2005 Monitoring of Peirson's Milk-vetch
in the
Algodones Dunes, Imperial County, California

Bureau of Land Management
California State Office
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Preface

The author of this report is John Willoughby, State Botanist, Bureau of Land Management (BLM), California State Office. Dunes-wide monitoring that began in 2004 (Willoughby 2005b) was continued and intensified in 2005. The 2004 monitoring was an expansion and refinement of a pilot monitoring study conducted in 2003 in two of the seven management areas of the Dunes that support Peirson's milk-vetch. The 2003 pilot study itself benefited from previous pilot sampling of Peirson's milk-vetch and Algodones Dunes sunflower in 2001 and 2002 that was conducted in conjunction with an abundance class monitoring study implemented by BLM between 1998 and 2002 (see Willoughby 2000, 2001, and 2004 for a description of the 1998-2002 monitoring study). The 2003 pilot sampling study is described in Willoughby (2005a); some results from that study are also included in this report.

The study was designed by John Willoughby in consultation with Chris Knauf of the El Centro Field Office, the BLM office responsible for management of the Algodones Dunes. Chris coordinated every aspect of monitoring implementation. The study would not have been possible without his extraordinary leadership. Joelle Viau was contracted by BLM to assist Chris and provided exemplary day-to-day oversight of the monitoring. Erin Dreyfuss and Daniel Steward, both of the El Centro Field Office, also provided very valuable assistance in coordinating and carrying out the study. Erin assisted in the daily oversight of the project, provided training to the monitors in plant identification, and substituted for monitors in walking transects as required. Daniel assisted primarily in the computer applications required by the study. Fran Evanisko of the BLM California State Office provided extremely valuable support in applying the ArcGIS Geographical Information System (ESRI 2004) to the planning of the study and to the analysis and presentation of the data collected.

The study itself was carried out by 36 employees of the Environmental Careers Organization of Boston, Massachusetts, working in teams of 3. The following ECO personnel walked the 3,098 kilometers of transects, took and recorded the data required for the study, and provided data input and quality control: Kellie Burtch, Ursula Carliss, Michael Carlson, James Christopolous, Tami Clayton, Cato Cook, Saana Deichsel, Brent Eastly, Robert Eckert, Jesse Erickson, Laurie Gilligan, Jamie Granger, Dawn Graydon, Emily Howe, Danielle Jarois, Karen Kavenaugh, Aaron Keller, Matt Lachance, Steve Lee, Michelle Maley, Holly Mercier, Brenda Morton, Carlos Navarro Jr., Shannon Page, Lila Prichard, Gina Radieve, Matt Reed, Darwin Richardson, Dana Robison, Diane Rombalski, Dan Thomas, Andrew Trouette, Joe Veverka, Matt Villaneva, Carey Zinck, and Jordon Zylstra. The success of the study is a direct result of their dedication and hard work.

Executive Summary

In late winter and spring 2005, the Bureau of Land Management (BLM) implemented a monitoring program to estimate the density and population size of Peirson's milk-vetch (*Astragalus magdalenae* var. *peirsonii*) in the Algodones Dunes (also called Imperial Sand Dunes), located in southeastern Imperial County, California. Peirson's milk-vetch is a Federally-listed threatened species and a State-listed endangered species.

The Imperial Sand Dunes Recreation Area Management Plan (ISDRAMP), approved by the BLM California State Director in 2005, established eight management areas. The objective of BLM's Monitoring/Study Plan, contained in the ISDRAMP, is to obtain density and population size estimates of the species in each of the seven management areas in which it occurs. Dunes-wide monitoring for ASMAP began in 2004, following pilot monitoring in the Wilderness and Gecko management areas in 2003.

A total of 510 belt transects, ranging in length from 2.35 to 7.75 kilometers, were positioned systematically with a random start within 16 sampling areas located within the seven management areas. Sampling areas were positioned to incorporate as much Peirson's milk-vetch habitat as practical. Transects were 25m wide, and counts were recorded in 25m segments along each of the transects. Counts were made of the number of plants in each of six categories: (1) seedlings and young, nonflowering plants, (2) flowering plants, (3) total number of plants (this is the total of categories 1 and 2), (4) number of plants greater than 1-year old, (5) number of plants showing damage from off-highway vehicles (OHVs), and (6) number of plants showing damage from sources other than OHVs.

The 2004-2005 growing season was very favorable for the germination and establishment of *Astragalus magdalenae* var. *peirsonii* and was probably the best growing season for the species since the 1997-1998 growing season. Rains beginning in October 2004 resulted in a significant germination event. As a result, there were an estimated 1,831,076 Peirson's milk-vetch plants throughout the seven management areas of the Dunes in 2005. This translates into an estimated density of 86.3 plants/hectare, but the species was not uniformly distributed throughout the seven management areas. The highest estimated ASMAP density was in the Ogilby Management Area (132.0 plants/ha) and the lowest estimated density was in the Glamis management area (21.5 plants/ha), which had a significantly lower density that any of the other management areas. The Adaptive Management Area (118.0 plants/ha) had the second highest density and was not significantly different from the Ogilby Management Area. The Buttercup Management Area (88.5 plants/ha) had the next highest estimated density, but because of the variability between sampling units in that area, its estimated density was not significantly different from any of the other management areas except Glamis. The Gecko (80.8 plants/ha) and Wilderness (71.9 plants/ha) management areas were not significantly different from each other, though the estimated density of the former was greater than the latter. The Mammoth Wash Management Area (55.0 plants/ha) had the second lowest density.

The low density in the Glamis Management Area is likely related to the geographic position of this management area east of the areas of the Dunes with the highest concentrations of the species. There is also something of a south to north density gradient, with higher densities in the

southern portion of the Dunes compared to the north. This correlates to a similar gradient in both sand field width and dune size, both of which become larger toward the south.

An average of 75 percent of the plants in spring 2005 had flowered at the time of counting. Only 1.6 percent of the total number of flowering plants were determined to be more than 1-year old. The percentage of plants flowering ranged from a low of 62 percent for the Buttercup Management Area to a high of 85 percent for both the Mammoth Wash and Wilderness management areas. Some of these differences in percent flowering plants were likely the result of the differential timing of the monitoring.

There were major differences between 2005 and the years 2003 and 2004, both in numbers of plants and percent of plants flowering. The favorable 2004-2005 growing season resulted in much higher numbers of plants in spring 2005 than in either 2003 or 2004, and the onset of rains in October 2004 resulted in a high percentage of plants flowering at the time of 2005 monitoring. In contrast, only 0.5% and 2.3% of the total number of plants were flowering at the time of 2003 and 2004 monitoring, respectively. The percentage of plants flowering in 2005 was more similar to percentages observed between 1998-2002.

About 0.44% of the estimated total number of Peirson's milk-vetch plants showed evidence of OHV damage at the time of the survey. Estimates of OHV damage for each of the management areas ranged from 0.0% to 2.37%. Another 4.43% of the total number of plants showed evidence of damage from sources other than OHVs. Estimates of non-OHV damage for each of the management areas ranged from 0.29% to 6.69%. Although this category was originally intended to keep track of damage from insects and disease, observers in 2005 included damage from desiccation, which was by far the most common entry in this category. Consequently, the management areas with the highest percentage of non-OHV damage were those that were monitored late in the sampling period, by which time temperatures were high and soil moisture diminished.

Only 21,777 (1.6%) of the Peirson milk-vetch plants in 2005 were more than a year old. Thus, 98.4% of the 2005 plants represented a 2004-2005 growing season cohort. This supports previous contentions that this species functions more like an annual than a perennial and that the majority of seeds in the seed bank are produced from current year plants in good rainfall years.

The seed bank of this species is likely very large. Most of the seeds that germinated in 2003 and 2004 did not survive to reproduce and were therefore lost to the seed bank prior to the 2004-2005 growing season. Despite this loss, nearly two million plants germinated in the 2004-2005 growing season.

Because of the very favorable 2004-2005 growing season, we now have the clearest picture yet of the distribution of Peirson's milk-vetch in the Algodones Dunes.

Introduction

In late winter and spring 2005, the Bureau of Land Management (BLM) implemented a monitoring program to estimate the density and population size of Peirson's milk-vetch (*Astragalus magdalenae* var. *peirsonii*, hereafter referred to as ASMAP) in the Algodones Dunes (also called Imperial Sand Dunes), located in southeastern Imperial County, California. ASMAP is a Federally-listed threatened species and a State-listed endangered species. Though the survey began in late winter 2005, it will be referred to simply as the spring 2005 survey hereafter.

The Imperial Sand Dunes Recreation Area Management Plan (ISDRAMP), approved by the BLM California State Director in 2005, established eight management areas (Map 1). The objective of BLM's Monitoring/Study Plan, contained in the ISDRAMP, is to obtain density and population size estimates of the species in each of the seven management areas in which it occurs (the species does not occur in the Dune Buggy Flats Management Area). Dunes-wide monitoring for ASMAP began in 2004, following pilot monitoring in the Wilderness and Gecko management areas in 2003. The results of the 2004 monitoring were reported in Willoughby (2005b); results from the 2003 pilot monitoring were reported in Willoughby (2005a). The 2005 results are reported here.

Methods

Two or more rectangular sampling areas were delineated in each of the seven management areas of the Algodones Dunes (Map 2), for a total of 16 sampling areas. Sampling area boundaries were placed so that the major part of the habitat of ASMAP was encompassed within the sampling areas. Rectangles were used to facilitate the systematic random placement of belt transects. This resulted in two sampling areas in each of the management areas except for the Adaptive Management Area (AMA), in which four sampling areas were established. Each of the sampling areas was given a unique number, as shown on Map 2.[1]

Each of the sampling areas consisted of a rectangle with its long sides oriented approximately northwest to southeast (the Buttercup 11 sampling area approximates a square). The shorter top side of each sampling area rectangle functioned as a baseline from which 25m wide belt transects were run perpendicular to the baseline and therefore parallel to each of the long sides of the sampling area rectangle. The starting points for each of the transects established in 2004 was determined using systematic sampling with a random start (see Willoughby 2005b for more information on this process). A total of 135 transects were established in 2004 (Table 1 shows

[1] Based on the 2004 monitoring data, four additional sampling areas were added in 2005. The Mammoth Wash, Wilderness, and Ogilby management areas each had a single sampling area in 2004. These single 2004 sampling areas were each divided into two sampling areas for the 2005 sampling. The Adaptive Management Area (AMA) had three sampling areas in 2004. One of these AMA sampling areas was divided in two for the 2005 monitoring. Sampling areas 3, 4, 5, 6, 7, 8, 11, and 12 on Map 2 are the same sampling areas monitored in 2004. Sampling areas 13, 14, 15, 16, 17, 18, 19, and 20 were newly created for the 2005 sampling, as described above. To avoid confusion, 2004 sampling areas that were divided in 2005 were given different numbers. Thus, no 2005 sampling areas were given the numbers 1, 2, 9, or 10. The total habitat area sampled in 2005 was the same as in 2004; the only difference in 2005 was how that area was divided for purposes of sampling. Density and population estimates for each of the management areas are directly comparable between 2004 and 2005.

the number of 2004 transects in each of the sampling areas). In 2005 all of the transects established in 2004 were reread and additional transects were added to improve the precision of the 2005 estimates. These additional transects were added again by using systematic sampling with a random start, with the caveat that no new transect could be within 25m of a transect established in 2004. Table 1 shows the number of transects placed in each of the sampling areas, the lengths of each transect, and the total area encompassed by each sampling area.

