by Automobile Club of Southern California.

BLM. 2003. Final Environmental Impact Statement for the Imperial Sand Dunes Recreation Area Management Plan and Proposed Amendment to the California Desert Conservation Plan 1980. Electronic document, accessed 31 May, 2006. http://www.blm.gov/ca/pdfs/elcentro_pdfs/FinalEISandRAMP/FinalEIS.pdf

BLM. 2004. Visitation in the Imperial Sand Dunes for 2002/03 and 2003/04 Season. Electronic document, accessed 1 June, 2006. http://www.blm.gov/ca/pdfs/elcentro_pdfs/imperialdunes/Visitation.pdf

BLM. 2005. 2004 Monitoring of Special Status Plants in the Algodones Dunes, Imperial County, California. Bureau of Land Management, California State Office, Sacramento, CA. March 2005

Bowers, J. E. 1986. *Seasons of the Wind*. Northland Press, Flagstaff, AZ. 156 p.

California Department of Water Resources. 2003, 2004, 2005, 2006. Historic precipitation records for Buttercup and Cahuilla weather stations. http://cdec.water.ca.gov/cgi-progs/plotReal?staid=CAU&send_date=now. Electronic document.

CNPS. 2001. *Inventory of rare and endangered vascular plants of California.* 6th ed. California Native Plant Society Press, Sacramento, CA.

Norris, R. M. and K. S. Norris. 1961. Algodones Dunes of southeastern California. Geological Society of America Bulletin 72: 605-620.

Phillips, A. M., III, D. J. Kennedy, and M. Cross. 2001. Biology, distribution, and abundance of Peirson's milkvetch and other special status plants of the Algodones Dunes, California. Report submitted by Thomas Olsen Associates, Inc. to the American Sand Association. 29 p.

Phillips, A. M., III and D. J. Kennedy. 2002. The Ecology of *Astragalus magdalenae* var. *peirsonii:* Distribution, reproduction and seed bank. Report submitted to the American Sand Association. 41 p.

Phillips, A. M., III and D. J. Kennedy. 2003. The Ecology of *Astragalus magdalenae* var. *peirsonii:* Germination and survival. Report submitted to the American Sand Association. 27 p.

Phillips, A. M., III and D. J. Kennedy. 2004. The Ecology and Life History of Peirson's Milkvetch in the Algodones Dunes, California: 2003-2004. Report submitted to the American Sand Association.

Phillips, A. M., III and D. J. Kennedy. 2005. The Life History of Peirson's Milkvetch (*Astragalus magdalenae* var. *peirsonii*) in the Algodones Dunes, California: 2004-2005. Report submitted to the American Sand Association.

Porter, J. Mark. 2003. Natural history of Peirson's milkvetch. Progress Report: March 1, 2003. Submitted to California Fish & Game Dept. 7 p.

Shreve, F. 1964. Vegetation of the Sonoran Desert. IN: Shreve, F., and I. L. Wiggins. *Vegetation and flora of the Sonoran Desert.* Stanford University Press, Stanford, CA. Vol. 1, Part 1.

U. S. Fish and Wildlife Service. 1998. Determination of status for five plant taxa from California: … Peirson's milkvetch … Final Rule. Federal Register 63(193): 53598-53615. Oct. 6, 1998.

U. S. Fish and Wildlife Service. 2003a. Proposed Rule for Critical Habitat for *Astragalus magdalenae* var. *peirsonii.* 68 FR 46143, Aug. 5, 2003.

U. S. Fish and Wildlife Service. 2003b. 90-day finding on petition to delist *Astragalus magdalenae* var. *peirsonii.* 68 FR 52784. Sept. 5, 2003.

U. S. Fish and Wildlife Service. 2004. 12-month finding for a petition to delist *Astragalus magdalenae* var. *peirsonii* (Peirson's milkvetch). 69 FR 31523-31531. Jun. 4, 2004.