Table 1. Sampling areas for the 2005 special status plant monitoring in the Algodones Dunes.

Management Area	Sampling Area Number	Number of 2004 Transects *	Number of 2005 Transects **	Transect Length (km)	Area Within Sampling Area (ha)
Mammoth Wash	13	15	30	4.45	668.22
	14	15	30	4.45	668.22
Wilderness	15	15	25	7.08	1,246.46
	16	15	25	7.08	1,246.22
Gecko	3	9	25	6.54	1,891.7
	4	9	25	6.54	1,888.6
Glamis	5	9	25	6.24	1,815.29
	6	9	25	6.24	1,817.87
AMA	7	5	38	6.15	1,362.91
	8	5	33	5.38	1,176.88
	17	5	42	6.95	1,527.49
	18	4	42	6.95	1,527.49
Ogilby	19	9	43	7.73	1,698.49
	20	9	43	7.73	1,698.49
Buttercup	11	16	29	2.35	463.63
	12	16	30	3.58	509.23
Total		165	510		21,207.19

* The Mammoth Wash and Wilderness management areas each had a single sampling area sampled by 15 transects in 2004. In 2005 each of the 2004 sampling areas was divided in half by a line running perpendicular to the direction of the transects. Thus, each of the new sampling areas within each management area included the same number of transects as 2004, but the length of the transects in each of the 2005 sampling areas was half the length of the 2004 transects. This is the reason that this column totals 165 transects instead of the 135 transects that were actually read in 2004.
** The number of 2005 transects includes the 2004 transects plus the transects added in 2005.

The sampling objective articulated in the ISDRAMP Monitoring/Study Plan is to achieve estimates that are within 30% of the true total population size at the 95% confidence level for each of the management areas. The number of transects to be placed in each of the sampling areas in 2005 was determined based on the sample variance obtained for each of the management areas in 2004.

Each transect was a 25m wide belt. The beginning and ending points of each transect were entered into Hewlett Packard iPAQ Personal Data Assistants running ArcPad Mobile GIS (ESRI 2004), along with points corresponding to each 25m segment along each transect. GPS units attached to the iPAQs were then used to navigate between each of the 25m points from the beginning to the end of each transect. Counts were made of the number of ASMAP in each of 6 categories described below within each of the 25m segments. This enabled the creation of maps showing the cells along each of the transects that were occupied by these species and the number of plants found in each of the cells. Separate counts were made for the following categories: (1) seedlings and young, nonflowering plants, (2) flowering plants, (3) total number of plants (this is the total of categories 1 and 2), (4) number of plants greater than 1-year old, (5) number of plants showing damage from OHVs, and (6) number of plants showing damage from sources other than OHVs.

Density and population estimates were made based on the transect values. Estimates of densities and population totals were made separately for each sampling area, treating the systematic random samples as if they were simple random samples (this is a common practice in natural resource sampling—see, for example, Schreuder et al. 2004). Sampling area estimates were consolidated into a management area estimate by treating each sampling area as a separate stratum and using formulas for stratified random sampling. The survey module in the statistical program Stata Release 9 (StataCorp 2005) automates these formulas and was used to calculate the estimates and confidence intervals reported here. Because sampling was without replacement, the finite population correction factor was used in the calculation of the confidence intervals. Because transects were of different lengths, a ratio estimator of the mean number of plants per transect divided by the mean area per transect was used to estimate density and population size as recommended by Stehman and Salzer (2000) to avoid potential problems in estimating these parameters for the Dunes and a whole and for those management areas (AMA and Buttercup) with belt transects of unequal area. [2]

Precipitation data were obtained from two remote area weather stations (RAWS), one located in the northern half of the dunes at the Cahuilla Ranger Station near State Highway 78 on the western edge of the dunes and the other at Buttercup in the southern part of the dunes south of Interstate 8. These data were compared to long-term average precipitation obtained from the Western Regional Climate Center for weather stations in the vicinity of the Dunes. The locations of these stations are shown in Willoughby (2004).

Except for the precipitation graphs, which were constructed using Microsoft Excel 2003, all graphs were constructed using SYSTAT version 10.2 (SYSTAT 2002).

[2] Ratio estimation proved to be an unnecessary precaution with this dataset. The data were analyzed using both the svy: ratio and svy: total commands in Stata release 9 (the latter command ignores the difference in belt area) and the estimates of population densities and totals and their confidence intervals derived from these two commands were effectively equivalent.

Results

Transects were read by 12 teams of 3 individuals each. Monitoring began on February 15, 2005, and ended on April 26, 2005. Table 2 shows the number of transects read by sampling area during each week of the monitoring.

Table 2. Number of transects read each week during 2005 by sampling area.

Management and Sampling Area *	Number of Transects by Week **										
	1	2	3	4	5	6	7	8	9	10	11
MW 13	0	9	0	0	0	21	0	0	0	0	0
MW 14	0	0	0	0	4	26	0	0	0	0	0
Wilderness 15	0	0	9	6	7	2	0	0	1	0	0
Wilderness 16	0	0	2	5	9	2	3	0	4	0	0
Gecko 3	1	11	1	0	6	0	1	0	0	5	0
Gecko 4	0	4	3	0	7	0	9	0	0	2	0
Glamis 5	0	0	13	0	0	12	0	0	0	0	0
Glamis 6	0	0	15	0	0	10	0	0	0	0	0
AMA 7	0	0	0	13	0	0	11	11	0	0	3
AMA 8	0	0	5	0	12	5	0	10	0	0	1
AMA 17	0	0	0	1	10	0	0	15	1	14	1
AMA 18	0	0	0	11	0	0	11	0	0	20	0
Ogilby 19	0	0	0	12	0	0	10	0	8	0	13
Ogilby 20	0	0	0	0	9	0	0	11	11	0	12
Buttercup 11	0	27	0	0	1	0	0	1	0	0	0
Buttercup 12	0	0	0	0	8	0	0	0	22	0	0

* Sampling area numbers are as shown on Map 2. The name in front of the sampling area number corresponds to the management area within which the sampling area is located. Two management area names have been abbreviated as follows: MW = Mammoth Wash; AMA = Adaptive Management Area.
** Based on starting date of transects. In a few cases the ending date of the transect may be > 1 week from starting date. Week 1 = Feb. 15-20; week 2 = Feb. 21-27; week 3 = Feb. 28-Mar. 6; week 4 = Mar. 7-13; week 5 = Mar. 14-20; week 6 = Mar. 21-27; week 7 = Mar. 28-Apr. 3; week 8 = Apr. 4-10; week 9 = Apr. 11-17; week 10 = Apr. 18-24; week 11 = Apr. 25-May 1.

Weather

Because weather is critical to the interpretation of these monitoring data, it will be discussed first.

Growing Season Precipitation. Growing season precipitation is defined as the amount of precipitation between the months of September 1 and June 30, which corresponds to the definition used by Sneva and Hyder (1962) in the Intermountain West (they term this period the "crop-year"). Although some rain often falls in the Dunes in the months of July and August as a result of tropical storms from the Gulf of California, this rain likely does not promote germination and growth of ASMAP because of the intense heat during those months.

Table 3 shows the total growing season precipitation recorded by the two RAWS stations for growing seasons 2002-2003, 2003-2004, and 2004-2005. Figures 1, 2, and 3 show the monthly precipitation totals recorded by each of the stations for these growing seasons.

Table 3. Growing season (September-June) precipitation from the two remote area weather stations (RAWS) in the Algodones Dunes. The long-term growing season average of the WRCC stations in the vicinity of the dunes is given for comparison. All units are in inches.

Growing Season	Cahuilla RAWS	Buttercup RAWS	Average of the two RAWS	Long-term average of all WRCC Stations
2002-2003	2.68	1.15	1.92	2.50
2003-2004	2.2	2.46	2.33	2.50
2004-2005	4.87	4.68	4.78	2.50

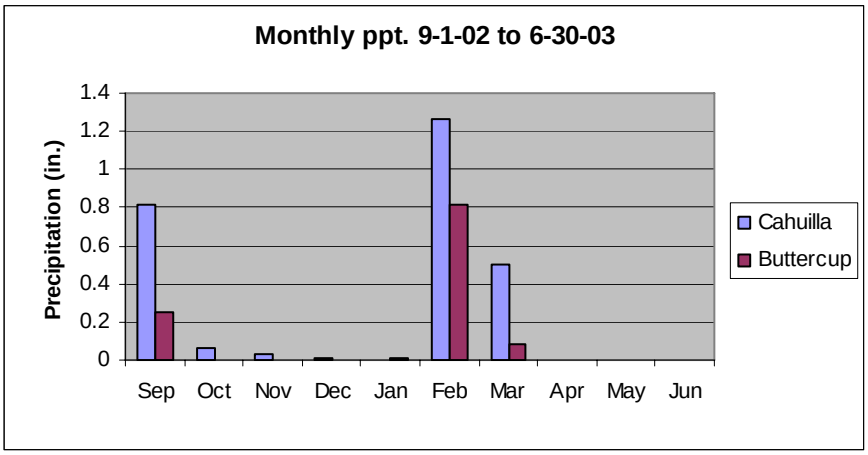

Figure 1. Monthly total precipitation between September 2002 and June 2003 for the two RAWS stations in the Algodones Dunes.

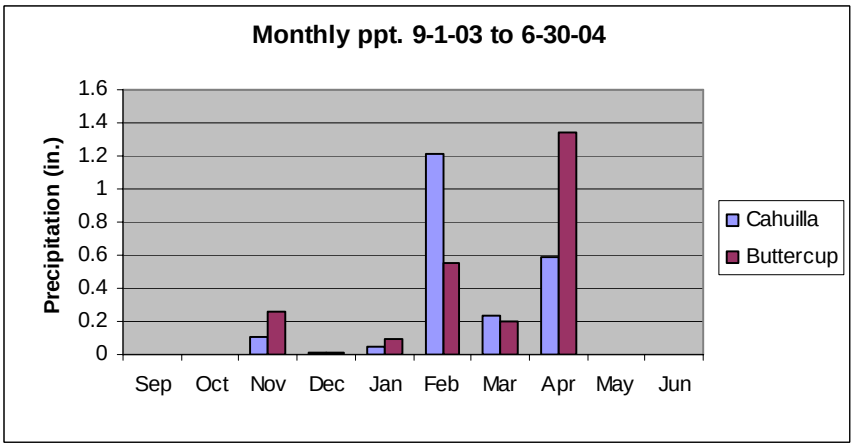

Figure 2. Monthly total precipitation between September 2003 and June 2004 for the two RAWS stations in the Algodones Dunes.

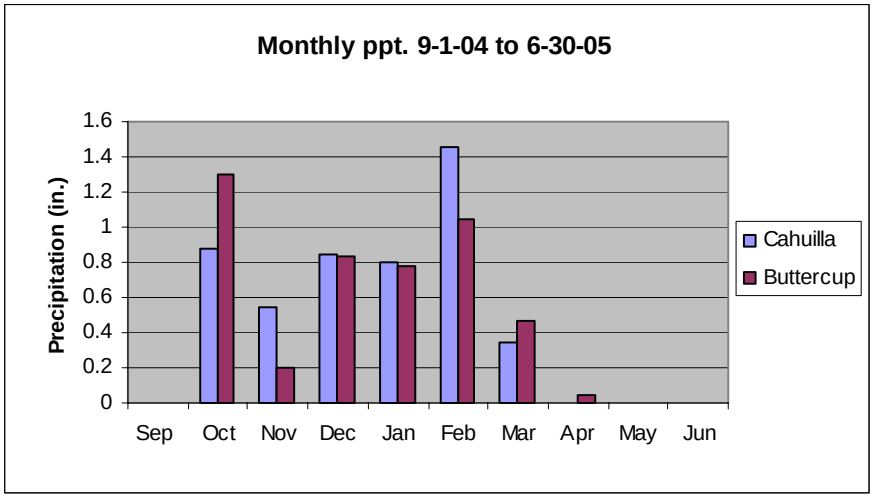

Figure 3. Monthly total precipitation between September 2004 and June 2005 for the two RAWS stations in the Algodones Dunes.

Astragalus magdalenae* var. *peirsonii

Figures 3 and 4 show the estimates of density (number of plants/hectare) and total population size, respectively, of ASMAP in each of the management areas and the contribution of the two stage classes (nonflowering and flowering) to the totals. Table 4 shows the actual density and population estimates for each of the 6 categories for each management area and the Dunes as a whole. Figures 5-16 are dot graphs and 95% confidence intervals showing estimates of ASMAP density (plants/ha) and total population size for each of the 6 categories for which data were collected. For each of these categories there is a pair of graphs, the first one showing estimates of density (number of plants/hectare) and the second one showing estimates of total population size. Density estimates are shown for each management area and the Dunes as a whole. Population estimates are shown for each management area.

Figures 17 and 18 compare the density and total population size estimates, respectively, for each of the seven management areas and the entire dunes in 2004 and 2005 and for the Wilderness and Gecko management areas in 2003 (only the Wilderness and Gecko management areas were sampled in 2003 as part of a pilot sampling effort).

Maps 3-8 show the distribution and abundance of ASMAP in all of the 25m x 25m cells sampled in 2005 as follows:

Map 3: All ASMAP individuals.
Map 4: Nonflowering ASMAP individuals.
Map 5: Flowering ASMAP individuals.
Map 6: ASMAP individuals > 1 year old.
Map 7: ASMAP individuals showing evidence of OHV damage.
Map 8: ASMAP individuals showing evidence of damage from sources other than OHVs.

Appendix 1 gives ASMAP population and density estimates for each of the 16 sampling areas of the Algodones Dunes. These sampling area statistics are given to highlight differences between the sampling areas in each of the management areas. The sampling objective in the Monitoring/Study Plan for the Imperial Sand Dunes Recreation Area Management Plan (to achieve estimates that are within 30% of the true total population size at the 95% confidence level) are based on estimates for each of the *management* areas, which are the statistics shown in Table 4 and discussed in this report.

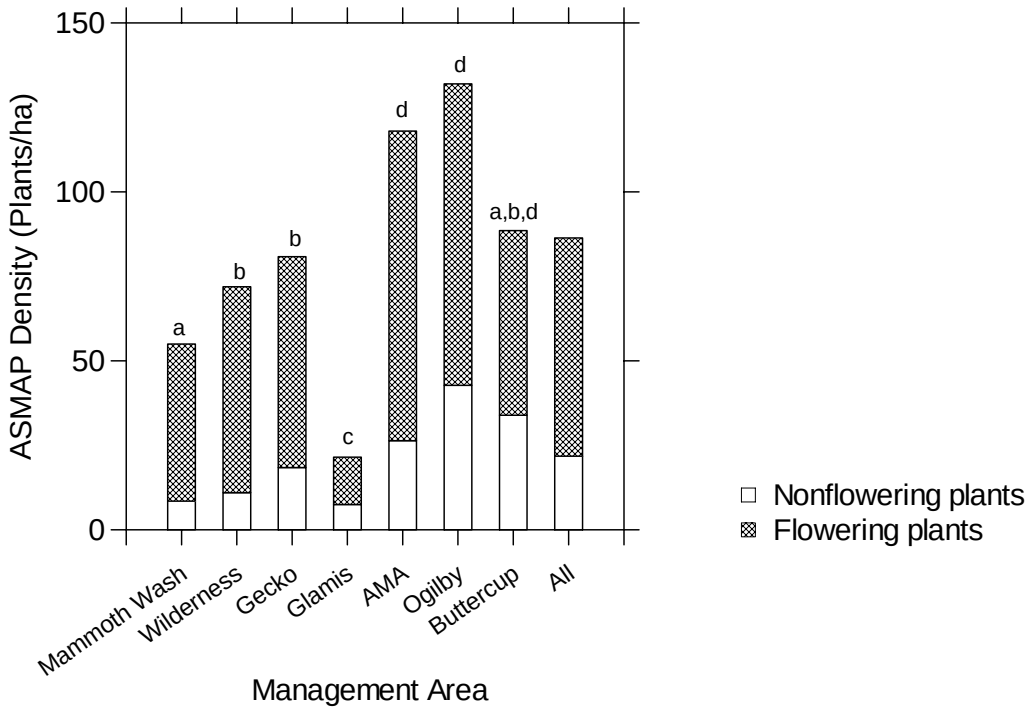

Figure 3. ASMAP estimated density (plants/ha) for each of the management areas and the Dunes as a whole ("all") in spring 2005. Densities of management areas with different letters at the tops of the bars are significantly different at $P<0.05$.

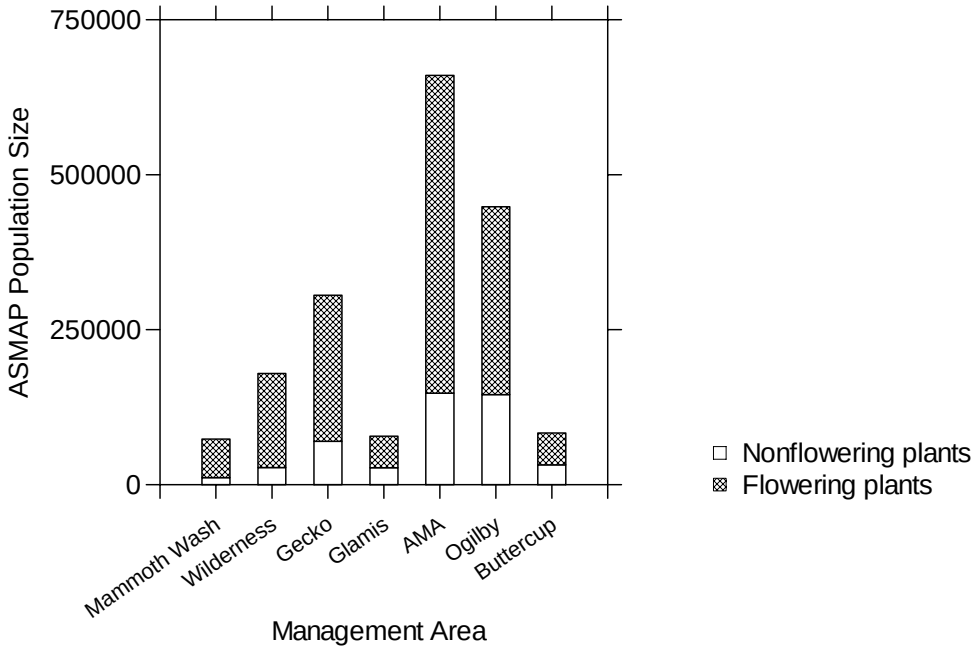

Figure 4. ASMAP estimated population size for each of the management areas in spring 2005.

Table 4. Spring 2005 population and density estimates for ASMAP in the 7 management areas of the Algodones Dunes and the entire dunes. Estimates from survey module of Stata release 9.

Mammoth Wash

Category	Density estimate (plants/ha)	95% Confidence Limits Lower	95% Confidence Limits Upper	Population Estimate	95% Confidence Limits Lower	95% Confidence Limits Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	8.498	7.084	9.912	11,357	9,467	13,246	16.64%
Flowering and past flowering	46.500	40.428	52.573	62,145	54,030	70,260	13.06%
Total number of plants	54.998	47.897	62.099	73,502	64,012	82,991	12.91%
Plants > 1 year old	0.445	0.245	0.645	594	327	862	44.99%
Plants with OHV damage	0.061	0.039	0.084	82	52	112	36.32%
Plants with other damage	0.160	0.084	0.237	214	112	317	47.87%

Wilderness

Category	Density estimate (plants/ha)	95% Confidence Limits Lower	95% Confidence Limits Upper	Population Estimate	95% Confidence Limits Lower	95% Confidence Limits Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	11.021	8.029	14.013	27,475	20,016	34,934	27.15%
Flowering and past flowering	60.896	49.116	72.675	151,808	122,442	181,173	19.34%
Total number of plants	71.917	57.587	86.247	179,283	143,559	215,006	19.93%
Plants > 1 year old	0.506	0.180	0.894	1,262	448	2,229	76.62%
Plants with OHV damage	0.000	0.000	0.000	0	0	0	0.00%
Plants with other damage	1.240	0.440	2.113	3,090	1,097	5,267	70.42%

Gecko

Category	Density estimate (plants/ha)	95% Confidence Limits Lower	95% Confidence Limits Upper	Population Estimate	95% Confidence Limits Lower	95% Confidence Limits Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	18.464	15.524	21.404	69,798	58,684	80,912	15.92%
Flowering and past flowering	62.372	53.324	71.420	235,785	201,581	269,990	14.51%
Total number of plants	80.836	69.786	91.886	305,583	263,810	347,356	13.67%
Plants > 1 year old	1.826	1.295	2.358	6,904	4,895	8,912	29.10%
Plants with OHV damage	0.532	0.255	0.810	2,012	963	3,061	52.12%
Plants with other damage	2.676	1.248	4.103	10,114	4,718	15,511	53.35%

Table 4. Spring 2005 population and density estimates for ASMAP in the 7 management areas of the Algodones Dunes and the entire dunes. Estimates from survey module of Stata release 9.

Glamis

Category	Density estimate (plants/ha)	95% Confidence Limits Lower	95% Confidence Limits Upper	Population Estimate	95% Confidence Limits Lower	95% Confidence Limits Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	7.454	5.795	9.114	27,083	21,054	33,112	22.26%
Flowering and past flowering	14.070	10.976	17.164	51,118	39,877	62,360	21.99%
Total number of plants	21.524	16.971	26.078	78,201	61,658	94,744	21.15%
Plants > 1 year old	1.102	0.802	1.402	4,004	2,915	5,094	27.22%
Plants with OHV damage	0.314	0.202	0.427	1,142	734	1,550	35.74%
Plants with other damage	0.565	0.161	0.969	2,052	583	3,520	71.56%

Adaptive Management Area

Category	Density estimate (plants/ha)	95% Confidence Limits Lower	95% Confidence Limits Upper	Population Estimate	95% Confidence Limits Lower	95% Confidence Limits Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	26.372	21.742	31.002	147,546	121,644	173,449	17.56%
Flowering and past flowering	91.619	80.108	103.129	512,585	448,187	576,983	12.56%
Total number of plants	117.991	102.580	133.402	660,131	573,909	746,353	13.06%
Plants > 1 year old	1.168	0.870	1.465	6,534	4,870	8,199	25.47%
Plants with OHV damage	0.184	0.123	0.245	1,030	688	1,373	33.20%
Plants with other damage	6.284	4.642	7.927	35,160	25,972	44,347	26.13%

Ogilby

Category	Density estimate (plants/ha)	95% Confidence Limits Lower	95% Confidence Limits Upper	Population Estimate	95% Confidence Limits Lower	95% Confidence Limits Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	42.785	32.252	53.319	145,341	109,559	181,123	24.62%
Flowering and past flowering	89.165	71.138	107.192	302,892	241,655	364,129	20.22%
Total number of plants	131.950	104.682	159.218	448,233	355,604	540,861	20.67%
Plants > 1 year old	0.656	0.405	0.908	2,229	1,374	3,085	38.36%
Plants with OHV damage	0.532	0.313	0.752	1,808	1,062	2,554	41.27%
Plants with other damage	8.827	6.630	11.024	29,984	22,521	37,447	24.89%

Table 4. Spring 2005 population and density estimates for ASMAP in the 7 management areas of the Algodones Dunes and the entire dunes. Estimates from survey module of Stata release 9.

Buttercup

Category	Density estimate (plants/ha)	95% Confidence Limits		Population Estimate	95% Confidence Limits		Precision (+/- percent of estimate)
		Lower	Upper		Lower	Upper	
Nonflowering seedlings and juveniles	33.914	17.517	50.312	32,994	17,042	48,946	48.35%
Flowering and past flowering	54.632	29.816	79.448	53,149	29,007	77,292	45.42%
Total number of plants	88.546	48.838	128.255	86,143	47,513	124,774	44.84%
Plants > 1 year old	0.256	0.095	0.419	249	92	407	63.32%
Plants with OHV damage	2.095	1.014	3.177	2,038	986	3,091	51.62%
Plants with other damage	0.575	0.216	0.934	559	210	908	62.41%

Entire dunes

Category	Density estimate (plants/ha)	95% Confidence Limits		Population Estimate	95% Confidence Limits		Precision (+/- percent of estimate)
		Lower	Upper		Lower	Upper	
Nonflowering seedlings and juveniles	21.766	19.471	24.060	461,594	412,936	510,251	10.54%
Flowering and past flowering	64.576	59.756	69.395	1,369,482	1,267,269	1,471,695	7.46%
Total number of plants	86.341	79.607	93.076	1,831,076	1,688,259	1,973,893	7.80%
Plants > 1 year old	1.027	0.882	1.172	21,777	18,707	24,848	14.10%
Plants with OHV damage	0.383	0.302	0.463	8,113	6,399	9,826	21.12%
Plants with other damage	3.828	3.209	4.447	81,174	68,045	94,302	16.17%

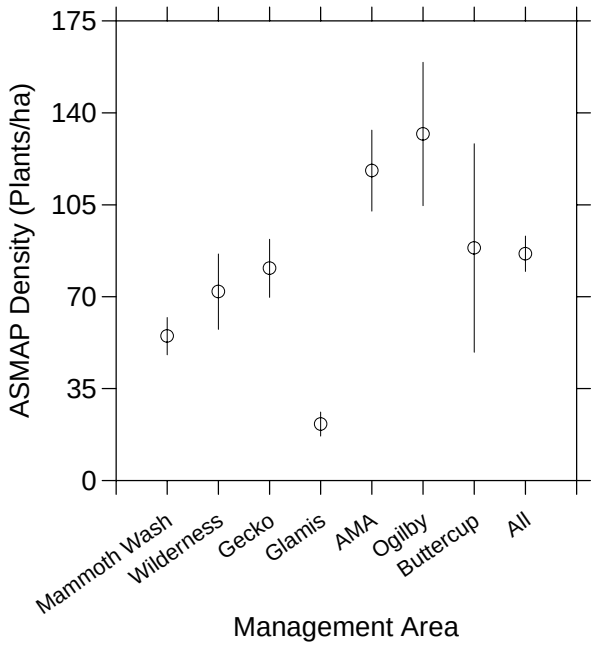

Figure 5. Density (plants/ha) of all ASMAP plants in spring 2005 for each of the management areas and the Dunes as a whole ("All"). Error bars are 95% confidence intervals.

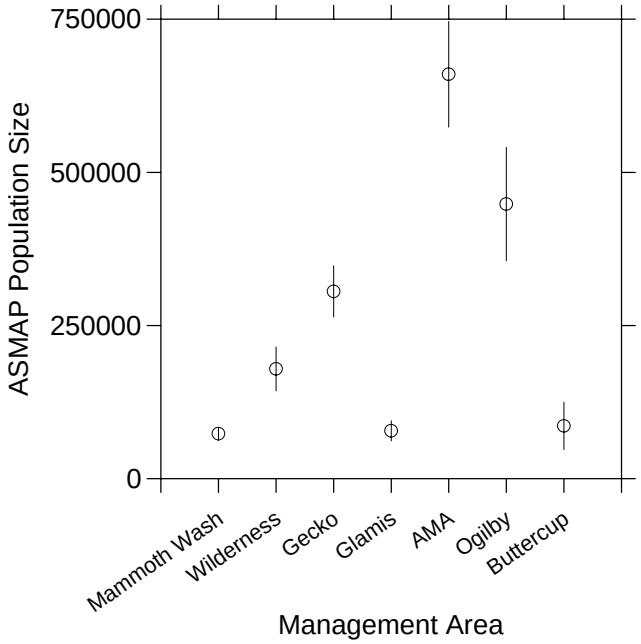

Figure 6. Population size of all ASMAP plants in spring 2005 for each of the management areas. Error bars are 95% confidence intervals.

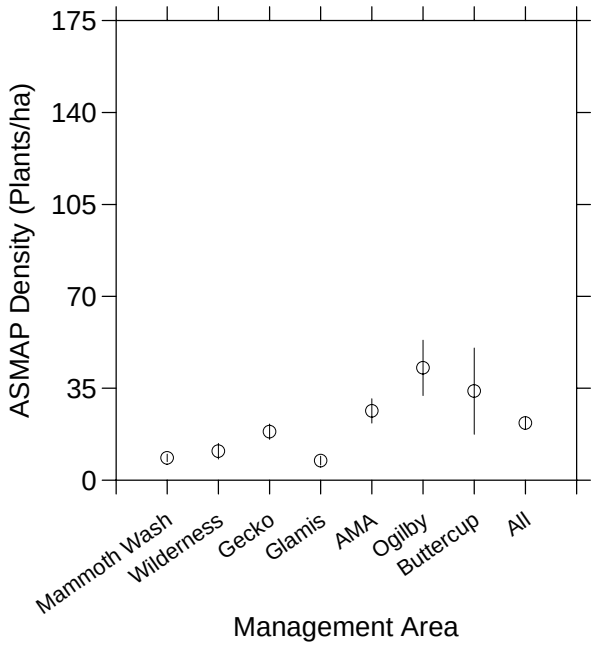

Figure 7. Density (plants/ha) of seedlings and young, nonflowering ASMAP plants in spring 2005 for each of the management areas and the Dunes as a whole ("All"). Error bars are 95% confidence intervals.

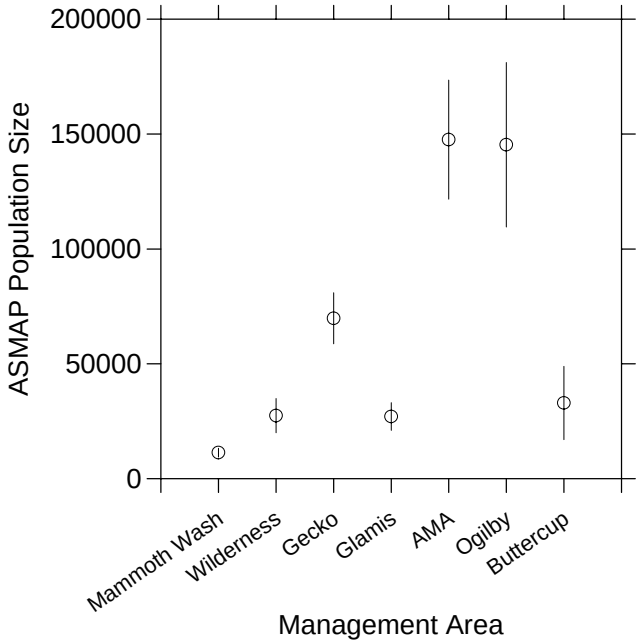

Figure 8. Population size of seedling and young, nonflowering ASMAP plants in spring 2005 for each of the management areas. Error bars are 95% confidence intervals.

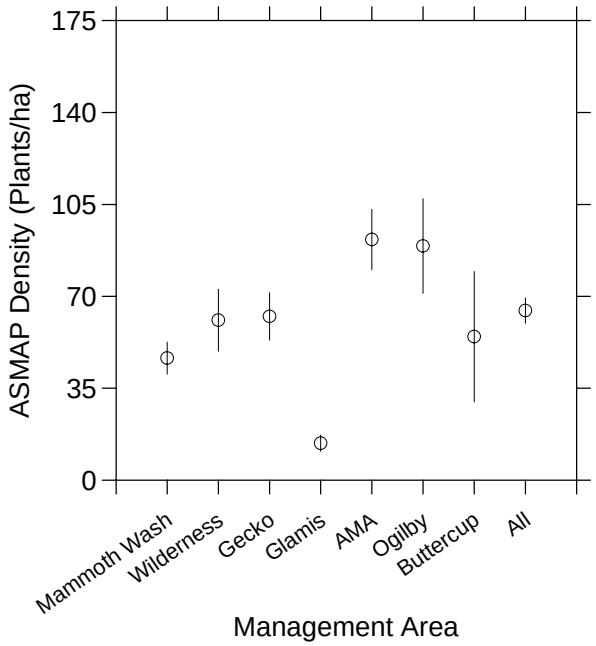

Figure 9. Density (plants/ha) of flowering ASMAP plants in spring 2005 for each of the management areas and the Dunes as a whole ("All"). Error bars are 95% confidence intervals.

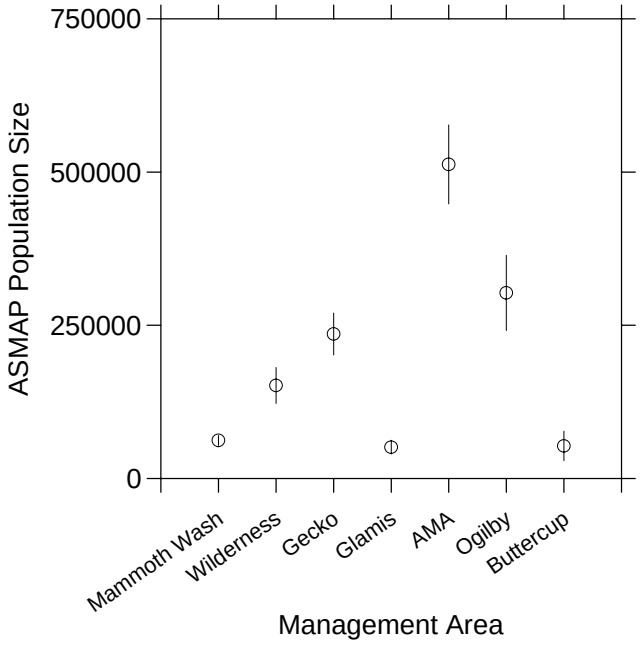

Figure 10. Population size of flowering ASMAP plants in spring 2005 for each of the management areas. Error bars are 95% confidence intervals.

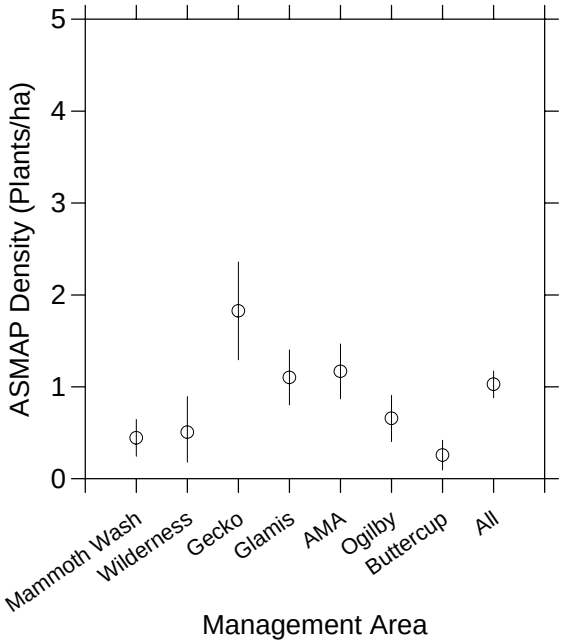

Figure 11. Density (plants/ha) of > 1 year-old ASMAP plants in spring 2005 for each of the management areas and the Dunes as a whole ("All"). Error bars are 95% confidence intervals.

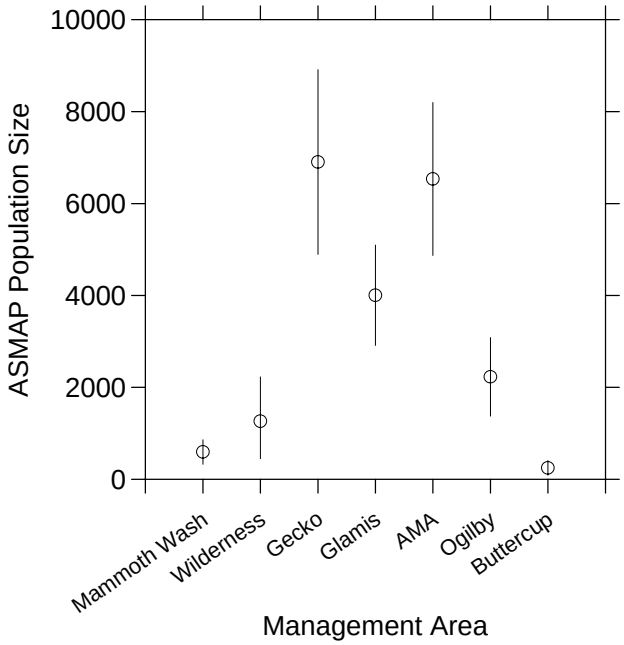

Figure 12. Population size of > 1 year-old ASMAP plants in spring 2005 for each of the management areas. Error bars are 95% confidence intervals.

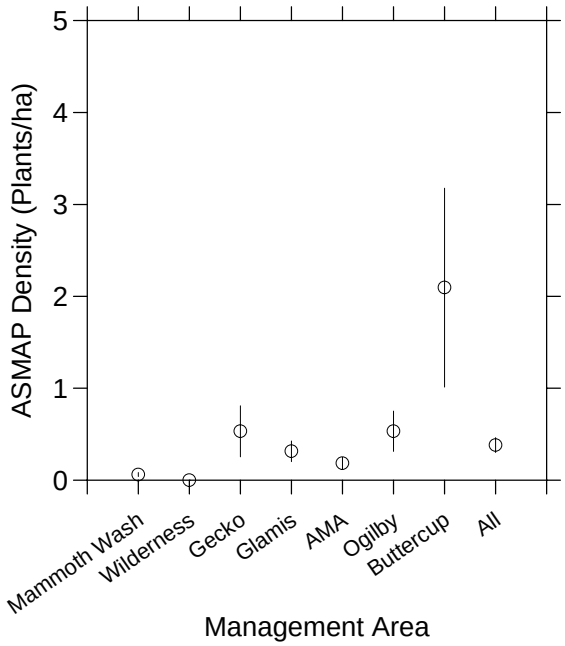

Figure 13. Density (plants/ha) of ASMAP plants showing OHV damage in spring 2005 for each of the management areas and the Dunes as a whole ("All"). Error bars are 95% confidence intervals.

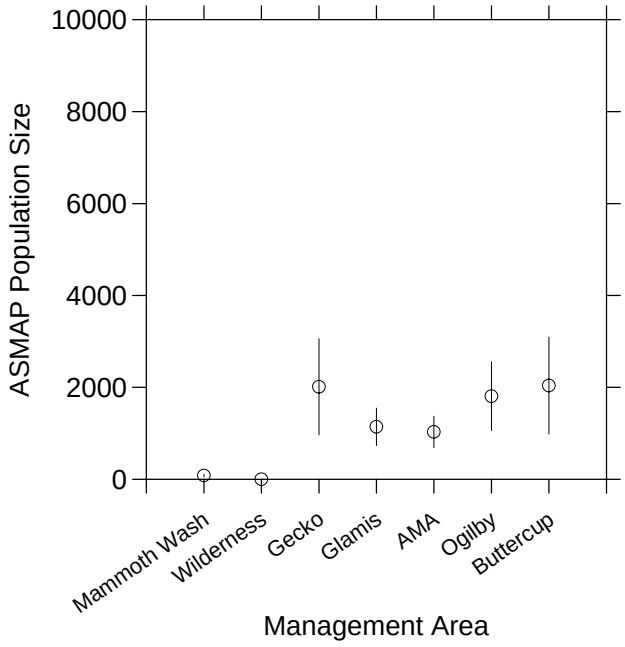

Figure 14. Population size of ASMAP plants showing OHV damage in spring 2005 for each of the management areas. Error bars are 95% confidence intervals.

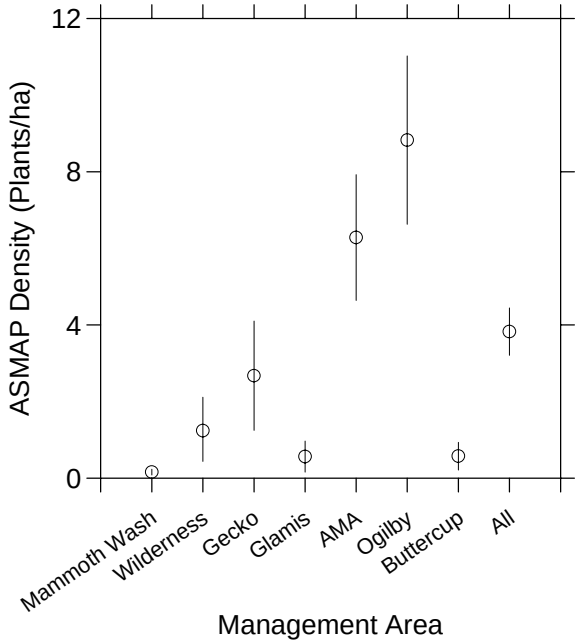

Figure 15. Density (plants/ha) of ASMAP plants showing non-OHV damage in spring 2005 for each of the management areas and the Dunes as a whole ("All"). Error bars are 95% confidence intervals.

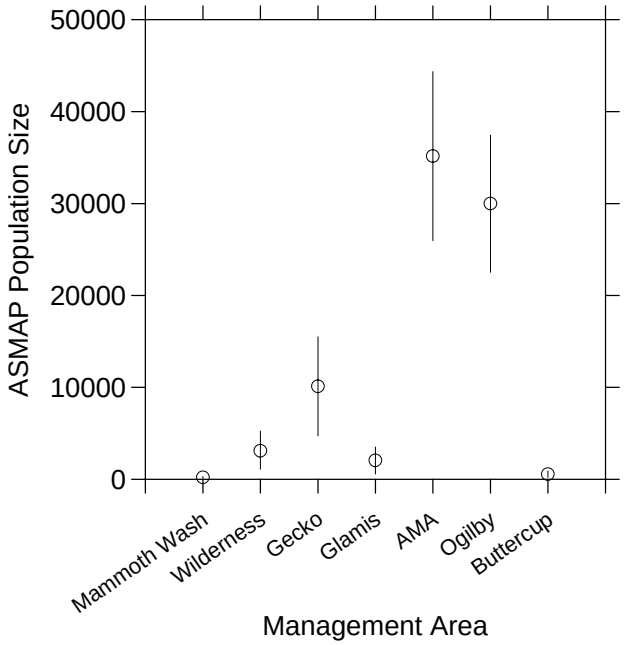

Figure 16. Population size of ASMAP plants showing non-OHV damage in spring 2005 for each of the management areas. Error bars are 95% confidence intervals.

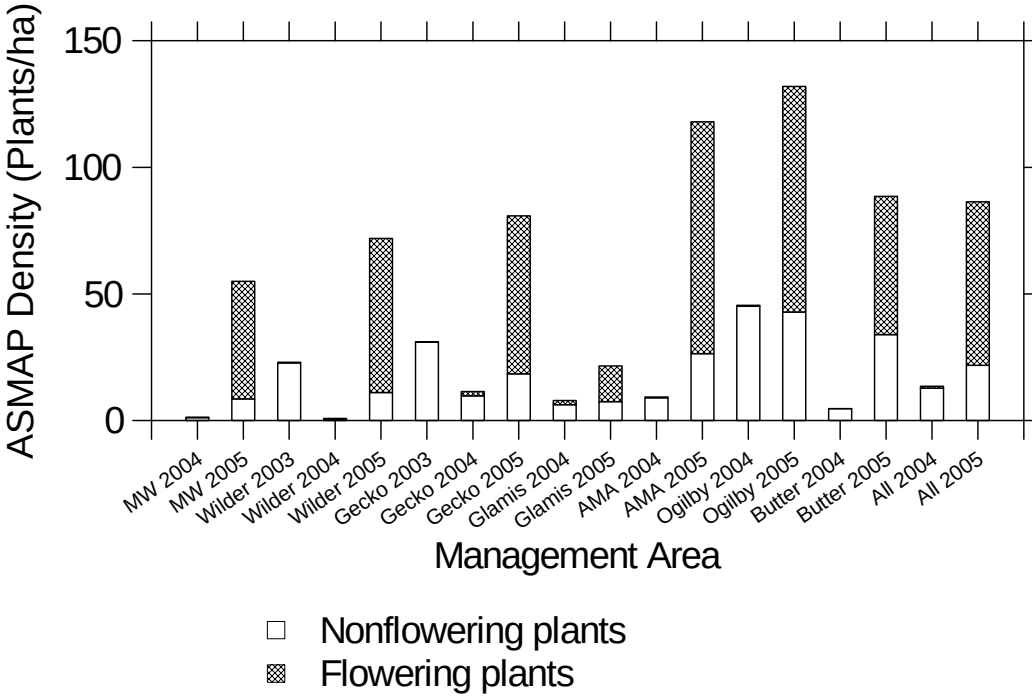

Figure 17. ASMAP density (plants/ha) in each of the seven management areas and the entire dunes in 2004 and 2005 and in the Wilderness and Gecko management areas in 2003. Management area abbreviations are as follows: MW = Mammoth Wash; Wilder = Wilderness; AMA = Adaptive Management Area; Butter = Buttercup; All = entire dunes.

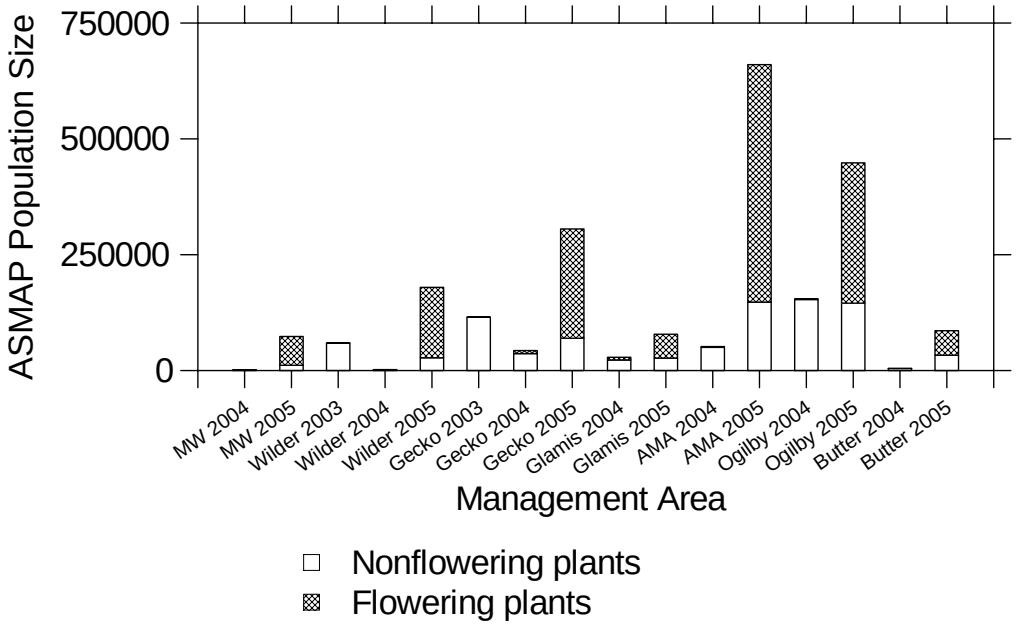

Figure 18. ASMAP population size in each of the seven management areas and the entire dunes in 2004 and 2005 and in the Wilderness and Gecko management areas in 2003. See Figure 1 for abbreviations of management areas.

Discussion

Distribution and abundance. There were an estimated 1,831,076 ASMAP plants throughout the seven management areas of the Dunes in 2005. This translates into an estimated density of 86.3 plants/hectare, but as Figures 3 and 4 and Map 3 show, ASMAP was not uniformly distributed throughout these seven management areas.

Because management areas are different sizes, density (plants/ha) is a better parameter than population size to use to compare management areas.[3] ASMAP densities between management areas were compared using pairwise t tests.[4] Figure 3 shows the results of these t tests. The highest estimated ASMAP density was in the Ogilby Management Area (132.0 plants/ha) and the lowest estimated density was in the Glamis management area (21.5 plants/ha), which had a significantly lower density that any of the other management areas. The Adaptive Management Area (118.0 plants/ha) had the second highest density and was not significantly different from the Ogilby Management Area. The Buttercup Management Area (88.5 plants/ha) had the next highest estimated density, but because of the variability between sampling units in that area, its estimated density was not significantly different from any of the other management areas except Glamis. The Gecko (80.8 plants/ha) and Wilderness (71.9 plants/ha) management areas were not significantly different from each other, though the estimated density of the former was greater than the latter. The Mammoth Wash Management Area (55.0 plants/ha) had the second lowest density. The average density over the entire dunes was 86.3 plants/ha.

The Dunes-wide total population estimate for 2005 was 1,831,076 million plants. The Adaptive Management Area with an estimated 660,131 plants accounted for the highest percentage (36.1%) of this total. Totals and percentages in descending order for the other management areas are as follows: Ogilby (448,233 plants, 24.5%), Gecko (305,583 plants, 16.7%), Wilderness (179,283 plants, 9.8%), Buttercup (86,143 plants, 4.7%), Glamis (78,201 plants, 4.3%), and Mammoth Wash (73,502 plants, 4.0 %). Note that because of differences in the sizes of the management areas, this order is different from the order based on density.

The low density in the Glamis Management Area is likely related to the position of this management area in the Dunes. Phillips and Kennedy (2002, page 16) noted that ASMAP sites "were generally in the western portion of the dunes, in an area of moderate-sized, well-developed dunes sandwiched between the sand ridges of the western edge and the "high dunes" in the central part of the dune field…." Data from this study support this conclusion. Map 3 shows that the distribution and abundance of ASMAP in the two sampling areas (5 and 6) that comprise the Glamis Management Area are similar to sampling areas 8 and 17 in the eastern part of the AMA and Sampling Area 20 in the eastern part of the Ogilby Management Area (refer to Map 2

[3] The use of density expressed as the number of plants per hectare should not in any way imply that ASMAP is uniformly distributed throughout a management area, which is definitely not the case. In fact, the highly clumped distribution exhibited by the species led to the use of stratification and very long belt transects in order to more efficiently estimate the number of plants. Density is used here as a means of standardizing the estimates for different-sized management areas in order to make meaningful comparisons between these areas.

[4] No corrections (such as the Bonferroni correction) were applied to the *P* values from these tests to control for multiple testing because these were planned comparisons and because recent researchers have shown these corrections to be counterproductive (see, for example, Cabin and Mitchell 2000, Moran 2003, Nakagawa 2004, and Perneger 1998).

for sampling area numbering). The density estimates for these sampling areas (Appendix 1) are as follows: (1) Sampling Area 8: 10.9 plants/ha; (2) Sampling Area 17: 11.1 plants/ha; and (3) Sampling Area 20: 19.7 plants/ha. These estimates are even lower than the 21.5 plants/ha estimate for the Glamis Management Area. The majority of ASMAP plants in the AMA and Ogilby management areas are in the sampling areas on the western side of these management areas, which greatly increases the overall density estimates for these two areas. Unlike the AMA and Ogilby management areas, the Glamis Management Area does not include any of the "prime" ASMAP habitat on the western side of the Dunes; therefore, the estimate for the management area is low.

Because the 2004-2005 growing season was very favorable for the germination and establishment of ASMAP, Map 3 provides the clearest picture yet of the distribution of the species in the Dunes.

Stage-class composition. An average of 75% of the plants in spring 2005 had flowered at the time of counting (Table 5). An estimated 1,369,482 of the dune-wide estimate of 1,831,076 were flowering adults (Table 4, Figures 8 and 10); of these, 21,777 or 1.6 percent of the total number of flowering plants were determined to be more than 1-year old (Table 4, Figure 12). Maps 4 and 5 show the distribution and abundance of nonflowering and flowering plants, respectively.

Table 5 shows the percentages of plants flowering at the time of monitoring based on the estimated numbers given in Table 4. As the table shows, the percentage of plants flowering ranged from a low of 62 percent for the Buttercup Management Area to a high of 85 percent for both the Mammoth Wash and Wilderness management areas. Some of these differences in percent flowering plants appear to be related to the timing of the monitoring. For example, all but two of the 29 transects read in Sampling Area 11 in the Buttercup Management Area were read in the second week of the study (Table 2), at which time a smaller percent of the plants were in flower than if the transects had been read later in the survey. Because Sampling Area 11 supports the vast majority of the plants in the Buttercup Management Area (of the estimated 86,143 plants in that management area, 85,543 were in Sampling Area 11—see Appendix 1), the percent of plants flowering in the entire Buttercup Management Area is lower than the percentages for the other management areas. Similarly, more than 50% of the Glamis Management Area had been sampled by the end of the third week of monitoring, which likely accounts for the comparatively low percent of flowering plants in that management area. At the other extreme, all of the monitoring in the Mammoth Wash Management Area occurred during the fifth week of monitoring, by which time most plants had flowered, leading to a comparatively high percent of plants flowering in that management area. However, some of the differences in the percent of plants flowering appear to be unrelated to the timing of monitoring. The relatively high percentage of plants flowering in the Wilderness Management Area and the relatively low percentage flowering in the Ogilby Management Area do not appear to be adequately explained by the timing of the monitoring (though much of the monitoring in the Ogilby Management Area took place late in the sampling period and thus may have picked up more plants that germinated late in the growing season).

Table 5. Percent of 2005 plants flowering at time of monitoring by management area.

Management Area	Percent of Plants Flowering at Time of Monitoring
Mammoth Wash	84.5%
Wilderness	84.7%
Gecko	77.2%
Glamis	65.4%
AMA	77.6%
Ogilby	67.6%
Buttercup	61.7%
Average for Entire Dunes	74.8%

The 2005 stage-class composition was much different than the stage-class composition in both 2003 and 2004 (Figures 17 and 18). Because rains sufficient for significant germination did not occur until February in both 2003 and 2004, most of the plants were seedlings or juvenile, nonflowering plants at the time of monitoring in both of those years. Only 5.7% of the plants counted in spring 2004 were flowering and more than half of these were plants greater than 1-year old. Only 2.3% of the plants that germinated in fall/winter 2003-2004 were flowering at the time of the spring 2004 survey (Willoughby 2005b). The percentage of plants flowering in 2003 was 0.5% (Willoughby 2005a).

The reason for the much higher percentage of flowering plants in 2005 as compared to either 2004 or 2003 is clearly the occurrence of precipitation sufficient to induce germination beginning in October 2004 and continuing in every month through early March with the possible exception of November for the southern part of the Dunes (Figure 3). As a result of these early fall rains, ASMAP seeds germinated and had time to mature by the time monitoring occurred in spring 2005. The stage-class composition observed in 2005 was more similar to compositions observed during a different Peirson's milk-vetch monitoring study between 1998 and 2002 (Willoughby 2004), in which 99% of the plants tallied in 1998 were flowering, 100% of those tallied in 1999 and 2000 (both poor rainfall years) were flowering, 87.5% of those tallied in 2001 were flowering, and 93.3% of those tallied in 2002 were flowering. Phillips and Kennedy (2005) revisited 25 sample sites in the Dunes during November 2004, December 2004, March 2005, and April 2005. Their November visit documented germination from the October rains. Their December visit documented additional germination that had taken place since the November visit. Similarly, their March visit documented additional germination that had taken place since the December visit.

Only 21,777 (1.6%) of the estimated 1,369,482 flowering plants were determined to be more than 1-year old. Map 6 shows the distribution and abundance and Table 6 shows the percentages of these > 1-year old plants by management area.

Table 6. Percent of 2005 flowering plants > 1-year old by management area.

Management Area	Percent of Flowering Plants > 1-year Old
Mammoth Wash	1.0%
Wilderness	0.8%
Gecko	2.9%
Glamis	7.8%
AMA	1.3%
Ogilby	0.7%
Buttercup	0.5%
Average for Entire Dunes	1.6%

It is unclear why the percentage of > 1-year old plants in the Glamis Management Area (7.8%) is so much higher than the Dunes-wide average. That management area also had the smallest number of plants of any management area in the Dunes.

The relatively small percentage of flowering plants > 1-year old is not surprising given the relatively low and poorly distributed rainfall of the previous two growing seasons. As pointed out above, most plants germinated late in both spring 2003 and 2004 in response to February rains and most of these plants did not survive to reproduce. Additionally, the 2001-2002 growing season was also unfavorable. Consequently, most 2005 plants > 1-year old would have likely germinated in 2001 in response to the relatively good rainfall of the 2000-2001 growing season, and then would have had to survive through 3 unfavorable growing seasons. Phillips and Kennedy (2003) found that only 0.27% of the plants that germinated in the 2000-2001 growing season survived even until 2003. They also found that only 0.05% of the seedlings that germinated in February 2003 survived until 2004 (Phillips and Kennedy 2004). Based on Phillips and Kennedy's numbers, it seems likely that our 2005 estimates of plants > 1-year old may be high: it is possible that observers may have incorrectly placed some large plants that germinated in October 2004 in the > 1-year old category.

The fact that at least 98.4% of the 2005 flowering plants represented a 2004-2005 growing season cohort supports previous contentions that this species functions more like an annual than a perennial and that the majority of seeds in the seed bank are produced from current year plants in good rainfall years (Willoughby 2002 and 2004, Phillips and Kennedy 2002 and 2005). [5]

Differences in density and abundance between 2003, 2004, and 2005. The drastic difference in stage-class composition between that observed in 2005 and that observed in both 2003 and 2004 was discussed above. The differences in density and population size between 2005 and the previous two years are even more striking. Figures 17 and 18 display density and population size, respectively, for these three years. As these figures demonstrate, densities and population

[5] It has been contended (U.S. Fish and Wildlife Service 2004) that plants greater than 1-year old are important to maintenance of the seed bank based on the conclusions of Romspert and Burk (1979) that plants that become reproductive in the first season do not contribute significantly to the seed bank. However, Willoughby (2002) looked at precipitation patterns preceding and during the Romspert and Burk study, which took place between June 1978 and April 1979, and concluded that many, if not most, of the plants Romspert and Burk considered to be more than 1-year old were likely part of a cohort from the current growing season.

sizes were much higher in every management area and the Dunes as a whole than they were in 2004. Densities and population sizes were also much higher in 2005 than in 2003 in the Wilderness and Gecko management areas (the only two management areas sampled in 2003). These differences are clearly the result of the much higher and well-distributed growing season precipitation in 2004-2005 as compared to the previous two growing seasons (see Table 3 and Figures 1-3). Refer to Willoughby 2005a and Willoughby 2005b for the actual 2003 and 2004 estimates.

The seed bank of this species is likely very large. Phillips and Kennedy (2002) conservatively estimated that 2.5 million seeds were produced in the 2000-2001 growing season at the 60 sites they examined. Most of the seeds that germinated in 2003 and 2004 did not survive to reproduce and were therefore lost to the seed bank prior to the 2004-2005 growing season (Willoughby 2005a and 2005b, Phillips and Kennedy 2003 and 2004). Despite this loss, almost two million plants germinated in the 2004-2005 growing season.

Precision of the estimates. The sampling objective articulated in the ISDRAMP Monitoring/Study Plan is to achieve estimates that are within 30% of the true total population size at the 95% confidence level for each of the management areas. Table 7 shows the precision levels attained for estimates of total population size in each of the management areas and the Dunes as a whole. Table 4 gives precision levels obtained for the other categories for which estimates were made.

Table 7. Precisions attained for 2005 estimates of the total number of ASMAP plants in each of the management areas and the Dunes as a whole.

Management Area	Precision (+/- percent of the population estimate)
Mammoth Wash	12.9%
Wilderness	19.9%
Gecko	13.7%
Glamis	22.0%
Adaptive Management Area	13.1%
Ogilby	20.7%
Buttercup	44.8%
Entire Dunes	7.8%

As Table 7 shows, the sampling objective was achieved in every management area except for the Buttercup Management Area. Because of the high variability in the spatial distribution of plants in the Buttercup Management Area (almost all of the plants are confined to the westernmost of the two Buttercup sampling areas—see Map 3 and Appendix 1), we were only able to achieve a precision of 44.8% despite sampling more than 43% of the entire area. Based on these results it appears unlikely that we will be able to meet the objective 30% precision with any reasonable level of sampling. Either we will have to be satisfied with a precision level similar to that obtained in 2005 or we will have to modify the area sampled within the Buttercup Management Area. Because more than 99% of the plants in the Buttercup Management Area occur in Sampling Area 11 (Appendix 1), a reasonable approach would be to only conduct sampling in Sampling Area 11 and use that number as the estimate for the entire management area. Under

this approach, some or all of the sampling effort that was allocated to Sampling Area 12 in 2005 could be shifted to Sampling Area 11 in 2006. Splitting Sampling Area 11 into two new sampling areas, a western sampling area and an eastern sampling area, would also likely help achieve better precision levels for the Buttercup Management Area because there is a higher concentration of ASMAP in the western part of the current Sampling Area 11 (Map 3).

Precision levels for the other management areas were more than acceptable and far better than those achieved in 2004 (Willoughby 2005b). The improvement from 2004 is a combination of adding four sampling areas and increasing the number of transects sampled. The 7.8% precision for the Dunes-wide estimate is remarkably good.

OHV effects. Figures 13 and 14 display the density and population size, respectively, of plants with signs of damage from OHVs at the time of the survey. Actual numbers are included in Table 4. Map 7 shows the distribution and abundance of these impacted plants. Table 8 shows the percent of the total number of plants that showed signs of impact from OHVs in 2005.

Table 8. Percent of ASMAP plants showing signs of damage from OHVs in 2005.

Management Area	Percent of Total Number of Plants Impacted
Mammoth Wash	0.11%
Wilderness	0.00%
Gecko	0.66%
Glamis	1.46%
Adaptive Management Area	0.16%
Ogilby	0.40%
Buttercup	2.37%
Entire Dunes	0.44%

Dunes-wide, an estimated 8,113 plants, representing 0.44% of the total estimated plants, showed signs of impact from OHVs. A higher percentage of the plants in the Buttercup Management Area were impacted by OHVs, which is to be expected given its relatively high OHV use and relatively small size compared to the other management areas. The Glamis and Gecko management areas experienced the next highest percentage of plants with OHV damage (1.46% and 0.66%, respectively).

Other damage. Figures 15 and 16 display the density and population size, respectively, of plants damaged by sources other than OHVs. Actual numbers are included in Table 4. Map 8 shows the distribution and abundance of non-OHV damaged plants. Table 9 shows the percent of the total number of plants that showed signs of damage from sources other than OHVs in 2005.

Table 9. Percent of ASMAP plants with damage from sources other than OHVs in 2005.

Management Area	Percent of Total Number of Plants Damaged
Mammoth Wash	0.29%
Wilderness	1.72%
Gecko	3.31%
Glamis	2.62%
Adaptive Management Area	5.33%
Ogilby	6.69%
Buttercup	0.65%
Entire Dunes	4.43%

Dunes-wide, an estimated 81,174 plants, representing 4.43% of the total estimated plants, showed signs of damage from sources other than OHVs. This category was originally intended to serve as a means of ascertaining the extent of damage from insects and/or disease, but observers in 2005 included desiccation in this category, and the majority of the 81,174 plants showed this type of damage. Indeed, the higher percentage of damaged plants in the Ogilby and Adaptive management areas likely result from the fact that many of the transects in these two areas were read in the last two weeks of the study (the weeks beginning April 18 and 25) when temperatures were high and soil moisture diminished (Table 2). Many of these damaged plants may have already flowered and set seed, but because data on damaged plants was not recorded separately by stage class this is impossible to tell. Phillips and Kennedy (2005) noted that many of the first-year plants they tracked in 2005 that were in fruit in March were dead in April. Likewise, some of the plants that had not yet flowered during their March visit were also dead in April.

Summary

The 2004-2005 growing season was very favorable for the germination and establishment of *Astragalus magdalenae* var. *peirsonii* and was likely the best growing season for the species since the 1997-1998 growing season. Rains beginning in October 2004 resulted in a significant germination event and an estimated 1,831,076 plants occupied the Dunes in spring 2005. Of this total, 1,369,482 plants (75%) were flowering or past-flowering at the time of monitoring. Only 21,777 (1.6%) of these plants were more than a year old. Thus, 98.4% of the 2005 plants represented a 2004-2005 growing season cohort. This supports previous contentions that this species functions more like an annual than a perennial and that the majority of seeds in the seed bank are produced from current year plants in good rainfall years.

There were major differences between 2005 and the years 2003 and 2004, both in numbers of plants and percent of plants flowering. The favorable 2004-2005 growing season resulted in far more plants in spring 2005 than in either 2003 or 2004 and the onset of rains in October 2004 resulted in a high percentage of plants flowering at the time of 2005 monitoring. In contrast, only 0.5% and 2.3% of the total number of plants were flowering at the time of 2003 and 2004

monitoring, respectively. The percentage of plants flowering in 2005 was more similar to percentages observed between 1998-2002.
The seed bank of this species is likely very large. Phillips and Kennedy (2002) conservatively estimated that 2.5 million seeds were produced in the 2000-2001 growing season at the 60 sites they examined. Most of the seeds that germinated in 2003 and 2004 did not survive to reproduce and were therefore lost to the seed bank prior to the 2004-2005 growing season (Willoughby 2005a and 2005b, Phillips and Kennedy 2003 and 2004). Despite this loss, almost two million plants germinated in the 2004-2005 growing season.

ASMAP density was lowest in the Glamis Management Area, likely as a result of its geographic position to the east of the areas of the Dunes with the highest concentrations of the species. There is also something of a south to north density gradient, with higher densities in the southern portion of the Dunes compared to the north. This correlates to a similar gradient in both sand field width and dune size, both of which become larger toward the south.

About 0.44% of the estimated total number of Peirson's milk-vetch plants showed evidence of OHV damage at the time of the survey. Estimates of OHV damage for each of the management areas ranged from 0.0% to 2.37%.

Because the 2004-2005 growing season was very favorable for the germination and establishment of ASMAP, Map 3 provides the clearest picture yet of the distribution of the species in the Dunes.

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Appendix 1

Spring 2005 Population and Density Estimates for ASMAP in the 16 Sampling Areas of the Algodones Dunes.

The following table gives population and density estimates for *Astragalus magdalenae* var. *peirsonii* for each of the 16 sampling areas of the Algodones Dunes, along with 95% confidence limits and precisions of the estimates. These sampling area statistics are given here to highlight differences between the sampling areas in each of the management areas. The sampling objective in the Monitoring/Study Plan for the Imperial Sand Dunes Recreation Area Management Plan (to achieve estimates that are within 30% of the true total population size at the 95% confidence level) are based on estimates for each of the *management* areas. Estimates and levels of precision for each of the management areas are given in Table 4 in the body of the report.

Mammoth Wash Sampling Area 13

Category	Density Estimate (plants/ha)	95% Confidence Limits Lower	Upper	Population Estimate	95% Confidence Limits Lower	Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	8.980	6.680	11.280	6,000	4,464	7,537	25.61%
Flowering and past flowering	40.024	32.951	47.097	26,745	22,018	31,471	17.67%
Total number of plants	49.004	40.573	57.434	32,745	27,112	38,379	17.20%
Plants > 1 year old	0.626	0.313	1.022	418	209	683	63.30%
Plants with OHV damage	0.045	0.022	0.071	30	15	48	58.44%
Plants with other damage	0.195	0.097	0.341	130	65	228	75.07%

Mammoth Wash Sampling Area 14

Category	Density Estimate (plants/ha)	95% Confidence Limits Lower	Upper	Population Estimate	95% Confidence Limits Lower	Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	8.016	6.267	9.764	5,356	4,188	6,525	21.82%
Flowering and past flowering	52.977	42.782	63.172	35,400	28,588	42,213	19.24%
Total number of plants	60.993	49.183	72.803	40,756	32,865	48,648	19.36%
Plants > 1 year old	0.263	0.163	0.364	176	109	243	38.27%
Plants with OHV damage	0.078	0.041	0.115	52	27	77	47.84%
Plants with other damage	0.126	0.069	0.182	84	46	122	45.02%

Wilderness Sampling Area 15

Category	Density Estimate (plants/ha)	95% Confidence Limits Lower	Upper	Population Estimate	95% Confidence Limits Lower	Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	11.296	7.347	15.244	14,080	9,158	19,001	34.96%
Flowering and past flowering	52.142	34.714	69.571	64,993	43,269	86,717	33.43%
Total number of plants	63.438	42.242	84.635	79,073	52,653	105,493	33.41%
Plants > 1 year old	0.344	0.154	0.533	428	192	664	55.13%
Plants with OHV damage	0.000	0.000	0.000	0	0	0	0.00%
Plants with other damage	1.098	0.390	2.185	1,369	486	2,724	98.95%

Wilderness Sampling Area 16

Category	Density Estimate (plants/ha)	95% Confidence Limits Lower	Upper	Population Estimate	95% Confidence Limits Lower	Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	10.747	6.041	15.452	13,395	7,530	19,261	43.79%
Flowering and past flowering	69.649	52.884	86.414	86,814	65,918	107,711	24.07%
Total number of plants	80.396	59.994	100.797	100,210	74,780	125,639	25.38%
Plants > 1 year old	0.669	0.237	1.443	834	296	1,798	115.63%
Plants with OHV damage	0.000	0.000	0.000	0	0	0	0.00%
Plants with other damage	1.381	0.490	2.806	1,721	611	3,498	103.20%

Gecko Sampling Area 3

Category	Density Estimate (plants/ha)	95% Confidence Limits Lower	Upper	Population Estimate	95% Confidence Limits Lower	Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	19.075	14.495	23.655	36,084	27,420	44,747	24.01%
Flowering and past flowering	48.638	40.049	57.228	92,009	75,761	108,258	17.66%
Total number of plants	67.713	56.607	78.820	128,093	107,083	149,103	16.40%
Plants > 1 year old	2.172	1.374	2.971	4,109	2,599	5,619	36.75%
Plants with OHV damage	0.775	0.254	1.319	1,467	439	2,495	70.09%
Plants with other damage	3.708	1.107	6.429	7,015	1,869	12,161	73.36%

Gecko Sampling Area 4

Category	Density Estimate (plants/ha)	95% Confidence Limits Lower	Upper	Population Estimate	95% Confidence Limits Lower	Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	17.851	13.921	21.782	33,714	26,292	41,137	22.02%
Flowering and past flowering	76.128	59.648	92.608	143,776	112,652	174,900	21.65%
Total number of plants	93.980	74.188	113.772	177,490	140,111	214,870	21.06%
Plants > 1 year old	1.480	0.736	2.223	2,795	1,390	4,199	50.24%
Plants with OHV damage	0.289	0.120	0.457	545	226	864	58.51%
Plants with other damage	1.641	0.556	2.727	3,099	1,049	5,149	66.14%

Glamis Sampling Area 5

Category	Density Estimate (plants/ha)	95% Confidence Limits Lower	95% Confidence Limits Upper	Population Estimate	95% Confidence Limits Lower	95% Confidence Limits Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	7.865	5.343	10.387	14,278	9,700	18,856	32.06%
Flowering and past flowering	12.741	8.020	17.462	23,129	14,559	31,698	37.05%
Total number of plants	20.606	13.690	27.523	37,406	24,851	49,962	33.57%
Plants > 1 year old	1.042	0.589	1.495	1,891	1,069	2,713	43.46%
Plants with OHV damage	0.413	0.200	0.626	750	364	1,136	51.52%
Plants with other damage	0.249	0.101	0.397	452	183	721	59.52%

Glamis Sampling Area 6

Category	Density Estimate (plants/ha)	95% Confidence Limits Lower	95% Confidence Limits Upper	Population Estimate	95% Confidence Limits Lower	95% Confidence Limits Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	7.044	4.754	9.335	12,805	8,641	16,969	32.52%
Flowering and past flowering	15.397	11.146	19.648	27,990	20,262	35,717	27.61%
Total number of plants	22.441	16.152	28.730	40,795	29,362	52,228	28.03%
Plants > 1 year old	1.162	0.745	1.580	2,113	1,354	2,872	35.92%
Plants with OHV damage	0.216	0.126	0.305	392	230	554	41.33%
Plants with other damage	0.880	0.189	1.696	1,600	343	3,083	92.69%

AMA Sampling Area 7

Category	Density Estimate (plants/ha)	95% Confidence Limits Lower	95% Confidence Limits Upper	Population Estimate	95% Confidence Limits Lower	95% Confidence Limits Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	18.794	13.429	24.159	25,615	18,302	32,927	28.55%
Flowering and past flowering	108.757	88.591	128.924	148,226	120,741	175,711	18.54%
Total number of plants	127.551	102.897	152.206	173,841	140,239	207,443	19.33%
Plants > 1 year old	1.389	0.684	2.094	1,894	933	2,854	50.74%
Plants with OHV damage	0.089	0.038	0.157	121	52	214	76.49%
Plants with other damage	5.145	2.492	7.798	7,012	3,396	10,628	51.57%

AMA Sampling Area 8

Category	Density Estimate (plants/ha)	95% Confidence Limits Lower	95% Confidence Limits Upper	Population Estimate	95% Confidence Limits Lower	95% Confidence Limits Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	1.801	1.186	2.416	2,120	1,396	2,843	34.14%
Flowering and past flowering	9.116	7.172	11.059	10,728	8,441	13,015	21.32%
Total number of plants	10.917	8.527	13.307	12,848	10,035	15,661	21.89%
Plants > 1 year old	0.241	0.105	0.377	284	123	444	56.54%
Plants with OHV damage	0.020	0.008	0.038	24	9	45	89.85%
Plants with other damage	0.306	0.146	0.467	360	171	549	52.41%

AMA Sampling Area 17

Category	Density Estimate (plants/ha)	95% Confidence Limits Lower	95% Confidence Limits Upper	Population Estimate	95% Confidence Limits Lower	95% Confidence Limits Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	1.555	0.977	2.133	2,375	1,492	3,259	37.18%
Flowering and past flowering	9.499	6.968	12.031	14,510	10,643	18,377	26.65%
Total number of plants	11.054	8.013	14.095	16,885	12,240	21,531	27.51%
Plants > 1 year old	0.264	0.126	0.419	404	193	640	58.34%
Plants with OHV damage	0.056	0.027	0.138	86	41	211	145.94%
Plants with other damage	1.696	0.947	2.445	2,591	1,447	3,735	44.16%

AMA Sampling Area 18

Category	Density Estimate (plants/ha)	95% Confidence Limits Lower	95% Confidence Limits Upper	Population Estimate	95% Confidence Limits Lower	95% Confidence Limits Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	76.882	60.236	93.529	117,437	92,009	142,864	21.65%
Flowering and past flowering	222.013	182.939	261.086	339,121	279,436	398,805	17.60%
Total number of plants	298.895	245.645	352.145	456,558	375,219	537,896	17.82%
Plants > 1 year old	2.588	1.687	3.490	3,953	2,576	5,330	34.83%
Plants with OHV damage	0.523	0.319	0.728	799	487	1,112	39.08%
Plants with other damage	16.495	10.869	22.121	25,196	16,602	33,790	34.11%

Ogilby Sampling Area 19

Category	Density Estimate (plants/ha)	95% Confidence Limits Lower	95% Confidence Limits Upper	Population Estimate	95% Confidence Limits Lower	95% Confidence Limits Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	82.679	61.330	104.029	140,430	104,168	176,692	25.82%
Flowering and past flowering	161.558	125.294	197.822	274,405	212,811	335,999	22.45%
Total number of plants	244.238	189.208	299.267	414,835	321,368	508,302	22.53%
Plants > 1 year old	1.235	0.727	1.744	2,098	1,234	2,963	41.19%
Plants with OHV damage	0.986	0.543	1.429	1,675	923	2,427	44.91%
Plants with other damage	13.495	9.178	17.812	22,922	15,589	30,254	31.99%

Ogilby Sampling Area 20

Category	Density Estimate (plants/ha)	95% Confidence Limits Lower	95% Confidence Limits Upper	Population Estimate	95% Confidence Limits Lower	95% Confidence Limits Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	2.891	1.763	4.020	4,911	2,994	6,827	39.02%
Flowering and past flowering	16.772	11.911	21.633	28,487	20,231	36,743	28.98%
Total number of plants	19.663	13.769	25.557	33,398	23,387	43,408	29.97%
Plants > 1 year old	0.077	0.038	0.123	131	64	209	59.42%
Plants with OHV damage	0.078	0.038	0.129	133	65	219	64.42%
Plants with other damage	4.158	3.041	5.275	7,062	5,165	8,960	26.86%

Buttercup Sampling Area 11

Category	Density Estimate (plants/ha)	95% Confidence Limits Lower	95% Confidence Limits Upper	Population Estimate	95% Confidence Limits Lower	95% Confidence Limits Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	70.948	35.751	106.144	32,893	16,575	49,211	49.61%
Flowering and past flowering	113.559	60.301	166.816	52,649	27,957	77,341	46.90%
Total number of plants	184.506	99.281	269.731	85,543	46,030	125,055	46.19%
Plants > 1 year old	0.534	0.196	0.882	247	91	409	65.25%
Plants with OHV damage	4.392	2.071	6.714	2,036	960	3,113	52.85%
Plants with other damage	1.202	0.442	1.972	557	205	914	64.05%

Buttercup Sampling Area 12

Category	Density Estimate (plants/ha)	95% Confidence Limits Lower	95% Confidence Limits Upper	Population Estimate	95% Confidence Limits Lower	95% Confidence Limits Upper	Precision (+/- percent of estimate)
Nonflowering seedlings and juveniles	0.197	0.104	0.362	100	53	184	83.45%
Flowering and past flowering	0.982	0.518	1.939	500	264	987	97.40%
Total number of plants	1.179	0.623	2.288	601	317	1,165	94.03%
Plants > 1 year old	0.004	0.002	0.009	2	1	5	140.54%
Plants with OHV damage	0.004	0.002	0.009	2	1	5	140.54%
Plants with other damage	0.004	0.002	0.009	2	1	5	140.54%