Appendix A

Summary of actual plant counts at 25 sample sites, stratified by location, 2001 – 2006

ASA PMV Study Sites - November 2004 - December 2005

Algodones Dunes (ISDRA), California

Site	Loc.	# Plants	# Nov.03-Mar.04 Sdl.	#03-04 Survivors	#New Seedl.	#New Seedl.	#2004-05 Plts.	#2004-05 Plts.	#2004-05 Plts.	#2004-05 Plts.	#2004-05 Plts.	#2004-05 Plts.
No.		Spring 01	Apr. 04	Dec. 04	Nov. 04	Dec. 04	Mar. 05	Fertile Mar. 05	Apr. 05	Fertile Apr. 05	Dec. 05	Fertile Dec. 05
6	Butrcup	340	0	0	55	207	208	187	157	62	3	0
7	"	3,127	1,465	126	5,535	18,880	24,681	12,274	17,982	3,420	377	3
21	"	1,327	82	3	700	1,842	2,175	1,054	2,203	580	21	0
22	"	807	49	5	400	824	634	476	837	460	34	0
23	"	2,800	26	0	215	2,894	1,525	862	3,186	966	9	0
28	"	978	530	21	1,300	2,400	4,364	3,172	2,292	899	47	0
29	"	3,994	732	33	1,860	3,750	8,039	4,934	4,893	909	59	1
32	Pat. Vly.	657	747	51	245	1,604	2,769	1,931	4,052	1,662	34	2
34	"	1,534	85	20	1,500	2,845	2,748	2,419	3,221	1,023	55	4
41	"	120	546	132	525	1,795	2,286	1,453	2,960	1,026	9	0
44	"	798	105	8	0	175	797	572	818	434	57	5
46	"	1,531	1,646	176	1,750	3,050	6,662	3,985	4,326	1,073	68	3
47	"	2,530	585	73	1,100	3,831	3,424	2,129	3,001	1,314	51	3
48	"	1,037	289	25	225	2,165	2,531	1,211	2,248	943	36	3
51	"	1,898	778	128	418	2,074	3,255	2,947	2,859	860	39	0
52	"	3,010	214	36	500	3,009	3,465	2,470	3,398	1,300	65	7
53	"	1,090	140	54	314	545	932	840	1,046	370	5	0
54	"	577	501	163	1,600	2,115	1,632	1,420	2,406	491	45	1
57	"	1,967	842	67	200	918	3,783	3,226	3,188	1,053	197	29
13	Glamis	230	272	47	100	610	1,712	1,238	1,543	990	15	0
15	"	28	0	0	1	28	30	22	19	14	0	0
16	"	265	0	0	114	92	95	48	90	24	0	0
19	"	77	214	0	15	79	117	64	170	62	0	0
60	"	88	5	0	30	40	18	7	11	3	0	0
61	"	41	0	0	125	46	40	17	25	7	7	2
		30,851	9,848	1,168	18,827	55,818	77,922	48,958	66,931	19,945	1,233	63
				(11.9%)				(62.8%)		(29.8%)		(5.1%)

Appendix B

In-field data form, December 2005

Algodones Dunes Rare Plant Surveys

December 2005

Peirson's Milkvetch

Astragalus magdalenae var. *peirsonii*

Site No. _____________ **Area 1 2 3 Date** ___________________

Investigators ____

****

Seedlings present? YES NO

No. of seedlings: 1-10 10-100 100-1000 1000+

No. of 2004-05 survivors _______________________________

No. of 2004-05 survivors reproductive ___________________

No. of perennial survivors _______________________________

No. of perennial survivors reproductive ____________________

Notes:

Appendix C

Seed bank survey in-field data form, March 2006

Algodones Dunes Rare Plant Surveys

Peirson’s Milkvetch

Astragalus magdalenae var. *peirsonii*

Seed Bank studies -- 2005-06

Site ____________________ Point No. ____________________ Area 1 2 3 Date ______________________________

Investigators ____

No.	Frame Size L / S	Seeds No. on Surface	Seeds No. Buried	Seedlings No. Emergent	Seedlings No. Buried	No.	Frame Size L / S	Seeds No. on Surface	Seeds No. Buried	Seedlings No. Emergent	Seedlings No. Buried
1	L					1	S				
2	L					2	S				
3	L					3	S				
4	L					4	S				
5	L					5	S				
6	L					6	S				
7	L					7	S				
8	L					8	S				
9	L					9	S				
10	L					10	S				
11	L					11	S				
12	L					12	S				
13	L					13	S				
14	L					14	S				
15	L					15	S				
16	L					16	S				
17	L					17	S				
18	L					18	S				
19	L					19	S				
20	L					20	S				

<u>Notes</u>: